IDEA

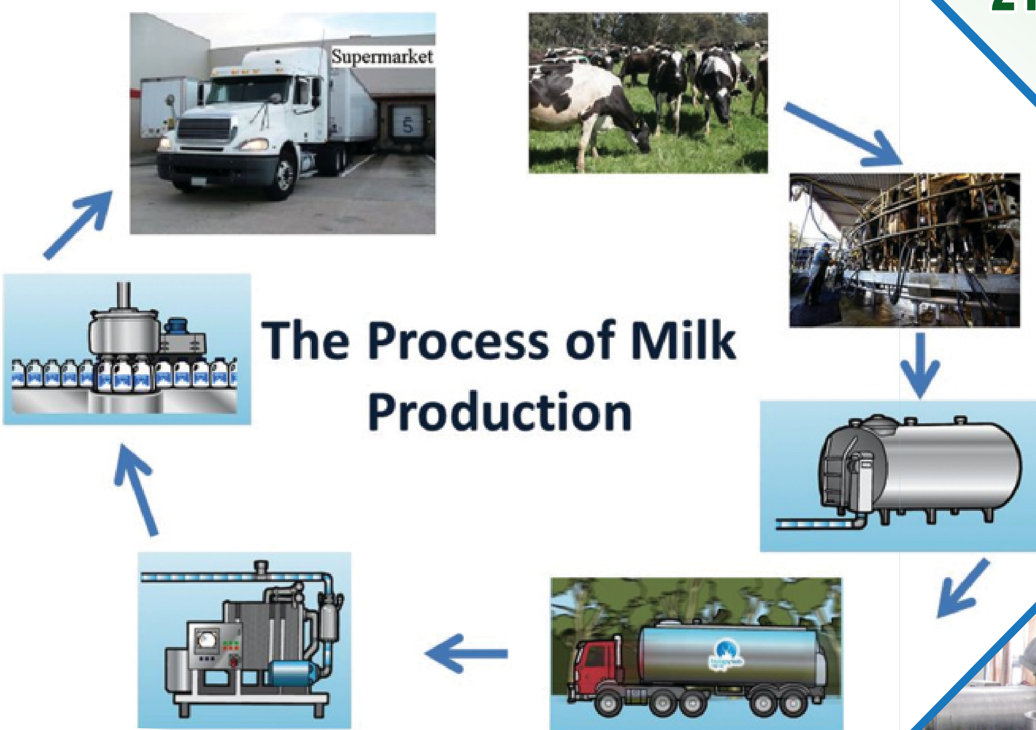
Souvenir

BME
Bharti Media & Events

11th National Convention & Seminar on

Dairy Process Engineering from 'Farm to Table'

on
21st to 22nd October, 2018



Organized by
INDIAN DAIRY ENGINEERS ASSOCIATION (IDEA)
&
BHARTI MEDIA & EVENTS

Venue
Labh Ganga Convention Centre
Bhopal Bypass, Indore (Madhya Pradesh)

Sponsors :

भाकृअनुप ICAR

Food & Biotech Engineers (india) Pvt. Ltd.

Vita

Process Engineers And Associates Sector 43, Noida, Uttar Pradesh

verka® Phulo Phalo. Pure Khao Piyo.

ANSI
American National Standard Institute

Process Engineers & Associates

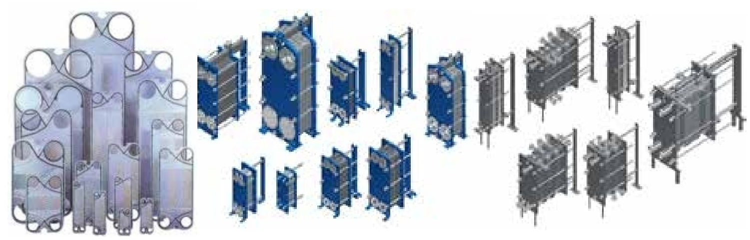
ISO 9001:2015 CERTIFIED COMPANY

Manufacturers of Plate Heat Exchangers & Dairy, Juice, Beverage & Food Processing Machinery

IN HOUSE FACILITY TO MANUFACTURE A WIDE RANGE OF DAIRY PRODUCTS –

** MILK CHILLERS*
** BULK MILK COOLERS*
** MILK PUMPS*
** SS INSULATED MILK STORAGE TANKS*
** SS INSULATED DIMPLE JACKET TANKS USED AS BATCH PASTEURIZER AND CURD INOCUALTION TANKS*
** ELECTRICALLY HEATED BATCH PASTEURIZERS*
** HTST & TUBULAR PASTEURIZERS*
** ICE CREAM MIX CHILLERS*
** CIP SYSTEM*
** CUP FILLING MACHINE --- MANUAL, SEMI AUTOMATIC AND FULLY AUTOMATIC FOR CURD MILK AND OTHER NON CARBONATED BEVERAGES*
** CUP WASHING STERLIZATION MACHINE*
** HOT WATER GENERATING SYSTEMS*
** INSTANT MILK CHILLING UNITS*
** JUICE PASTEURIZERS AND SYRUP,JUICE AND BEVERAGE CHILLERS & TANKS*
** FRUIT & VEGETABLE WASHER*

PHE PLATES WITH GASKET | INDUSTRIAL PHE | FOOD GRADE PHE



SS IINSULATED STORAGE TANK | MILK CHILLERS | MILK PASTEURIZER SYSTEM



POUCH FILLING MACHINE | HOMOZENIZER | PANER PRESS



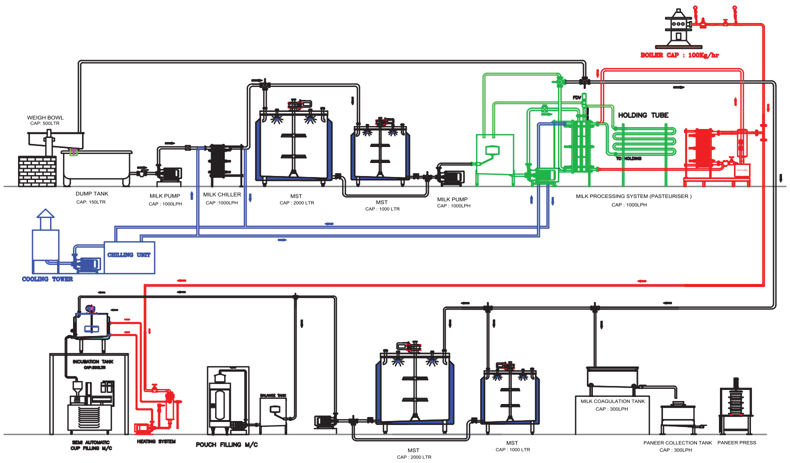
CUP WASHING STERLIZATION MACHINE | CUP FILLING MACHINE


VACCUM PAN & CONDENSOR | CIP SYSTEM


ELECTRICALY HEATED BATCH PAST. | TUBULAR JUICE PAST. | MILK SILO



MILK ,DAHI ,PANEER & GHEE PLANT LAYOUT



FRUIT & VEGETABLE WASHER

E-78 SECTOR 63 NOIDA 201307
TEL. NO. : +91-120-4976524,4213753
MOBILE : +91-9350545996 ,9717855996
+91-8527455996
Email : chawlamc@gmail.com
abhinav.pea@gmail.com
info@phe-india.com
Website : www.phe-india.com

PuraSure

Pure भी Sure भी

souvenir

of

11th National Convention & Seminar

of Indian Dairy Engineers' Association (IDEA)

On

Dairy Process Engineering from 'Farm to Table'

21th – 22nd October 2018

Venue:

Labh Ganga Convention centre

Bhopal Bypass, Indore (Madhya Pradesh)

Organised by:

INDIAN DAIRY ENGINEERS' ASSOCIATION

www.dairyidea.com

&

Bharti Media & Events Pvt. Ltd.
Delhi

BHARTI MEDIA & EVENTS

11th National Convention & Seminar
of Indian Dairy Engineers' Association (IDEA)
On

Dairy Process Engineering from 'Farm to Table'

21th – 22nd October 2018

souvenir

Dr. I. K. Sawhney, Emeritus Scientist, Dairy Engg. Division, ICAR-NDRI, Karnal
Convenor
Dr. P. Barnwal, Principal Scientist, Dairy Engg. Division, ICAR-NDRI, Karnal
Co-Convenor

Edited and Compiled by:
Er. Ankit Deep, Scientist, Dairy Engg. Division, ICAR-NDRI, Karnal
Dr. Chitranayak, Senior Scientist, Dairy Engg. Division, ICAR-NDRI, Karnal
Er. S. K. Chaudhary, CTO, Dairy Engg. Division, ICAR-NDRI, Karnal
Dr. P. Barnwal, Principal Scientist, Dairy Engg. Division , ICAR-NDRI, Karnal
Dr. I. K. Sawhney, Emeritus Scientist, Dairy Engg. Division, ICAR-NDRI, Karnal

Published by: INDIAN DAIRY ENGINEERS' ASSOCIATION

Disclaimer
The content and information in this souvenir is purely informative in nature and views expressed by authors are their own. The editors, publisher and organisers of the seminar are no way responsible and do not accept any liability, legal or otherwise.

Organised by:
INDIAN DAIRY ENGINEERS' ASSOCIATION
www.dairyidea.com
&
BHARTI MEDIA & EVENTS

Bharti Media & Events Pvt. Ltd.
Delhi

Gaurishankar Bisen

Minister
Farmer Welfare & Agriculture Development
Govt. of Madhya Pradesh (India)

MESSAGE

I am delighted to know that the India Dairy Engineers Association based at Dairy Engineering Division of ICAR-National Dairy Research Institute, Karnal is organizing the 11th National Convention of Dairy Engineers & Seminar on "Dairy Process Engineering From Farm to Table" jointly with Bharti Media & Events during 21-22 October 2018 at Indore, Madhya Pradesh.

India's economy is primarily based on Agriculture and Dairy sector is an integral part of agriculture. Most of the farmers in India simultaneosly keep animals for milk production and dairying is only their side business to sustain the farm economy. However, nowadays many farmers as well as smell entrepreneurs are taking interest in the dairy farms and dairy processing at commercial level. Engineering intervention and mechanization of the whole process starting from milk production stage to consumption stage is of utmost importance to ensure best quality and maximize productivity so that the dairy business becomes an attractive choice to all the stakeholders. It is also very well linked to the mission of our Prime Minister for doubling the farmers' income by 2022. So, in my view the theme of convention is very well chosen and I hope it will be successful in promoting dairy business in India. I wish the convention a great success.

Gaurishankar Bisen

कृषि वैज्ञानिक चयन मंडल
(भारतीय कृषि अनुसंधान परिषद)
कृषि अनुसंधान भवन-I, पूसा, नई दिल्ली 110 012

AGRICULTURAL SCIENTISTS RECRUITMENT BOARD
(INDIAN COUNCIL OF AGRICULTURAL RESEARCH)
Krishi Anusandhan Bhavan I, Pusa, New Delhi 110 012

प्रो. (डॉ.) ए.के. श्रीवास्तव
अध्यक्ष
Prof. (Dr.) A.K. Srivastava
Chairman

सन्दर्भ सं/Ref. No. **PPS/CHAIRMAN/2018**
दिनांक/Dated **08.10.2018**

MESSAGE

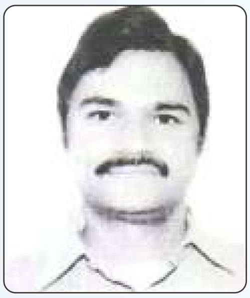
I am happy that the Indian Dairy Engineers Association (IDEA) is organizing 11th National Convention of Dairy Engineers and National Seminar on "Dairy Process Engineering from Farm to Table" in collaboration with Bharti Media & Events during 21-22 October 2018 at Indore, Madhya Pradesh.

Post production losses in the agricultural sector including those in the diary subsector are causing concern as we lose the precious dairy produce. While we may take pride in excelling in the total milk production in India, the extent of avoidable losses in this sector are substantial. It's incumbent on the dairy professionals', especially dairy engineers to ensure that all the holes in the dairy supply and value chain are effectively plugged. The relevant quality assurance protocols at various points in the value chain need to be developed and implemented to ensure quality dairy product for domestic as well as export markets. Human resource development, infrastructure, strategies and processing technologies need to be upgraded to meet these standards. Engineering inputs are very important in this up gradation. I would sincerely hope that the convention would address these issues in their deliberations.

I wish the convention all success.

Srivastava

A.K. Srivastava



K.C. Gupta, IAS

Principal Secretary
(AH & Dairying)
Govt. of Madhya Pradesh

MESSAGE

I am glad to learn that the Indian Dairy Engineers Association based at Dairy Engineering Division of ICAR-National Dairy Research Institute, Karnal is organizing the 11th National Convention of Dairy Engineers & Seminar on " Dairy Process Engineering from Farm to Table" during 21-22 October 2018 at Indore, Madhya Pradesh. The theme of convention is of great signficance in the "Make in India" Programme of GOI.

The share in GDP of Dairy sector is largest compared to other agriculture sectors in India. The role of dairy processing in the food and nutritional security of the country as well as its major contribution in the employment generation cannot be ignored. Though India has emerged as the largest producer of milk but without quality processing and converting it in value added products in an organized way, the real benefits cannot be harnessed. By providing solutions to each of the problem faced in the area of milk production and processing through engineering interventions, the quality standard, improved profit of producers at reasonable price and wide acceptability of the packed dairy products can be ensured. With this background, I feel the theme of convention is appropriate.

I hope the delegates will deliberate on all these issues and come out with plausible recommendations.

I wish the convention all the success.

K.C. Gupta

भा.कृ.अनु.प.-राष्ट्रीय डेरी अनुसंधान संस्थान
ICAR-NATIONAL DAIRY RESEARCH INSTITUTE
(मान्य विश्वविद्यालय)
(Deemed University)
(भारतीय कृषि अनुसंधान परिषद)
(Indian Council of Agricultural Research)
करनाल-132001, (हरियाणा) भारत
KARNAL - 132001, (Haryana), India

डा. आर.आर.बी.सिंह
कार्यवाहक निदेशक
Dr. R.R.B. Singh
Acting Director

MESSAGE

I am pleased to know that the Indian Dairy Engineers Association based at Dairy Engineering Division of ICAR-National Dairy Research Institute, Karnal is organizing the 11th National Convention of Dairy Engineers & Seminar on Dairy Process Engineering from Farm to Table jointly with Bharti Media & Events during 21-22 October 2018 at Indore, Madhya Pradesh.

Dairy development in India has been acknowledged the world over as one of the highly successful programmes and now it is being closely related with the 'Make in india Programme' initiated by our honourable Prime Minister Sh. Narender Modi Ji. In the commercial milk production & processing, process engineering is applicable at every point from Farm to Table. It is not only required in mechanization of production, processing, value addition, storage, distribution and consumption of milk and milk products but is essential for cost minimization, meeting the enhanced quality standards and global competency to increase the export and global market share. Discussion on engineering solution for the problems faced by the industry, automation and process control, energy management, and cold chain management is the need of hour. With this background, I feel the theme of convention is very much appropriate.

I hope the delegates will deliberate on the these issues and come out with plausible recommendations.

I wish the convention all the success

R.R.B. Singh

राजस्थान इलेक्ट्रॉनिक्स एण्ड इन्ट्रूमेन्टस लिमिटेड

Rajasthan Electronics & Instruments Limited

(An ISO 9001:2008 & 14001:2004 "Mini Ratna" Public Sector Enterprise)

B-12, Kala Colony, JLN Marg Malviya Nagar, Jaipur - 302017

ए.के. जैन
प्रबन्ध निदेशक
A.K. Jain
Managing Director

MESSAGE

It gives me immense pleasure to know that Indian Dairy Engineers Association (IDEA) is organizing 11th National Convention & Seminar on Dairy Process Engineering from "Farm to Table" which is much needed in consistently growing dairy sector. India being Largest Milk producer in the world for last two decades can continue to do the wonders through adoption of best engineered innovative pracitices at each level across the value chain from Farm to Table.

During the illustrious journey of more than 16 years, IDEA had worked closely amongst engineering professionals in dairy industry, academicians & research workers and has been sharing experiences and innovations that are benefitting the dairying in India.

I am sure that this Annual Convention and National Seminar will be an excellent platform to get rewarded from the vast knowledge of eminent engineer professionals through their presentations/de;iberation on various areas of engineering interventions. The aim is also achieved to create awareness and educate the dairy fraternity about latest happening in the field of Dairy process Engineering through informative technical session and exhibitions & come out with recommendations towards making India major contributor to the Global export market of milk products and taking Indian dairying to new heights.

I, while feeling proud to be part of dairy industry, would like to congratulate the team and wish the event a great success and hope that the IDEA would touch to highest levels of recognition for its invaluable service to the Country.

With warm Regards

A.K. JAIN

भारतीय कृषि अनुसंधान परिषद्
कृषि भवन, डा० राजेन्द्र प्रसाद मार्ग, नई दिल्ली-110 001
INDIAN COUNCIL OF AGRICULTURAL RESEARCH
Krishi Bhawan, Dr. Rajendra Prasad Road, New Delhi-110 001

Shiv Prasad Kimothi
(ADG, Coordination)

MESSAGE

It gives me immense pleasure to note that Indian Dairy Engineering Association (IDEA) is organizing the 11th National Convention of Dairy Engineers & Seminar on "Dairy process Engineering from Farm to Table" jointly with Bharti Media & Events during 21st-22nd October, 2018 at Indore, Madhya Pradesh.

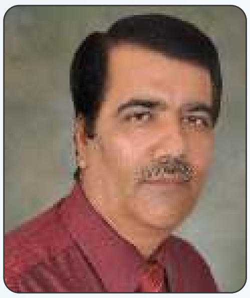
The growth potential of Indian Dairy Industry is enormous. It is also equally true that a multiplicity of challenges exit in improving the efficiency and quality milk and milk products begins on the farm and maintaining it continues through various handling, processing and distribution channels. One of the most important facets of the quality control network is regular compliance of quality parameters at every stage to ensure best possible quality of the end product. The engineering technologies and interventions play vital role in achieving these objects. The focal theme of this convention " Dairy Process Engineering form Farm to Table" thus assumes great significance.

I congratulate, the organizers for selecting an appropriate theme for this very important convention. I am sure all issues of topical importance will be discussed at length during the two days long convention and implementable recommendations will emanate from these deliberations.

I wish the National Convention a grand success

Shiv Prasad Kimothi

भारतीय कृषि अनुसंधान परिषद
Indian Council of Agricultural Research
कृषि अभियांत्रिकी अनुभाग
Agricultural Engineering Division
कृषि अनुसंधान भवन-।।, पूसा, नई दिल्ली-110012
KAB – II, Pusa, New Delhi – 110012



Dr. S. N. Jha, *ARS*
डा. एस. एन. झा, ए.आर.एस.
FISAE, FNAAS, FIE, FNADSI, FJSPS Japan, HSI Gold Medallist,
LMAFSTI , LMDTSI, ICAR Rafi Ahmed Kidwai Awardee
Assistant Director General (Process Engineering)
उपमहानिदेशक (प्रोसेस अभियांत्रिकी)

MESSAGE

I am happy to know that the Indian Dairy Engineers Association based at Dairy Engineering Division of ICAR-National Dairy Research Institute, Karnal is organizing the 11th National Convention of Dairy Engineers & Seminar on Dairy Process Engineering from Farm to Table jointly with Bharti Media & Events during 21-22 October 2018 at Indore, Madhya Pradesh.

Over the years, India has emerged as one of the world's biggest producers of milk, with the total milk production rising from 122 million Metric Tons in 2010 to around 170 million Metric Tons in 2017. Despite this, the majority of the dairy industry in India is still highly unorganized and dominated by small and marginal dairy farmers and dairy processors. Hygienic conditions of dairy based sweet manufacturing and shops needs considerable improvements, which can be done when dairy operations in theses shops and manufacturing hubs are mechanized. Milk and milk products' quality and safety are other big aspects of R & D to check adulterations and saving the health of citizens. To give a boost to technological development for organized as well as unorganized dairy industries (cooperative as well as private) for the benefit of milk producers and dairy products consumers, these kinds of deliberations of dairy process engineer are very important. It has a big role in improving profits of milk producers, generation of employment and contributions to the health and nutrition of people of the country. With this background, I feel the theme of convention is timely and appropriate.

I hope the delegates will deliberate on all these issues and come out with plausible recommendations.

I wish the convention all the success

S. N. Jha

एम.पी.स्टेट को-ऑपरेटिव डेयरी फेडरेशन लिमिटेड
M.P. STATE CO-OPERATIVE DAIRY FEDERATION LTD.
(मध्य प्रदेश सहकारी सोसायटीज अधिनियम 1960 के अधीन पंजीकृत)
दुग्ध भवन, दुग्ध मार्ग, हबीबगंज, भोपाल - 462024
Dugdha Bhawan, Dugdha Marg, Habibganj, Bhopal -462024
Telephone Nos : +91755258400, 2580401

Abhishek Singh
IAS
Managing Director

MESSAGE

I am pleased to learn that the Indian Dairy Engineers Association based at Dairy Engineering Division of ICAR-National Dairy Research Institute, Karnal is organizing the 11th National Convention of Dairy Engineers & Seminar on "Dairy Process Engineering from Farm to Table" jointly with Bharti Media & Events during 21-22 October 2018 at Indore, Madhya Pradesh.

I hope that all participants and delegates from the students, teachers, researchers and developers fraternity would be benefitted immensely by sharing the view and knowledge during these two days of National Convention. The theme "Farm to Table" is also very challenging for the Researchers and developers, to think in the direction of recent innovations and their upgradation in the area of dairy processing and explore their application at ground level. This two-days event will be an opportunity of meeting engineers participating from different parts of the country and sharing their area specific availability of milk, related equipments, transportation facilities, climatic effects, problems in processing etc., so that a clear road map for growth of dairy industry in future may be prepared. I would sincerely hope that the convention would come out with some fruitful deliberations.

I wish the convention a great success.

Abhishek Singh

Indian Dairy Engineers Association

"IDEA" Registered Under The Societies
Registration Act No.-742/ 2001-2002
Website : www.dairyidea.com | Email : ideaseminar2018@gmail.com

Er. S.C. Aggarwal
President (IDEA) &
Ex. Addl. Managing Director,
Milk Fed., Punjab

MESSAGE

Indian Dairy Engineers Association is organizing its 11th National Convention & Seminar at INDORE (MP) on 21st & 22nd October 2018 on the subject **Dairy Process Engineering from Farm to Table.** I must congratulate the Organizing Committee for selecting a topic of the Seminar which is highly compatible to the existing needs of the Dairy Industry.

Milk production in India is growing at a steady rate of growth and milk is available in sufficient quantity to think about value added products and diversification. Progress of any industry depends upon direct development of infrastructure and hence the role Dairy Engineers in Dairy Industry. The subject matter of Seminar will give us lot of opportunity to learn latest developments in field of infrastructure development. I do hope that my fellow delegates will be immensely benifitted from the proceedings .
I do take the opportunity to extend my thanks & gratitude to Dr IK Sahwney and his team to take extreme care in every field of activity for success of the event

S.C. AGGARWAL

Indian Dairy Engineers Association

"IDEA" Registered Under The Societies
Registration Act No.-742/ 2001-2002
Website : www.dairyidea.com | Email : ideaseminar2018@gmail.com

Dr. I. K. Sawhney
Convener
11th IDEA National Convention
Emeritus Scientist & Former Head
Dairy Engineering Division
ICAR-NDRI, Karnal

MESSAGE

On behalf of the organizing committee it is my pleasure to welcome all the delegates from academia and dairy industries to the 11th National Convention of Dairy Engineers at Indore.

The focal theme of the Convention "Dairy Process Engineering from Farm to Table" is highly relevant in present times. Indian dairy industry is one of the fastest growing segments of the food processing industry. Our dairy industry is mostly regional and there is a multitude of brands focusing on only one or two districts or in some case only one state. There are very few national brands and the major reason behind slow growth of the smaller players is the high perishability of dairy products. The future prospect of India's milk products market is promising for manufacturers, suppliers and retailers. While a number of regional entrepreneurs have already started expanding, the entry of new players has further intensified the struggle to get a bigger market share. The small and medium milk products manufacturers in India are now being able to enhance their product range, volumes and profitability by utilizing the more affordable Indian made equipments. Way forward is to utilize integrated sales and distribution system and employing the value added dairy industry segment.

The 11th National Convention organized by IDEA would provide an ideal opportunity for researchers, delegates from industries and students to apprise themselves of the latest developments and discuss the research plans and priorities. I am confident that deliberations on important issues would bring out implementable strategies and policy frame work.

I would like to take this opportunity to express gratitude towards the Patrons, members of National Committee and other committees for their valuable advice, suggestions and support in organizing this convention. I gratefully acknowledge Bharti Media & Events Pvt. Ltd. for jointly co organizing this mega event with us. I thank all the reviewers, sponsors of various events and the media. It is the endeavor of the organizing committee to ensure that you all have a memorable experience at this convention to cherish for long time.

With best wishes

Dr. I. K. Sawhney

INDIAN DAIRY ENGINEERS ASSOCIATION (IDEA)
CITATION
LIFE TIME ACHIEVEMENT AWARD
DR. RAVI KUMAR SRIBHASHYAM

Dr. Ravi Kumar Sribhashyam has been chosen by the IDEA for conferring this honour on him during the 11th Convention (2018), in recognition of his professional excellence in the field of Dairy Engineering.

Dr. Ravi Kumar completed his graduation from National Dairy Research Institute Karnal in 1976 and joined inAndhra Pradesh Co-operative Dairy Federation Ltd, where he worked for 12 years in various capacities as Asst. Dairy Manager, Dairy Manager and Marketing Manager. As the Dairy Manager he had revived and brought to profit making, many Dairy Plants which were either closed, or under loss. During the same period, he was deputed to study for post graduate degree in Dairy Engineering.

He later joined as Associate Professor of Dairy Engineering in S.V. Veterinary University (the then APAU) Tirupati. He planned, executed and brought into operation an Experimental Dairy Plant for the department. He pursued his Doctoral studies in the field of Dairy Engineering, at NDRI Karnal, specializing in application of thermal energy for cooling milk. He was promoted as Professor of Dairy Engineering in 2001. As a Member, Board of Management of the University he played pivotal role in upgrading the Dairy Technology Programme at Tirupati University into a full-fledged College of Dairy Technology. He was also instrumental in reviving the closed department of Dairy Technology at Kamareddy and upgraded to College of Dairy Technology.

He was the Organizing Secretary of the 7th National Convention of Indian Dairy Engineers Association at Sri Venkateswara Veterinary University, Tirupati (AP) in 2012.

His abiding interest in utilization of non-conventional energy in dairy industry has propelled him to undertake various projects on solar energy utilization specially the Vapour Absorption Refrigeration system to chill milk at Village milk society's level. He was closely associated with successful completion of NAIP project on e-courses for B.Tech (Dairy Technology). He continues to hold great interest in teaching in various educational institutions.

In recognition of his meritorious service to the Dairy Engineering Profession, the organizing committee of the Convention & Seminar and IDEA take pride to honour Dr. Ravi Kumar Sribhashyam by presenting him this citation on the occasion of 11th IDEA Convention & Seminar held at Indore.

Date: Oct .21, 2018

President
Indian Dairy Engineers Association

INDIAN DAIRY ENGINEERS ASSOCIATION (IDEA)

CITATION

LIFE TIME ACHIEVEMENT AWARD

ER. RAMESH KUMAR CHUGH

Er. Ramesh Kumar Chugh has been chosen by the IDEA for conferring this honour on him during the 11th Convention (2018), in recognition of his professional excellence in the field of Dairy Engineering.

Er. Chugh was a bright student throughout his education. He graduated in Dairy Technology (1974-1978) and post graduated in Dairy Engineering (1979-1982) from National Dairy Research Institute, Karnal. A rare combination of Dairy Technology and Dairy Engineering made a great foundation for his journey in the field of Dairying.

He started his career with Haryana Dairy Development Cooperative Federation (HDDCF) as Dairy Supervisor at Milk Plant Jind, where he learned all the basics of operations and technologies of milk products. After completing Masters in Dairy Engineering in 1982, he joined M/S Dainy Dairy and Food Engineers Saharanpur as Erection and Commissioning Engineer and was later on promoted as Senior Project Engineer.

In 1985, he joined HDDCF as Dairy Engineer and was promoted to Chief General Manager (Production and Technical). He managed the expansion, modification, renovation of all the existing milk plants and chilling centres in the state of Haryana. As Chief General Manager, he played a major role in formulating and implementing policies which turned HDDCF from loss making to profit making organisation.

He is a Certified Energy Auditor. Presently he is the Vice President Indian Dairy Engineers Association, Executive Member of Indian Dairy Association (NZ), Joint Secretary NDRI Graduate Association and the Managing Director of self-founded consultancy firm the Reliable Dairy and Food Consultants.

In recognition of his meritorious service to the Dairy Engineering Profession, the organizing committee of the Convention & Seminar and IDEA take pride to honour Er. Ramesh Kumar Chugh by presenting him this citation on the occasion of 11th IDEA Convention & Seminar held at Indore.

Date: Oct. 21, 2018

President
Indian Dairy Engineers Association

Reliable Control Solutions

Reliability Like No Other.....

www.reliablecontrolsolutions.com

E-mail! info@rcsind.com

9811575514,0129-2274220/21

Reliable Control Solutions is establlished in 2003, based in New Delhi, as an ISO 9000 Certified Organization. We are Authorized System Integrator of **Rockwell Automation** (Allen Bradley).We Provide Solutions and Service for Industrial Automation and In strumentation as a Consultant and a Supplier.

We are Expertise in Design, Engineering, Training, Application Software, Erection and Comm issioning of Control System Including Field Instrumentation/ PLC/ DCS / SCADA/ Communication Network/ Wireless network.

Can You believe? Total Cost of Ownership is same!!!

As Per Reliable Control Solutions an Automation control Should be :

- Reliability like no other.
- 100% up time.
- User Friendly.
- Total Cost of Ownership should be low.
- Web Enabled.
- Customized reporting.
- Alarming/Trending/ History data.
- Engineering efforts should be minimum.
- Support should be available 24*7.
- Failure of one section should not forrce complete shutdown.

Our Domain knowledge are not limited to

- Dairy Plants
- Solvent Extraction Plants
- Cement Plants
- Polyester Fiber Plants
- Aluminum Plants
- Bio-Diesel Plant
- Distilled Fatty Acids Plants
- Special purpose packaging Machines.

But many more

15/1 Mile Stone, Plot No.3, Main Mathura Road ,Metro pillar No.599 faridabad Haryana-121003

Best compliments from : **Vijaipac**

In Business Since 1983

Double Head
(High Speed Machine)

Single Head
(5 Ltr. Milk Packing Machine)

Rotary Cup Filling Machine

Oil & Ghee Packing Machine

Double Head
(Normal Speed Machine)

Multi Head Weigh Filler Machine
(Granuale & Chips Packing)

Powder Packing Machine

Horizontal Flow wrap Machine

6Head Bottle Filling Machine

R.M.C. PACKAGING SYSTEMS PVT. LTD.

(Mfrs. of Automatic Form Fill Seal Machines)

Works & Office: Plot No. 101/A, Phase II, I.D.A. Cherlapally, Hyderabad - 500 051. (T.S),
Ph: 040-32901883, 27261444, Mobile : 09392742200, Fax: 040-27260898,
Email : vijaipac_rmc@yahoo.com, Web : www.vijaipac.com

BULK MILK COLLER & DAIRY EQUIPMENTS

Communication Address

STAR ENGINEERS

(An ISO 9001:2008 Certified Organization)
Factory 1 : D-9C, Industrial Estate, Delhi Road, Saharanpur-247001 (U.P.)
Factory 2 : 28-A, Raipur, Industrial Area, Bhagwanpur, Roorkee (U.K.)
Mob.: +91-9837301763
E-mail: deepakbansal1963@gmail.com
Web.: starengineers.in

Customer First, Commitment First, Technology First

Note : Right to change any specification is reserved


We help you in setting up your Dairy Farm
We are Dairy Farm Specialists
Manufacturers, Suppliers of Milking Machine Parlors and Providing Dairy Farm Management Solutions.
India's No 1 Brand
VANSUN
Making Dairy Farming Easy
Since 1999
Automated Milking Parlors
Manure Handling
Precision Software Supported Farming
Our World class Milking Systems & Advanced Dairy Farm Solutions have got us more than thousands of highly satisfied customers worldwide.
Barn Equipments
We have a top team of designers, fabricators, structural engineers and architects to plan small and large dairy farms on a turnkey basis.
Increase your Profitability & Sustainability
Feeding Systems
Bulk Milk Coolers
PARLORS Swingover / Herringbone Rapiflow / Line Milker Parlor Rapid Exit / Rotary
Bucket Milking Machines/Parlors
Our International Partners
afimilk
ZACO
Packo
InterPuls
VANSUN TECHNOLOGIES PVT. LTD.
An ISO 9001:2008 Certified Company
G - 159, Sector - 63, Noida - 201 301, Uttar Pradesh, INDIA
Telephone : 0120 - 4088395, 4381811
E-mail : sales@vansunmilking.com
www.vansunmilking.com

Committees for Organization of 11th National Convention & Seminar on Dairy Process Engineering from '*Farm to Table*' 21-22, Oct., 2018

National Advisory Committee:

- Dr. R. R .B. Singh, Director, ICAR-National Dairy Research Institute, Karnal Haryana
- Er. S.C. Agrawal, President (IDEA) & Ex. Addl. M.D. Milk Fed., Punjab
- Dr. I. K. Sawhney, Vice President (IDEA) & Emeritus Scientist, ICAR-National Dairy Research Institute, Karnal, Haryana
- Er. R. K. Chugh Vice President (IDEA) & Ex. Chief General manager (Technical) Haryana Dairy Federation
- Dr. A. K. Singh, Head Dairy Engineering ICAR-National Dairy Research Institute, Karnal Haryana
- Dr. A. K. Punia, Dean Dairy Science College, GADVASU, Ludhiana
- Dr. A. K. Agarwal, Head Dairy Engineering, College of Dairy Science & Food Technology, CKV, Raipur
- Dr. P. Sudir Babu, Dean Faculty of Dairy Science, KVASU, Mannuthy Kerala
- Dr. A. G. Badhania, Ex Head Dairy Engineering Dairy Science College, AAU Anand
- Dr. Ravi Kumar. Ex Dean College of dairy Technology, SVVU Tirupati
- Dr. G. Mahesh Kumar, Head Dairy Engineering Dairy Science College Hebbel, Bengaluru
- Er. Laxmikant Meena, Manager Engineering, Tetrapak, Pune
- Er. H. S. Grewal, Additional MD, Milkfed Punjab
- Er. S. S. Kohli, CGM (Technical) Haryana Dairy Federation
- Mr. Bharat Baliyan, Exhibition Director, Bharti Media & Events Pvt. Ltd. Delhi
- Er. S. K. Chaudhary, General secretary (IDEA) & Chief Technical Officer, ICAR-National Dairy Research Institute, Karnal Haryana

Core Organizing Committee

Er. S. C. Agrawal	President IDEA, Chairman
Er. R. K. Chugh	Vice President IDEA, Member
Er. S. K. Chaudhary	Secretary IDEA, Member
Er. K. L. Arora	Executive Member IDEA, Member
Dr. I. K. Sawhney	Vice President IDEA, Convenor
Dr. P. Barnwal	Principal Scientist, Co-Convenor

Registration Committee

Er. S. K. Chaudhary	Chairman
Dr. J. K. Dabas	Member
Er. Pavan Kumar	Member

Souvenir Compilation Committee

Dr. P. Barnwal	Chairman
Dr. Chitranayak	Member
Er. Ankit Deep	Member

Poster Session Committee

Er. Ankit Deep	Chairman
Er. Kushal Sandey	Member
Er. Yogesh Vekariya	Member

Technical Session Committee

Er. R. K. Chugh	Chairman
Dr. G. Mahesh Kumar	Member
Er. K. L. Arora	Member
Er. Kushal Sandey	Member
Er. Istiyak A. Chauhan	Member
Er. G. S. Spoorthy	Member
Er. Ankit Deep	Member
Er. Aswin Warrier	Member

Accommodation Committee

Dr. Chitranayak	Chairman
Dr. J. K. Dabas	Member
Er. Pavan Kumar	Member

Best M.Tech. & Ph.D. Thesis Award Committee

Dr. I. K. Sawhney	Chairman
Er. Ankit Deep	Member
Dr. J. K. Dabas	Member

Invited Speakers

Technical Session 1: 'Make in India' Initiatives in Manufacture of Dairy Processing Equipments

- Er. R.P. Singh, MD cum CEO, Food & Biotech. Engineers Pvt. Ltd.
- Mr. Rakesh Chopra, General Manager, Rajasthan Electronic & Instruments Ltd.
- Er. M. C. Chawla, Director, Process Engineers & Associates
- Dr. Mahesh Kumar, Head Dairy Engineering, DSC, Hebbal & Mentor of Milktech Engineers, Bangalore

Technical Session 2: Engineering Solutions for Automation, Energy and Supply Chain Management in Dairy Industry

- Er. Somesh Chugh, Director, Reliable Control Solutions
- Dr. Ravi Kumar, Ex-Dean, College of Dairy Science, Tirupati
- Dr. A. S. Khojare, Assistant Professor, Vivekanand College, Aurangabad
- Dr. P Barnwal, Principal Scientist, Dairy Engineering Division, ICAR-NDRI, Karnal
- Dr. Chitranayak, Senior Scientist, Dairy Engineering Division, ICAR-NDRI, Karnal
- Dr. J. K. Dabas, ACTO, Dairy Engineering Division, ICAR-NDRI, Karnal

Concurrent Poster Session

Technical Session 3: Oral Presentation by Researchers

Technical Session 4: Newer Challenges in Research, Education and Manpower Development in Dairy Sector

- Dr. S. N. Jha, ADG (Process Engineering) ICAR, New Delhi
- Dr. H. K. Desai, Advisor (Dairy Operations), Amul Dairy, Anand
- Dr. R. K. Malik, Ex-Joint Director (research), ICAR-NDRI, Karnal
- Dr. A. K. Agarwal, Head, Dairy Engineering Division, CODS Raipur
- Dr. A. K. Singh, Head, Dairy Engineering Division & I/c BPD ICAR-NDRI, Karnal

11th National Convention and Seminar on Dairy Process Engineering from 'Farm to Table'

21 to 22 October 2018 at Labh Ganga Convention Centre, Indore (M.P.)

Programme

Time	Particulars
Day: 1 Sunday, 21 October 2018	
08:30 AM onwards	Registration
09:00 AM to 11:00 AM	Inaugural Session
11:00 AM to 11:30 AM	Tea Break
11:30 AM to 01:00 PM	**Technical Session 1:** 'Make in India' Initiatives in Manufacture of Dairy Processing Equipments
01:00 PM to 02:00 PM	Lunch Break
01:30 PM onwards	Poster Session
02:00 PM to 03:30 PM	**Technical Session 2:** Engineering Solutions for Automation, Energy and Supply Chain Management in Dairy Industry
03:30 PM to 04:00 PM	Tea Break
04:00 PM to 06:00 PM	**Technical Session 3:** Oral Presentations by Young Researchers and Students
06:00 PM to 06:45 PM	General Body Meeting of IDEA
Day: 2 Monday, 22 October 2018	
09:30 AM to 11:00 AM	**Technical Session 4:** Newer Challenges in Research, Education and Manpower Development in Dairy Sector
11:05 AM to 11:25 AM	Tea Break
11:30 AM to 01:00 PM	Valedictory Session
01:00 PM to 02:00 PM	Lunch Break

Contents

Invited Talk Article Code: IN-NT-04

Technologies to Increase Efficiency of Dairy Value Chain

Rakesh Chopra[1], Arun Dwivedi[2]
[1]General Manager, [2]Manager, REIL, Jaipur

Rajasthan Electronics & Instruments Ltd., Jaipur (REIL) is a Schedule 'C' and "Mini-Ratna" Public Sector Enterprise under administrative control of Ministry of Heavy Industries & Public Enterprise, Govt. of India, New Delhi. The Company has a consistent track record of professional management and profitable operations since its inception in year 1981 with sustained growth. The company has recorded a growth of 135% for the last eight years (audited) with 855% increase in Profit. The Net Worth of the Company has increased five times and crossed three digits figure during the period. This growth vision is carried through product enhancements, cost reductions, larger markets through wider geographical reach, diversifications, absorption of new technologies and corporate governance.

Dairying has become an important source of income for millions of rural families and has assumed the most important role in providing employment and income. With the support of various schemes from Government of India, the per capita availability of the milk has also increased to a level of about 337 g. per day. Company has supplied various milk testing equipments like EMT, Auto EMT, Ultrasonic milk analyzer, Electronic Milk Adulteration Tester, Solar based Data Processor Milk Collection Unit , Automatic Milk Collection Unit, RFID based cattle registration / identification system for dairy animals etc. REIL introduced GPRS based solar DPMCU, which is equipped with GPRS technology to transfer the real time data which also reduces the transportation cost and solar power pack to reduce the dependency on utility grid.

- **A step towards … Solar Energy in Dairy Sector:**

Power requirements in the Value and Supply Chain in dairy sector are challenge today. Availability and quality of grid power were often became the issues in setting up of effective value and supply chain in the dairy sector. Dairy Sector needs approx. 221 MW power at village DCS, MCC, Plant level & Value Chain. It is estimated that renewable energy solutions in dairy sector may be beneficial for our society in terms to boost the climate condition. The objective to introduce Renewable Energy in Dairy is as under.

- Increase independence from fossil fuels
- Reduce electrical grid loads
- Improve security of energy supply
- Reduce running costs
- Reduce CO_2 emissions
- Plentiful availability and virtually inexhaustible
- Attractive Payback Period

Perhaps enough focus on automation of value and supply chain has already been given, now it is the time to focus on feeding critical energy need of supply and value chain. We have been blessed by the massive availability of sunlight. Solar Photovoltaic (SPV) is time proven technology for energy generation especially in the rural area. Appropriate use of on grid & off grid, SPV solutions can be effective for the dairy supply and value chain.

Rajasthan Electronics & Instruments Limited (REIL), Jaipur has been nominated by Govt. of India and Govt. of Rajasthan for electrifications of 9100 gram panchayat and 248 panchayat samiti of Rajasthan under Jawaharlal Nehru National Solar Mission spread across the area of 3.42 lakh sq. Kms. 1.12 KWp SPV Solution was installed at Gram Panchayat and 2.24 KWp SPV power solutions (total capacity 11 MWp) were installed at panchayat samitis. The project benefited rural masses with IT enabled services to exercise their rights under NREGA specially, submitting of application for job cards, work, muster roll scrutiny, and complaints etc. Above project can save 11 MW Grid power for other necessary use. Moreover, availability of SPV power is also ensured. The project is being monitor by a web portal and got access to all stake holders in the chain.

With success of that project, REIL explore possibilities in dairy sector wherein, each Dairy federation has thousands of DCSs and BMC/MCCs. A dedicated roof top SPV Power system similar to "Gram Panchayat" will be effective to meet the need of such village DCS and at BMC/MCC. REIL is also in the area of designing Grid interactive rooftop SPV power plant meeting the specific needs of dairy plants. These systems are cheaper than offline systems as battery bank is not required. Use of String Inverter will reduce the DC loss as they are commissioned nearer to SPV modules. Generation can be monitored at multiple locations through Remote Monitoring system. Payback period of the project is approx 6-7 years. The benefits of Grid interactive rooftop power plant are as under:

- Noiseless, pollution free and eco-friendly green power.
- Saving of precious fossil fuels

- Revenue generation through export of excess power to grid and production credit as per state govt policy. So more cost-effective than utility power.
- Very low operation and maintenance cost for the life span of the power plant.
- Monitoring of power generation through remote monitoring system.

SPV power plant capacity 1.12 & 2.24 KWp SPV power plant at Panchayat Samiti

Malabar Dairy, 30 KWp Solar (Off Grid) Rooftop Power

Parvati Dairy, 100 KWp Solar Grid connected Rooftop Power

Solar Roof top Power Plant in various dairies

REIL also explored the possibilities for use of SPV in the supply chain i.e. Cold Chain network and experience challenges on it. These experience need to be share to find out better solutions in this field. Refrigeration is a major energy consuming utility in dairy sector. It is estimated that electricity consumption of refrigeration plant is about 50-60% of total electrical consumption. To meet the cost effective need of SPV solutions, REIL exchange the ideas with the renowned German Refrigeration labs for use of solar energy for refrigeration. The projects like SPV Power back up system for Ice cream vending cart & BMC are on.

Solar energy can fulfill the required demand for energy in dairy sector with installation of rooftop SPV power plants in DCS for milk analysis and refrigeration purpose and plant level for milk and milk products which shall also fulfill the basic need. The thermal stress of cattle's will also be reduced with installation of Rooftop power plant on cattle shelters as well as water pumping systems to fulfil their basic requirements.

NDDB has also taken initiative to consider solar as an integral part of DPMCU in new NDP framework agreement. Till date 1.75 MWp SPV systems in dairy has already been deployed by REIL. These are solar based hybrid system which increases the life of the equipments as it works on 12 VDC.

- **Doubling the Farmer Income :**

NDDB Anand has taken initiative to install 2 KWp Grid interactive Hybrid SPV power plant in Mujhkuan village DCS to power up AMCU and their necessary appliance. This is a hybrid system where SPV, Grid and Batteries are working in parallel to feed the power to load according to priority decided. Net metering facility for hybrid system in battery backup system is subjected to the state Govt. policy.

Another important initiative taken by NDDB, Anand is to install 150 KWp micro grids for various water pumping systems in Mujkuva, Anand. H'ble Prime Minister has e-inaugurated India's first Solar Cooperative, Mujkuva Saur Urja Utpadak Sahakari Mandali on 30.09.2018 at Amul, Mogar plant at Anand.

Solar BMC

GPRS based solar DPMCU

Grid Interactive Hybrid SPV power plant in Mujhkuva

Inaugural Photograph of India's first Solar Cooperative, Mujkuva Saur Urja Utpadak Sahakari Mandali

This project is Engineered and Commissioned by REIL in agreement with NDDB and IWMI. The project is aimed for doubling farmer's income, reduce carbon emissions, encouraging renewable energy and save depletion of ground water level. The total project capacity is 150 KWp with 8 nos. of 15 HP and 3 nos. of 10 HP DC pumps. The project is commissioned and tested successfully and handed over to cooperative society.

Grid interactive Hybrid SPV power plant in Mujhkuva

If Battery is fully charged and load is less than generation than excess power will directly be feed to Grid and finally will be settled in next bill of Discom under net metering policy. If Battery is under charge and load is more than generation than load will be share by Solar and grid. During absence of grid, complete load will be shared by priority to SPV and Battery. Excess power generation will be exported to the grid and same shall be settle down by discom against consumed utility grid under net metering policy. Net metering policy makes Grid interactive solar power systems financially attractive as surplus power can be sold back to the utility.

- **Milk Hygiene& Safety:**

Optimum use of technology will ensure productivity & growth for dairy industry and ensure safe milk & milk products to the consumer. Now a day's Milk adulteration is big challenges for Indian Dairy Industry. The better way to address this problem is by preventing at village level before pouring and then at MCC or Plant before mixing. Available lab methods are not being used in village effectively.

We get milk of Cattle through village co-op society & process in different stages and finally it deliver to the consumer in the form of Milk and Milk products. During this process, we can maintain & improve the quality of milk by putting check marks through technology. With the help of technology, adulterated milk can be discarded on entry level and manual process delay can also be reduced up to a great extent, so that the generation of bacteria can be controlled. In this way, we can speed up & assure the delivery of milk & milk products to consumer in time.

Electronic Milk adulteration tester is based on Indigenous Green technology which is latest, economic & compatible equipment to check harmful adulterants at village level. It can analyse 90-100 samples per hour. It Checks harmful adulterants like Urea, Detergent, Salt, Soda, Ammonium Sulphate, Hydrogen Peroxide, Caustic Soda etc. It can also measure Fat, SNF, Protein, Lactose, TS & added water. High End technology can also be used at plant level but such critical technologies & instruments need a fair, reliable & trusted Indian technical partner to keep the check on price, product life cycle and Indigenous. Strip based Test for Detection of Adulterants is also available in market for analysis of Added Glucose, Hydrogen peroxide, Malt dextrin, Urea, Neutralizers and Sugar.

Adulterants	Limit of Detection
Urea	≥0.1 %
Soda (Sodium Bicarbonate)	≥0.3 %
Ammonium Sulphate	≥0.2 %
Salt	≥0.2 %
Detergent	≥0.3 %
Hydrogen Peroxide	≥0.3 %
Caustic Soda	≥0.3 %

Parameters	Limit of Detection
Fat	0.01% to 25%
SNF	3% to 15%
Protein	2% to 7%
Lactose	0.01% to 6%
Density	1015 to 1040 Kg/m3
Added water	0% to 70%

Electronic Milk adulteration tester (EMAT+)

Invited Talk Article Code: IN-NT-02

Energy Management in Dairy Industry for Enhanced Profitability

J. K. Dabas
ICAR-NDRI, Karnal

Introduction:

Milk contributes more to the national economy than any other farm commodity. Over the years, India has emerged as one of the world's biggest producers of milk, with the total milk production rising from 122 Million Metric Tons in 2010 to around 170 Million Metric Tons in 2017. Despite this, the majority of the dairy industry in India is still highly unorganised dominated by small and marginal dairy farmers. (https://www.researchandmarkets.com) The organized sector of the milk processing industry is small compared to the huge amount of milk produced every year. According to NDDB, the total installed processing capacity of the dairy cooperative sector is approximately 43 million litres per day while the total registered processing capacity of private dairy sector is 73 million litres per day. (Indian Dairy and Products Annual Report 2017) As per economic times news report of Dec 2017, the creation of eight thousand crore rupees fund for developing dairy processing capacities of cooperative sector through the National Bank for Agriculture and Rural Development (NABARD) will enable milk co-operatives to create an additional 50 million litres of milk processing capacity. As the industry possesses huge untapped opportunities, it has attracted a number of private companies and investors also. But the opportunities in both rural and urban markets will be bolstered by increasing margin pressures for dairy processors. Rising dairy farming input costs coupled with the costs for collecting, storing and transporting milk squeezes processors' profit margins. Private companies are dissuaded by issues like price pressure, low margins, and requirement for extensive distribution networks.

Still the trends supporting market growth include:

- Steady expansion of the organized sector
- Opportunities to differentiate basic products
- Urban consumer preference for convenient, healthy yet indulgent products that increase premiumization
- User disposition toward the taste of dairy-based health products despite the availability of several non-dairy substitutes
- Demand for and hence opportunity to create new categories in functional products and single serving units
- High acceptance of new brands in the wellness and premium segment, which enables easy market entry for new players

In this way we can see that there are huge opportunities available to be trapped along with big challenges in the Indian Dairy Industry. Major challenge as stated earlier is to reduce the processing cost while maintaining high quality standards to beat the competition and stand in market. We know that the dairy processing industry is one of the most energy intensive sectors and the energy cost involved in processing contributes to major share of the total processing cost. Thus there is a large scope of processing cost cutting through implementation of energy saving measures or applying effective energy management practices. The main driving forces in the implementation of best energy saving practices in an industrial plant are not only cost saving but also the environment regulations imposed by government regulating agencies and the subsidies available on using of renewable sources of energy.

Dairy manufacturing processes vary greatly from one product to the other, but most share the initial steps of raw milk processing: separation, standardisation, pasteurisation and homogenisation (for the liquid milk industry); as well as the required supporting utilities such as refrigeration, steam generation, water/ effluent treatment and Clean-in-Place (CIP) systems. The milk industry's competitive nature, energy-intensive operations, environmental targets and customer demand have resulted in a proactive approach to energy efficiency and cost reduction. The specific energy consumption per cum of milk has been steadily shrinking as different energy saving measures are being continuously implemented. However, there is still a wide range in specific energy performance across dairies, with the most efficient using 32 kWh/m^3 raw milk and the least efficient over 1,000 kWh/m^3 raw milk. This difference arises not only because of the product variation (e.g. evaporation and spray drying are more energy intensive operations) but also because the sites vary widely in how far they have implemented best practice energy efficiency measures. Thus sensitization to the importance of energy management and brief explanation of the scopes of energy saving in dairy/ food industry is very much necessary for the dairy industry stakeholders.

Important Terms related to Energy Saving:
Energy Efficiency: It is the ratio of output to input of equipment in terms of energy and involves the use of technology that requires less energy to perform the same function. It is related to and focussed on equipment.

Energy Conservation: It includes any behaviour/ technology that results in use of less energy or prevents loss of energy by efficiently managing the energy consuming activities during any energy conversion process. It is mainly focussed on people.

Energy Benchmarking: It is the practice of comparing the measured energy consumption or energy conversion performance of a device, process, facility, or organization relative to other similar device, process, facility, or organization, or to modelled simulations of a reference built to a specific standard (such as an energy code).

Energy Audit: The verification, monitoring and analysis of use of energy including submission of technical report containing recommendations for improving energy efficiency with cost benefit analysis and an action plan to reduce energy consumption are included in the energy audit.

Energy Management: The strategy of adjusting and optimizing energy using systems and procedures so as to reduce energy requirements per unit of output while holding constant or reducing total costs of producing the output from these systems is the energy management. Its purpose is the judicious and effective use of energy to maximize profits (minimize costs) and enhance competitive positions.

Energy Saving Opportunities in a Typical Dairy Plant:
The energy conservation opportunities can be identified in four major areas as: Energy Generation, Energy distribution, Energy Usage and Energy/ Fuel substitution. The main equipment/ systems having energy saving opportunities among these four areas have been discussed here.

(A) Dairy Processing Equipment: Energy saving opportunities lie in proper and efficient process control and operation of dairy equipments.

1) **Pasteurizer:** The intensive use of heat and cooling in the pasteurisation process suggests the following areas of opportunity:
   - Improved Regeneration Efficiency through more efficient heat exchangers.
   - Pasteuriser Hibernation is adopted during non-productive circulation periods which are longer than 10 minutes. During hibernation the cooling section is typically turned off, and the heating is reduced by about 90%, reducing the heating and cooling load by approximately 95%.
   - Low Temperature Pasteurization: Substituting (or supplementing) the current system of thermal pasteurisation with a lower temperature microbial destruction process suggested in alternative methods as using UV light, pulsed traditional light and pulsed electric field pasteurisation.

2) **Homogenisation:** The relatively large amount of energy needed for homogeniser pumps suggests the following areas of opportunity:
   - Partial Homogenisation: Reducing the homogeniser throughput by homogenising only the fat-enriched phase from the separator, and mixing this with the low-fat phase.
   - Reducing Head Pressure: Analysis shows that if the homogeniser working pressure can be reduced through innovations in orifice design, then the associated electrical energy needed to drive the system could also be reduced. For example upgrading the homogeniser head to the most efficient pressure design (180 bars down to 120 bars) could reduce electrical consumption by up to one third.

3) **CIP Optimisation**
   - Reduction of CIP water volume and/or temperature would reduce the energy consumption of CIP systems. Real aim is to control the microbial levels within the pipes and not the temperature or volume of the working fluid.
   - Reduction in the number of CIPs: Typically CIP cycles are instigated through timers, product change and operator discretion. Rather these should be instigated as per requirement.
   - Avoiding an unnecessary level of cleaning for a required standard of hygiene. Further investigation into how the design of a CIP system affects its energy demand is always needed to model accurately the potential savings.

- Cleaning of CIP detergent solution with membrane technology would reduce the amount of hot solution that is currently wasted to drain after becoming too contaminated to return to the main tanks.
- An alternative approach could be to minimise the heat capacity of process equipment through new equipment materials and design e.g. alternative pipe material.

Alternative CIP Technologies:

- Cleaning verification: Investigating the whole CIP process of a plant through advance monitoring to determine when individual parts of the system are clean. This information is then used to re-model the system in order to use the minimum energy and water possible.
- Ice pigging: Installing cleaning pipe systems using a crushed ice slurry that can be loaded with specific compounds such as caustic or acid while maintaining sharp product interfaces to reduce product loss and water wastage. This could either run as an independent system or in conjunction with existing CIP systems.
- Whirlwind pigging: This technology can clean through pipe systems using a fraction of the energy of traditional CIP systems while still providing the necessary disinfectant and sterilisation.
- Ultrasonic cleaning: Ultrasonic cleaning can be used alongside traditional CIP to reduce the demand on the hot detergent by removing material from areas which are difficult to clean.

(B) Dairy Utilities:

1) **Air Compressor**: An approximate data for electrical energy consumption of air compressors is 8-10 % of the total electricity consumption of a typical dairy plant. Following are the energy saving opportunities in compressed air systems:
   - Lower Pressure (loading and unloading) setting: If the process permits, 1 bar of pressure reduction saves 6% to 10% energy. Minimum difference between loading and unloading should be 0.6 bar.
   - Using of VFD particularly for frequently loading and unloading compressor is always beneficial
   - Minimization of Leakage in air line: The accepted level of air leakage in the plant is 10%. More than that should be limited by checking and replacing of wear parts, rubber 'o' rings and seal kits of pneumatic cylinders, pressure regulating valves, solenoid valves, pneumatic switches and moisture separators etc.
   - Replace overcapacity compressor. as it increase the idle running losses. Screw compressor is better than reciprocating due to low vibration and low maintenance and better efficiency but is most suitable for steady air demand. However, it becomes a best energy efficient choice if driven by VFD.
   - Use of multi-stage compressors in place of single stage is always an energy efficient choice.
   - Avoid high pressures drop in the compressed air line due to choked filters.
   - Heat recovery from air compressor after each stage of compression is beneficial for space heating or producing hot water to be used in CIP.

2) **Cooling and Refrigeration:** A centralized ammonia refrigeration plant to serve the cooling needs of storage as well as processing is the most important utility in a dairy plant but consumes nearly 50% of the total electric energy consumption of the plant. Thus there is a large scope of cost saving by adopting various energy saving opportunities in the refrigeration plant. Some are being summarized below:
   - Achieving stable plant operation at varying cooling load by smooth response to changes through effective control strategies is most important factor in energy/ cost saving.
   - Variable head pressure control with ambient sensor can save a lot of compressor power as the compressor power reduces 2-3% per 1°C reduction in condensing temperature.
   - Compressor control: Screw Compressor capacity can be better controlled by using VFD as compared to sliding vane control. Variable capacity by variable speed results in very low noise, smooth change and high efficiency at part loads.
   - Heat recovery: Heat recovery from the ammonia refrigeration plant can be done from three sources given in the order of increasing temperature as the lower discharge, the higher discharge and the oil cooler.
   - Defrost management: It is an important part of the operation of refrigeration plant and the optimum selection of defrost temperature, methods, cycle period etc. has large scope in

energy saving due to higher fraction (approximately 20%) of total energy consumption consumed in frosting only. Electric defrost is the worst method.

- Variable cold store temperatures: Individual real time temperature setting for each cold room and cooling application is critical to energy saving methodologies.
- Variable evaporator fan speeds: The evaporator fans speed can be reduced intermittently when the cold store doors are closed and during the night which cause considerable energy saving.
- Condensate sub-cooling: A design review must be done on an existing refrigeration plant to explore the full extent of performance enhancement through condensate sub-cooling.
- Non-Condensable Control by replacement of Manual Air-Purging with Auto Air-Purging.
- Design review: There may be sufficient possibilities of energy saving through design reviews and modifications in a multi pressure refrigeration plant.
- Maintenance review: Without following an effective preventive maintenance schedule, an efficient design may also cause loss of energy.
- Effective management of cooling produced by preventing any sort of loss / leakage and poor maintenance of refrigerant lines, insulation and vapour barrier.
- Alternate refrigeration technologies like vapour absorption/ adsorption refrigeration systems run by cheap/ waste heat energy.

3) **Boiler and steam distribution:** Following are the energy conservation opportunities in this area.
   - Reducing Stack Temperature: 20°C reduction in flue gas temperature increases boiler efficiency by 1%.
   - Feed Water Preheating using Economizer: For an older shell boiler, with a flue gas exit temperature of 260°C, an economizer could be used to reduce it to 200°C. Increase in overall thermal efficiency would be in the order of 3%. A 6°C raise in feed water temperature, by economizer/ condensate recovery, corresponds to a 1% saving in fuel consumption.
   - Combustion Air Preheating is an alternative to feed-water heating. In order to improve thermal efficiency by 1%, the combustion air temperature must be raised by 20°C.
   - Controlling Incomplete combustion: Poor oil fires can result from improper viscosity, worn tips, carbonization on tips and deterioration of diffusers. Increase in the fines in pulverized coal also increases carbon loss. A routine check through flue gas analyzer or boiler efficiency indicator is always a smart choice.
   - Controlling excess air is a direct energy saving technique as for every 10% reduction in excess air, 0.6% rise in efficiency takes place. Fit VSD to FD fan and feed pump.
   - Maximization of condensate return: The condensate should be recovered through proper recovery system. It not only saves the energy directly but also indirectly through saving in feed water treatment.
   - Optimization of steam generation and distribution pressure: A good design of steam distribution system with piping, insulation and condensate drain out points ensures minimum pressure and heat loss and less generation pressure demand resulting in fuel saving.
   - Blow-down heat recovery can also be thought off or use a de-aerator to reduce blow-down.

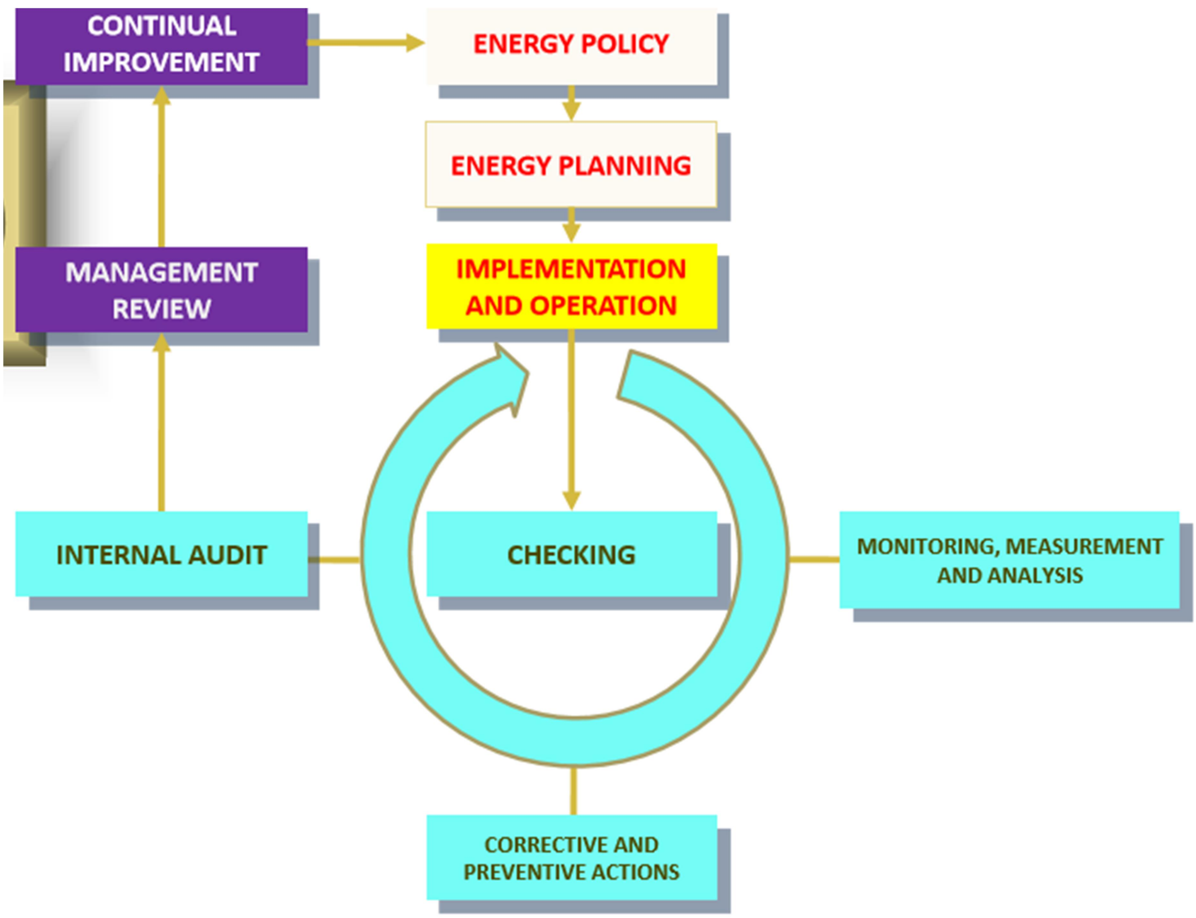
4) **Pumping Systems:** The various energy conservation opportunities in the operation of pumps are summarized below:
   - Selecting the right pump and operate pumps near best efficiency point.
   - Controlling the flow rate by speed variation
   - Pumps in parallel to meet varying demand
   - Eliminating flow control valve
   - Eliminating by-pass control
   - Start/stop control of pump
   - Modify pumping system/pumps losses to minimize throttling
   - Adapt to wide load variation with variable speed drives
   - Stop running multiple pumps - add an auto-start for an on-line spare or booster pump in the problem area
   - Replace old pumps by energy efficient pumps
   - If the system requirements keep on varying, variable speed drive (VSD) can be successfully used for energy conservation. If the system gets stabilized and no variations occur, trimming the impeller for the required head will be the ideal solution for energy conservation.

5) **Electrical Systems:** Here, the energy conservation opportunities lie in the following:
- Electricity billing analysis
- Electrical load management and maximum demand (MD) Control
- Power factor improvement and its benefit
- Transformer losses and optimization
- Energy Conservation in motors

Energy Management Practices:
The objectives of energy management are: To achieve and maintain optimum energy procurement and utilization throughout the organization; To minimize energy costs & waste without affecting production & quality and To enhance energy security, economic competitiveness and environmental quality. The energy audit and benchmarking are the basic preliminary steps of energy management, which decides the main areas of energy requirement, types of energy saving measures to be stressed upon and where modifications are to be planned.

Basic Methodology of Energy Audit:
- Pre-audit presentation. Understanding of all the energy consumption points.
- Collection of data / information.
- Measurements and monitoring with instruments.
- Computation, benchmarking and in-depth analysis. Identify the most likely areas for attention. Identify immediate (no-/low-cost) improvements. Identify areas for more detailed study/measurement
- Post-audit presentation to discuss the Energy Conservation Opportunities identified by the audit team.

An Energy Management System (EnMS) based on ISO 50001:2011 is usually adopted by the Industry. It is a structured approach for energy efficiency improvement The features of ISO 50001:2011 are illustrated below:



Plan: First establish the organization's energy policy and then conduct the energy use assessment, establish the baseline, energy performance indicators (EnPIs), objectives, targets and action plans necessary to deliver measurable results related to energy efficiency, use and consumption in line with the organization's energy policy.

Do: Implementation and operation of energy plan which includes:

- Competence, training and awareness of work force on their role, responsibilities and duties
- Communicate internally with workforce on energy performance & EnMS and establish a process through which suggestions can be invited to improve EnMS
- Records and document of the implementation and operation of the EnMS- scope and boundaries, energy policy , objectives , targets, action plan and other documents are required
- Operational controls of those operation and maintenance activities related to significant use of energy
- Design of new, modified and renovated facilities, equipment, systems and processes that can have a significant impact on energy performance.
- Procurement of energy efficient products, services and energy.

Check: It involves monitoring, measurement and analysis. Internal audits are conducted to ensure that Energy Management System (EnMS) confirms to planned arrangements for energy management, energy objectives or the targets established and effective implementation.

Act: Top management shall review the organization's EnMS to ensure its continuing suitability, adequacy and effectiveness and take corrective and preventive actions for continual improvement.

Reference:

[1] *Training Programme on "Improving Productivity and Profitability in Dairy Sector by Effective Energy Management Practices" National Productivity Council, 2016.*

Invited Talk Article Code: IN-NT-03

Bulk Milk Cooling – its use and misuse

S. Ravi Kumar
Ex-Dean, College of Dairy Science, Tirupati

Milk, the *Elixir* of human life is most perishable of the agricultural commodities and needs to be preserved from microbial spoilage. As the milk is collected from number of villages and needs to be transported to nearest processing centre, the period between the milking and the processing has to be reduced, and preferably temperature to be brought down to below 5 ˚C, to slowdown the population growth of microorganisms.

This was achieved, by a plate heat exchanger to chill the milk, using chilled water, generated by Refrigeration system. The milk chilling centres had to be provided with elaborate chilled water system, with an Ice Bank Tank. These units needed greater gestation time for installation and commissioning, as civil works were also involved. Further, it was found that this system to be economical needs larger volumes of milk handling.

To improve upon this situation, cooling in bulk at village itself was initiated, through Bulk milk coolers (BMCs), which need about 3 hrs to bring the temperature of milk down to below 5 ˚C from the ambient. Even this would need more than one village to meet its minimum capacity of 500 to 1000 litres.

However, care is to be taken in locating, and choosing the appropriate size of the BMC so that the time of milk collection at the village, and its transport to the processing centres is minimized. Keeping the raw milk for long at low temperatures, causes a change in the microbial population in milk towards psychotropic bacteria, which can cause, even after their elimination during the processing, certain flavour defects.

The issues here are i) the Standards ii) the size of the BMC and iii) the time taken for procurement

The Standards: The BMCs are being classified mostly as per ISO 5708 standard, which laydown the capacities and operating conditions. The BMCs categorisation as per safe operating temperatures of ambient is designated as A, B and C corresponding to 43, 38 and 32˚C respectively. Also, the rate of cooling is also designated as I, II, III, and IV corresponding to the rate of cooling of first milking from 35 to 4 ˚C in 2.5, 3.0, 3.5 and manufacturer declared performance, respectively. For example, a BMC performance designated as meeting ISO 5708 – 2 A II, indicates that, the BMC is designed to receive milk, twice a day and can operate with ambient temperature up to 43 ˚C. Further it can cool the first milking in 3.0 h.

An important observation here is that the ISO standards which are international assume large production of milk, and assume more than two milking on a single day. Further, the procurement to be equal in both morning and evening. However, under Indian conditions, the ratio of milk procurement between morning and evening is either 60:40 or even 70:30.

The Size: From company to company, the cooling capacities do vary for the same milk holding capacity. Further, the declared holding capacity and heat gain have to be carefully evaluated, before finalizing the choice of BMC as per specific requirement.

The economics of scale dictates that the size should be at least 2,500 litres capacity, as some studies indicate. But the typical Indian villages do not have that much of surplus of milk. Even village clusters do not meet this quantity of surplus milk. The most interfering factor now is the severe completion for the same quantity of surplus milk in village by many players, organized and unorganized. The BMC, sized, selected and installed initially finds handling less and less capacities.

The Time taken: To meet the capacity requirement of the BMCs, the procurement for this BMC itself is being organized in three or four routes, which are going as far as 10 to 12 km in some cases. This adds to the already delayed rate of cooling, the important aspect of time factor of milk procurement. The trend in villages also has changed from getting up early in the morning, and milking, and instead is milking at much later hours, even 7.00 am.

All this added up to one thing: a poor quality of milk and its consequent market effects. Some of the quality conscious dairies have avoided installing BMCs altogether, as they had limited control on the procurement situation in villages once it is installed. The very important observation also of the longer period of temperature being held at temperatures that are optimum for psychrotropic bacteria to grow. This has resulted in bitterness in the taste of milk when it is finally pasteurized, packed and distributed.

The solution is needed to correct this situation. Especially choosing the size of BMC to maximum that is possible for the milk procurement in the cluster villages, within 4 or 5 km, and curtailing the operational expenses that the smaller quantity of milk procurement would generate for the milk collection centres. Use of solar energy to some extent may mitigate the power requirement. Further, use of BMCs with Ice Bank Tank system, may be used in such cases where solar energy is used. An accompanying PHE, for recirculation, using the chilled water in the IBT may be possible, avoiding a larger IBT, with civil works and attendant refrigeration losses. The standards may also may also be tweaked to suit to the tropical conditions, so that faster cooling is targeted.

The small scale bulk coolers can also be powered by gas fuelled generators, gainfully using the biogas that could be produced in the village biogas plans. A recent trend in using solar photovoltaic cells for powering the measuring and testing accessories in BMCs, can in future be extended for powering the BMC itself.

Finally, though the introduction of Bulk milk cooling on the whole has fulfilled the long felt need of maintaining cold chain in the overall handling of milk in the dairy industry, it needs to be carefully managed.

Table1: Bulk Milk Coolers vs Conventional Milk Chilling

Parameter	Bulk Milk Cooler	Conventional Milk Chilling
Collection Time	½ to 1 hr	2.5 to 3 hr
Area of Collection	3 km radius	30 km radius
Chilling Temp	3 °C	6 to 7 °C
MBR time	More than 1 ½ hr	Less than 1 hr

Technical Article for Oral Presentation Article Code: IN-NT-04

Food Safety: Recent Approaches and Processes

R. K. Malik, Rajashree Jena
Dairy Microbiology Division, ICAR-NDRI, Karnal

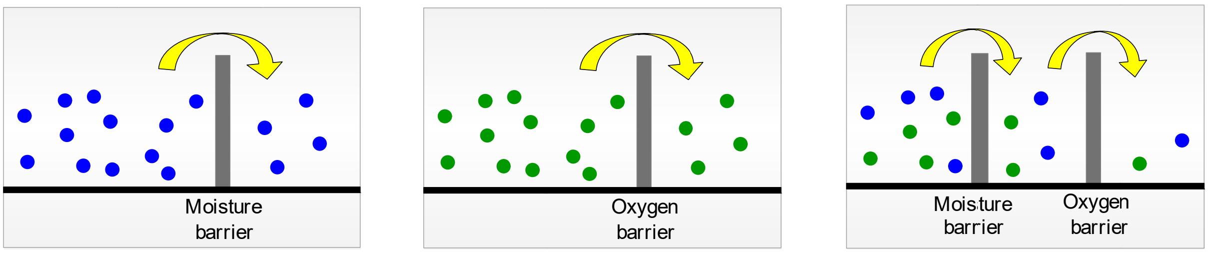
Introduction

Safety of food is an important health, social and economic issue. Food and its safety has become the topic of globally increasing research efforts, particularly in view of the growth of human population. Throughout the world, food production has become more complex. Frequently, raw materials are sourced globally and the food is processed through an increasing variety of techniques. No longer does the local farm serve the local community through a local shop. Nowadays, there are international corporations adhering to national and international regimes. Therefore, approaches to safe food production are being assessed on an expanding platform from national to international. Dealing with food safety problem is challenging, in part because they are changing. We have changes in our economy, and, therefore, lifestyle, eating habits and an aging population. Food producers, both industrially and domestically, need to be aware of these changes in order to improve the safety of foods. Industry and national regulators are striving for production and processing systems which ensure that all food is safe and wholesome, although a complete freedom from risks is an unattainable goal.

Extending the shelf-life of foods whilst maintaining safety and quality is a critical issue for the food industry As a result there have been major developments in food preservation techniques. Consumers demand products with fewer synthetic additives but increased safety and shelf-life. Nowadays packaging plays an increasingly important role in the whole food chain 'from the field to the consumer's table. Food packaging has developed strongly during the last few years, mainly due to increased demands on product safety, shelf-life extension, cost efficiency, environmental issues, and consumer convenience. Antimicrobial packaging is one of many applications of active packaging (Floros *et al*., 1997). Active packaging system possesses attributes beyond basic properties, which are achieved by adding active ingredients in the packaging system and/or using actively functional polymers (Han and Rooney, 2002). Antimicrobial packaging is the packaging system that is able to kill or inhibit spoilage and pathogenic microorganism that are contaminating foods. The new antimicrobial function can be achieved by adding antimicrobial agents in the packaging system and/or using antimicrobial polymers that satisfy conventional packaging requirements. When the packaging system acquires antimicrobial activity, the packaging system (or material) limits or prevents microbial growth by extending the lag period and reducing the growth rate or decreases live counts of microorganisms (Han, 2000). The primary goals of an antimicrobial packaging system are (i) safety assurance, (ii) quality maintenance, and (iii) shelf-life extension, which is the reverse order of the primary goals of conventional packaging systems. Nowadays security is a big issue and antimicrobial packaging could play a food security assurance.

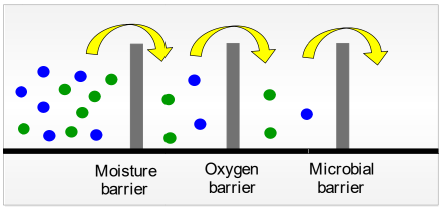
All antimicrobial agents have different activities which affect microorganism differently. There is no 'Magic Bullet' antimicrobial agent effectively working against all spoilage and pathogenic microorganisms. This is due to the characteristic antimicrobial mechanisms and due to the various physiologies of the microorganisms. Simple categorisation of microorganism may be very helpful to select specific antimicrobial agents. Such categories may consist of oxygen requirements (aerobes and anaerobes), cell wall composition (Gram positive and Gram negative), growth-stages (spores and vegetative cells), optimal growth temperature (thermophilic, mesophilic and psychrotrophic) and acid/osmosis resistance. Besides the microbial characteristics, the characteristic antimicrobial function of the antimicrobial agent is also important to understand the efficacy as well as the limits of the activity. Some antimicrobial agents inhibit essential metabolic pathways of microorganisms while some others alter cell membrane/wall structure. For example, lysozyme destroys cell walls without inhibiting metabolic pathways and results in physical cleavages of cell wall, while lactoferrin and EDTA act as coupling agents of essential cationic ions and charged polymers. Two major functions of microbial inhibition are microbial-cidal and microbial-static effects. In the case of microbial-static effects, the packaging systems have to possess the active function of maintaining the concentration above the minimal inhibitory concentration during the entire storage period or shelf-life in order to prevent re-growth of target microorganism.

The basic principle of antimicrobial packaging is a hurdle technology and the extra antimicrobial function of the packaging system is another hurdle to prevent the degradation of total quality of packaging foods while satisfying the conventional functions of moisture and oxygen barriers as well as physical protection. The microbial hurdle may not contribute to the protection function from physical damage. However, it provides tremendous protection against microorganism, which has never been achieved by conventional moisture and oxygen barrier packaging materials.



Single Layer Package (LDPE) | Single Layer Package (EVOH) | Composite Package (LDPE/EVOH)

Conventional Packaging System



Antimicrobial Packaging System

Adapted from HAN J H (2000), 'Antimicrobial Food Packaging' in Novel Food Packaging Techniques, Ed. Raija Ahvenainen

Antimicrobial agents

There are many antimicrobial agents that exist and are widely used in the foods, pharmaceuticals and cosmetic products. The industry must follow the guidelines and regulations of the country that they are going to use them e.g., FDA and/or EPA in the United States. This implies that new antimicrobial packaging materials may be developed using only agents which are approved by the authorisation agencies or notified-to-use within the concentration limits for food safety enhancement or preservation. Various antimicrobial agents may be incorporated in the packaging system, which are chemical antimicrobials, antioxidants, biotechnology products, antimicrobial polymers, natural antimicrobials and gas.

Antioxidants are effective antifungal agents due to the restrictive oxygen requirement of moulds. Food grade chemical antioxidants could be incorporated in to packaging materials to create an anaerobic atmosphere inside packages, and eventually protect the food against aerobic spoilage (Smith *et al., 1990)*. Therefore, in order to maintain the low concentration of oxygen barrier materials such as EVOH, PVDC or aluminium foil that prevents the permeation of oxygen. Besides the antioxidants, a multi-ingredient oxygen scavengers system, such as commercial oxygen-absorbing sachets, can be used to reduce oxygen concentration inside the package.

Various bacteriocins that are produced by microorganisms also inhibit the growth of spoilage and pathogenic microorganisms. These fermentation products include nisin, lacticins, pediocin, diplococcin and propionicins (Daeschul, 1989; Han, 2002). These biologically active peptides possess strong antimicrobial properties against various bacteria. Other non-peptide fermentation products such as reuterin also demonstrate antimicrobial activity. Besides the above food grade bacteriocins, other bacteriocins would be utilised for the development of antimicrobial packaging systems.

Ultraviolet or excimer laser irradiation can excite the structure of nylon and create antimicrobial activity. Among natural polymers, chitosan (chitin derivative) exhibits antimicrobial activity. Short or medium size chitosan possesses quite good antimicrobial activity, while long change chitosan is not effective. Chitosan has been approved as a food ingredient by FDA, recently. Therefore, the use of chitosan for new product development as well as a natural antimicrobial agent would become more popular.

The use of natural plant extracts is desirable for the development of new food products and nutraceuticals, as well as new active packaging systems. Some plant extracts such as grapefruit seed, cinnamon, horseradish and clove have been added to packaging systems to demonstrate effective antimicrobial activity against spoilage and pathogenic bacteria. More use of natural extracts is expected because of the easier regulation process and consumer preference when compared to the chemical antimicrobial agents.

Gaseous antimicrobial have some benefit compared to the solid or solute types of chemical antimicrobial agents. An ethanol sachet is one example of gaseous antimicrobial systems. Headspace ethanol vapour can inhibit the growth of moulds and bacteria. The use of chlorine dioxide has been permitted with no objection notification from FDA recently and can be incorporated into packaging material. Chlorine dioxide shows effective antimicrobial activity and some bleaching effect.

Since most antimicrobial agents have different antimicrobial mechanisms, the mixture of antimicrobial agents can increase antimicrobial activity through synergic mechanisms when they do not have any interference mechanisms. Therefore, the optimisation study on the combination of various antimicrobials will extend the antimicrobial activity of the mixture and maximise the efficacy and the safety of the antimicrobial packaging systems.

Antimicrobial agents and packaging systems

Antimicrobials	Packaging materials	Foods	Microorganisms
Organic Acids			
Benzoic acids	PE	Tilapia fillets	Total bacteria
	Ionomer	Culture media	*Pen.ssp.,Asp. nige*
Parabens	LDPE	Simulants	Migration test
	PE coating	Simulants	Migration test
	Styrene-acrylates	Culture media	*S.cerevisiae*
Benzoic & Sorbic acids sorbates	PE-co-met-acrylates	Culture media	*Asp.niger, pen.spp.*
	LDPE	Culture media	*S.cerevisiae*
	PE, BOPP, PET	Water, cheese	Migration test
	LDPE	Cheese	Yeast, moulds
	MC/palmitic acid	Water	Migration test
	MC/HPMC/fatty acid	Water	Migration test
	MC/chitosan	Culture media	-
	Starch/glycerol	Chicken breast	-
	WPI	Culture media	*S.cerevisiae,. Asp niger, Pen. Roqueforti*
	CMC/paper	Cheese	-
Sorbic anhydride	PE	Culture media	*S.cerevisiae, moulds*
Sorbates & Propionats	PE/foil	Apples	Firmness test
Acetic, Propionic acid	Chitosan	Water	Migration test
Enzymes			
Lysozyme, nisin, EDTA	SPI, Zein	Culture media	*E.coli, Lb.plantarum*
Lysozyme, nisin, EDTA, propyl paraben	WPI	Culture media	*L.monoctogenes, Sal.typhimurium, E.coli, B.thermosph., S.arueus*
Immobilised lysozyme	PVOH, nylon, cellulose acetate	Culture media	Lysozyme activity test
Glucose oxidase		Fish	-
Bacteriocins			
Nisin	PE	Beef	*B.thermosph.*
	HPMC	Culture media	*L.monocytogenes, S.aureus*
Nisin, lacticins	Corn zein	Shredded cheese	Total aerobics
	Polyamide/LDPE	Culture media	*M.favus, L.monocytogenes*
Nisin, lacticins	Polyamide/LDPE	Culture media	*M.flavus*
Nisin, EDTA	PE, PE-co-PEO	Beef	*B.thermosphacta*
Nisin, citrate, EDTA	PVC, nylon, LLDPE	Chicken	*Sal.typhimurium*
Nisin, organic acids mixture	Acrylics, PVA-co-PE	Water	Migration test
Nisin, lauric acid	Zein	Simulants	Migration test
Nisin, pediocin	Cellulose casing	Turkey, breast, ham, beef	*L.monocytogenes*
Fungicides			
Benomyl	Ionomer	Culture media	-
Lmazalil	LDPE	Bell pepper	-
	PE	Cheese	Moulds
Polymers			
Chitosan	Chitosan/paper	strawberry	*E.coli*

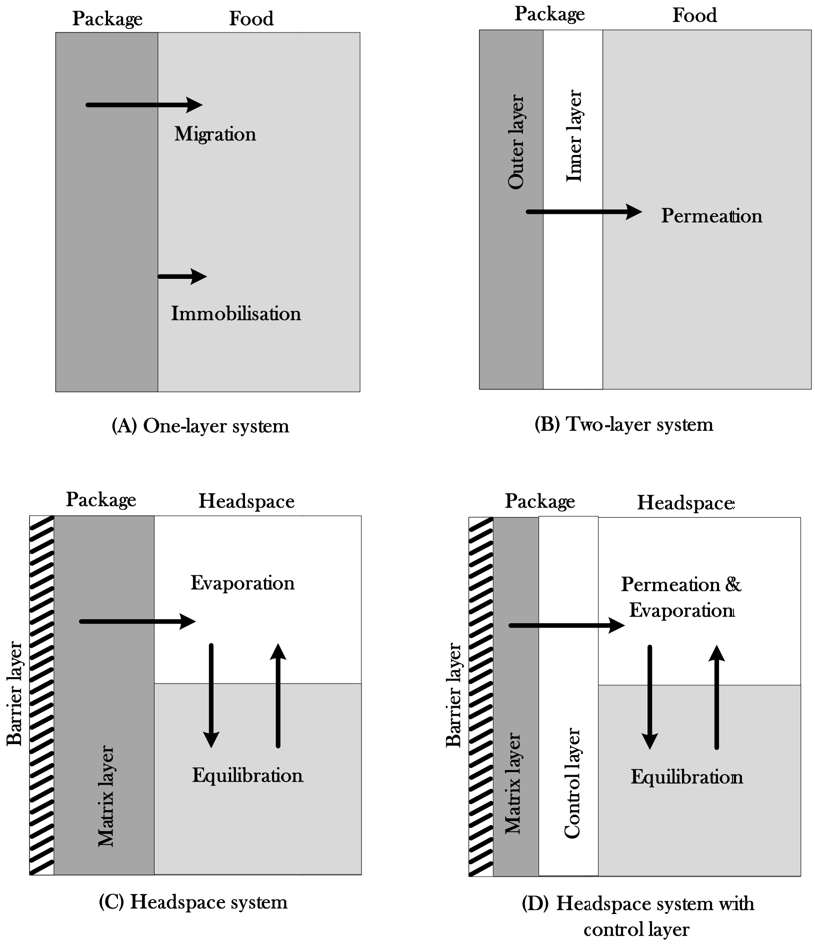
Chitosan, herb extract	LDPE	Culture media	*Lb.plantarum,. E.coli, S.cerevisiae, Fusarium oxysporum*
UV/excimer laser irradiated nylon	Nylon	Culture media	*S.aureus, Pseudo.flurorescens, Enterococcus faecalis*
Natural extracts			
Grapefruit seed extract	LDPE, nylon	Ground beef	Aerobics. coliforms
Clove extract	LDPE	Lettuce, soy-sprouts	*E.coli, S.aureus*
	LDPE	Culture media	*L.plantrum, E.coli, F.oxysporum, S.cerevisiae*
Herb extract, Ag-Zirconium	LDPE	Lettuce, cucumber	*E.coli, S.aureus, L.mesenteroides, S.cervisiae, Asp. Spp, Pen. Spp.*
Eugenol, cinnam aldehyde	LDPE	strwberry	Firmness
	chitosan	Bologna, ham	*Enterobac.*, lactic acid bacteria, *Lb.sakei, serratia spp.*
Horseradish extract	Paper	Ground beef	*E.coli 0157:H7*
Allyl isothiocyanate	PE film/pad	Chicken, meats, smoked salmon	*E.coli, S.enteritidis, L.monocytogenes*
Oxygen absorbers			
Ageless	Sachet	Bread	Moulds
BHT	HDPE	Breakfast cereal	-
Gases			
Ethanol	Silicagel sachet	Culture media	-
	Silicon oxide	Bakery	-
	(Ethicap) sachet	-	-
Hinokithiol	Cyclodextrin/plastic	Bakery	-
	(Seiwa) sachet	-	-
C102	Plastic films	-	-
Others			
Hexamethylenetchtramine	LDPE	Orange juice	Yeast, lactic acid bacteria
Silver zeolite, silver nitrate	LDPE	Culture media	*S.cerevisiae, E.coli, S.aureus, Sal.typhimurium, Vibrio parahaemolyticus*
Antibiotics	PE	Culture media	*E.coli, S.aureus, Sal.typhimurium , Klebsiella neumoniae*

MC: methyl cellulose; HPMC: hydroxyl methyl cellulose; WPI: whey protein isolate; CMC: carboxy methyl cellulose; SPI: soy protein isolate

Constructing an antimicrobial packaging system

Antimicrobial agents can be incorporated in to a packaging system through simple blending with packaging materials, immobilisation or coating differently depending on the characteristic of packaging systems, antimicrobial agent and food. The blended antimicrobial agents can migrate from packaging materials to foods; while the immobilised agent cannot migrate. Fig. 1 explains the antimicrobial systems and their releasing profiles. Systems (A) and (B) release antimicrobial agents through diffusion, while systems (C) and (D) releases volatile antimicrobial agents by evaporation. Fig (A) presents one-layer system: the antimicrobial agent is incorporated in to the packaging material or chemically bound on the packaging material by immobilisation. (B) two-layer system: the antimicrobial agent (outer layer) is coated on the packaging material (inner layer), or the antimicrobial matrix layer (outer layer) is laminated with the control layer (inner layer) to control the release rate specifically. (C) Headspace system: the volatile antimicrobial agent initially incorporated into the matrix layer releases into the headspace. Headspace antimicrobial agent is partitioned with the food product by equilibrium sorption/isotherm. (D) Headspace system with control layer: the control layer specifically controls the permeation of the volatile antimicrobial agent and maintains specific headspace concentration.

The coating process can produce an antimicrobial packaging system. Over-coating on the pre-packaged products or edible coating on the food itself can produce an extra physical barrier layer that also contains antimicrobial agents. The antimicrobial agents in the over-coating material have to penetrate through the inner liner to reach the food surface to be effective.



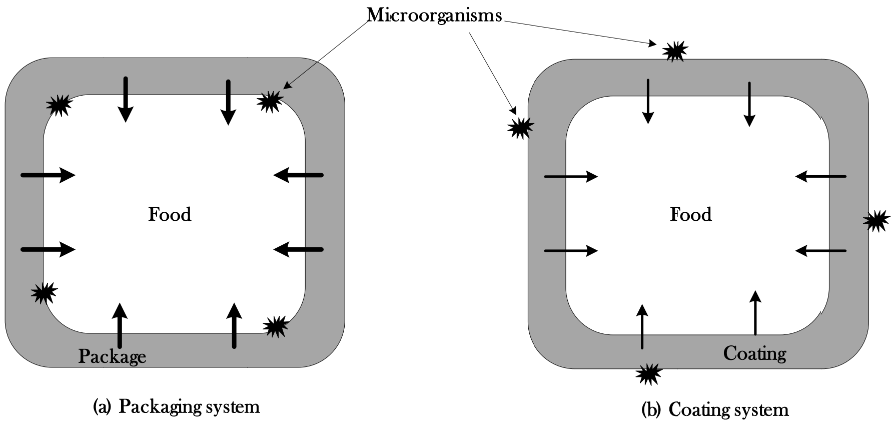
Antimicrobial Packaging system

Adapted from HAN J H (2000), 'Antimicrobial Food Packaging' in Novel Food Packaging Techniques, Ed. Raija Ahvenainen

Factors affecting the effectiveness of antimicrobial packaging

Many factors should be considered in designing antimicrobial packaging systems besides the factors described above such as antimicrobial agents characteristics, incorporation methods, permeation and evaporation. Extra factors include specific activity, resistance of microorganisms, controlled release, release mechanisms, chemical nature of foods and antimicrobials, storage and distribution conditions, film/container casting process conditions, physical and mechanical properties of antimicrobial packaging materials, organoleptic characteristics and toxicity of antimicrobials and corresponding regulations. An antimicrobial agent has its own specific inhibition activity against each microorganism. Therefore, the selection of antimicrobial agent is dependent on its activity against a target microorganism. Due to the characteristics of food products such as pH, water activity, compositions and storage temperature, the growth of potential microorganism that can spoil food products are predictable.

The design of an antimicrobial packaging system requires controlled releases technology and microbial growth kinetics. When the migration rate of antimicrobial agent is faster than the growth rate of the target microorganism, the antimicrobial agent will be depleted before the expected storage period and the packaging system will lose its antimicrobial activity because of packaging food has an almost infinite volume compared to the volume of packaging material and the amount of antimicrobial agent. Therefore, the release rate of the antimicrobial agents from the packaging material to food is specifically controlled to match the release rate with the growth kinetics of the target microorganism. Fig. also shows the importance of the mass transfer kinetics and growth kinetics in the cases of a film-packaging system and coating system. Antimicrobial agents which have been incorporated in the packaging material (A) or coating material (B) will migrate into the foods during storage and distribution. Packaging system (A) mostly has contaminating microorganism on the surface of the food product inside the package, while coating system (B) which has been coated by the antimicrobial material, may have the contaminating microorganisms on the surface of coating layer. The migration of antimicrobial agents from the package into the food product is an essential phenomenon to inhibit the growth of microorganisms of the surface of food products.



Antimicrobial Packaging and edible coating systems

Adapted from HAN J H (2000), 'Antimicrobial Food Packaging' in Novel Food Packaging Techniques, Ed. Raija Ahvenainen

The chemical nature of antimicrobial agents is also an important factor. Some agents are soluble in water but some are not. If water-soluble agents are mixed into plastic resins to make antimicrobial films, special consideration of film properties should be involved to obtain high quality films. Due to the hydrophilic nature of the agents compared with the hydrophobic nature of plastic, the plastic extrusion may interfere with various problems including hole creation in the films, powder-blooming, the loss of physical antimicrobial agents and packaging material is an important factor. Most antimicrobial chemicals change their activity with respect to pH. The pH of packaging systems depends mostly on the pH of packaged foods. Therefore, consideration of food composition with the chemical nature of the antimicrobial agent is important as well as the consideration of packaging materials properties with the chemical nature of the agents.

The solubility of the antimicrobial agents to the foods is also a critical factor. If the antimicrobial agents are highly soluble in the food, the migration profile will follow the unconstrained free diffusion Fig while the very low solubility creates the monolithic systems. The left side (grey coloured) is an antimicrobial packaging material and right side (white) is a food. The dashed line indicates MIC (minimal inhibitory concentration) of antimicrobial agents. Unconstrained free diffusion model (A) shows the highly soluble antimicrobial agent positioned in the packaging materials migration in to the food layer and the concentration of the antimicrobial agent inside the package decreases as migration continues. The concentration of the antimicrobial agent inside the package decreases as migration continues. The concentration of the antimicrobial agent on the surface of the food (Cs) decreases as the concentration inside the package decrease and eventually reduces below the MIC losing the antimicrobial activity. Monolithic system (B) consist of not very soluble (or lower affinity) migrants to the food layer. In this system, the concentration of antimicrobial agent on the surface of food (Cs) is much lower than the of soluble migrants. The concentration is highly dependent on the solubility of the antimicrobial agent in the food. Until complete depletion of the antimicrobial agent in the package, the surface concentration (Cs) is maintained as a constant concentration (actually maximum solubility) maintaining constant antimicrobial activity, while the total amount of antimicrobial agent inside the package decreases.

The storage and distribution conditions are important factors. The conditions include storage temperature and time. This time-temperature integration effects the microbial growth profile to prevent growth, a storage period at the favourable temperature range for microbial growth should be avoided or minimised during the whole period of storage and distribution.

If the antimicrobial agent is compatible with the packaging material and does not interfere with the polymer-polymer interaction, a fair amount any physical and mechanical integrity deterioration (Han, 1996). However, the excess amount of antimicrobial agent that is not capable of being blended with packaging materials will decrease physical strength and mechanical integrity (Cooksey et al., 2000). Polymer morphology logically studies are very helpful in predicting the physical integrity decrease by adding the antimicrobial agent in to the packaging material. Small size antimicrobial agents can be blended with polymeric structure. If the high level of antimicrobial agent is mixed into the packaging materials, the space provided by the amorphous region will be saturated and the mixed agent will start to interfere with the polymer-polymer interactions at the crystalline region. Although there is no physical integrity damage observed after a low level of antimicrobial there is no physical integrity damage observed after damage observed after a low level of antimicrobial agent addition, optical properties can be changed by losing transparency of changing colour of the packaging material (Han and Floros, 1997).

Since the antimicrobial agent is contacting the food or migrating into food, the organoleptic property and toxicity of the antimicrobial agent should be satisfied to avoid quality deterioration and to maintain the safety of the packaged food. The antimicrobial agents may possess strong taste or flavour, such as a bitter or sour taste as well as an undesirable aroma that can affect the sensory quality adversely. In the case of antimicrobial edible protein materials, such as peanut protein, soy protein and wheat gluten should be considered before use (Han, 2001).

From the foregoing, the most critical factor that should be considered in designing an antimicrobial packaging system is regulation. The use of an antimicrobial agent is regulated by the various regulatory agencies, for examples, FDA, EPA and USDA in the United States. An antimicrobial agent is an additive of packaging material, not a food ingredient. However, most antimicrobial agents migrate in to packaged food ingredients. The use of an antimicrobial agent should be classified as one of package additive, food contact substance or food ingredient. However, all three categories are applied to a new antimicrobial packaging system in terms of regulatory aspects. The use of natural antimicrobial agents such as plant extracts is a very challenging method because it is simple to deal with the permission process compared with chemical antimicrobial agents.

Conclusions

Antimicrobial packaging is a promising form of active food packaging and an emerging technology. Antimicrobial packaging systems can inhibit the growth of spoilage and pathogenic microorganism, and contribute to the improvement of food safety and the extension of shelf-life of the packaged food. These innovative food packaging concepts have been introduced as a response to the continuous changes in current consumer demands and market trends. The need to package foods in a versatile manner for transportation and storage, along with the increasing consumer demand for fresh, convenient, and safe food products presents a bright future for antimicrobial packaging. Many factors are involved in designing the antimicrobial packaging system, however, most factor are closely related to the characteristics of antimicrobial agents, packaged foods and target microorganisms. The major potential food applications of antimicrobial films include meat, fish, poultry, bakery goods, cheese and fermented dairy products, fruits and vegetables. Research is essential to identify the types of food that can benefit most from antimicrobial packaging materials. It is likely that future research into a combination of naturally-derived antimicrobial agents, biopreservatives and biodegradable packaging materials will highlight a range of antimicrobial packaging in terms of food safety, shelf-life and environmental friendliness.

References

[1] COOKSEY D K, GREMMER A, and GROWER J (2000), 'Characterstics of nisin-containing xron zein pouches for reduction of microbial growth in refrigerated shredded cheddar cheese', in Book of Abstracts (2000 IFT Annual Meeting, Dallas, TX), Institute of Food Technologists, Chicago, 188.

[2] DAESCHUL M A (1989), 'Antimicrobial substances from lactic acid bacteria for use as food preservatives', *Food Technol*, 43(1), 164-7.

[3] HAN J H (1996), Modeling the Inhibition Kinetics and the Mass Transfer of Controlled Releasing Potassium Sorbate to Develop an Antimicrobial Polymer for Food Packaging (Ph.D. dissertation), Purdue University, West Lafayette. IN.

[4] HAN J N, and FLOROS J D (1997), 'Casting antimicrobial packaging films and measuring their physical properties and antimicrobial activity', *Journal of Plastic Film and Sheeting*, 13, 287-98.

[5] HAN J N AND ROONEY M L (2002), *personal communications*. Active Food Packaging Workshop, Annual Conference of the Canadian Institute of Food Science and Technology (CIFST), May 26, 2002.

[6] RODRIGUES E T, HAN J H, and HOLLY R A (2002), 'Optimized antimicrobial edible whey protein films against spoilage and pathogenic bacteria', in *Book of Abstracts* (2002 IFT Annual Meeting), Chicago, Institute of Food Technologists, 252.

[7] RODRIGUES E T, and HAN J H, (2000), 'Antimicrobial whey proteins films against spoilage and pathogenic bacteria', in Book of Abstracts (2000 IFT Annual Meeting), Chicago, Institute of Food Technologists, 191.

[8] SMITH J P, RAMASWAMY H S, and SIMPSON B K (1990), 'Developments in food packaging technology. Part II: Storage aspects', *Trends in Food Science & Technology*, November, 1990, 111-18.

Technical Article for Oral Presentation Article Code: OP-ED-01

Design, Development and performance evaluation of SSHE for manufacture of *Kheer*

I. A. Chauhan, A. D. Patel, A. M. Rathva, Sunil Patel, Sapana Jain, A. G. Bhadania
Dairy Engineering Department, Sheth M C College of Dairy Science, AAU, Anand

Abstract

Kheer is a partially heat desiccated cereal-based sweetened, indigenous dairy dessert. It is considered nutritious as it is a rich source of protein, minerals, vitamins and other nutrients. As the systematic work on the development of suitable equipment for the mechanized production of such product was not reported, the study was planned to develop a SSHE and to evaluate its performance in terms of quality attributes of the products. The study includes development of horizontal scraped surface heat exchanger (SSHE), its components and performance evaluation of the machine. The steam was used as a source of thermal energy required in manufacture of products. The performance of the machine was evaluated at steam pressure of 1.0, 1.5 and 2.0 kg/cm^2, at scraper speeds of 10, 20 and 30 rpm and three levels of batch size viz., 10, 15 and 20 kg during *kheer* making.

Introduction

The commercial production of TIDP has been identified as one of the important priority areas by government and other policy makers. In view of this, availability of simple and reliable equipment is a basic need to achieve traditional value change. Scraped Surface Heat Exchanger (SSHE) designed suitably has a huge potential in manufacture of TIDP in which multiphase fluid unit operations are treated very effectively. The efforts are being made to develop a SSHE for the manufacture of indigenous products like *kheer*. The study also covers standardization of operating conditions, performance evaluation of the SSHE during manufacture of these products. The present work covers the development of a SSHE equipped with spring-loaded scraper assembly and scraper drive for the manufacture of *kheer* and evaluation of the sensory quality of the product prepared in SSHE.

Materials and Methods

Development of Scraped Surface Heat Exchanger:

Product Tube: Steam is used as heating medium in the SSHE during manufacture of the product and the steam is supplied in the jacket of the product tube. The product tube and the jacket were fabricated from 5 mm thick AISI 304 grade stainless steel plate. The technical drawing of the SSHE and its photograph are shown in Figure 1. The product tube has a bore (D) of 500 mm and length (L) of 600 mm. The product tube has been provided with a jacket which covers 550 mm length of SSHE leaving 25 mm length unjacketed on either side with an angle of 180° at the lower part of the product tube. The unjacketed area of product tube on the top consists of 208 holes each of 18 mm diameter for the escape of the vapour from the product tube. A feed hopper is provided on the top of the product tube having diameter of 65 mm towards drive side of the machine. The product tube has been provided with a hinged door fabricated from 10 mm thick AISI 304 grade stainless steel plate. A groove 15 mm wide x 8 mm deep was made on the door to fix a food grade gasket on the door.

Rotor-scraper assembly: The scraper assembly of the SSHE consists of a solid stainless steel shaft of 25 mm diameter on which supports for holding blades were welded. The four scraper blades were fixed on these supports after placing S.S. springs so as to provide necessary contact pressure for effective scarping of product to achieve scraping action during rotation of the assembly. The spring loaded Teflon edged scraper blades were arranged in such a way that the whole surface was efficiently scraped during operation of the SSHE.

Drives for scraper assembly: An A. C. motor (0.746 kW, 3-phase, 415 volt) was used to drive the assembly through a worm gear box having speed reduction ratio of 15:1. The power is transmitted from gearbox to scraper assembly. A Variable Frequency Drive (VFD) was used to regulate the speed of motor required to operate the scraper assembly at different speeds for experimental trials.

Parameters for evaluation of SSHE

The performance evaluation of the SSHE in terms of quality attributes of the product is very important for adoption of mechanization in the manufacture of *Kheer*. The operating variables greatly influence the quality of the final product. Therefore, it is necessary to optimize and control the operating parameters to achieve desirable attributes in the product. In manufacture of *kheer*, the performance of the SSHE was evaluated at different scarper speeds (S_1=10 r.p.m., S_2=20 r.p.m., S_3=30 r.p.m.), operating steam pressures (P_1=1.0 kg/cm^2, P_2=1.5 kg/cm^2, P_3=2.0 kg/cm^2) and batch sizes (B_1=10 kg, B_2=15 kg, B_3=20 kg).The sample of product prepared in the laboratory by adopting conventional traditional method was used for control samples.

Experimental procedure for *kheer* making in SSHE

The flow diagram of the method followed for the manufacture of *kheer* in the SSHE is depicted in Figure 2. The sensory quality of the products prepared in the SSHE were judged by a panel of 8 judges with 9 point hedonic score card.

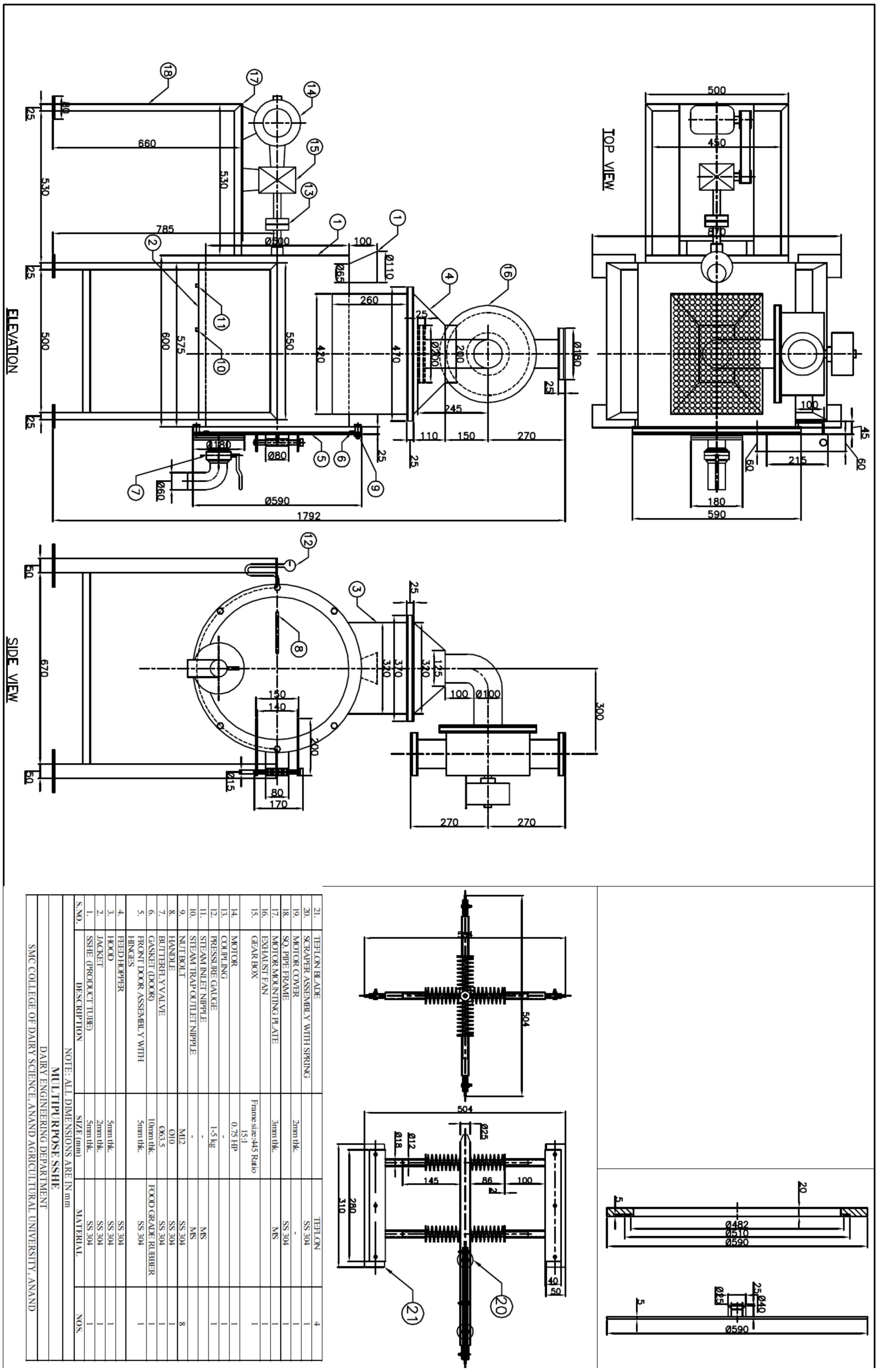


Figure 1. Technical drawing of SSHE

Results and Discussion: Sensory evaluations of the *kheer*

Statistical Analysis of overall acceptability scores of the *Kheer* samples prepared under various operating conditions of SSHE (Factorial CRD, 3 factors) are shown in Table 1.

The $P_1B_3S_3$ combination had the highest scores of 8.14 for overall acceptability indicating that product is liked very much by the panel of the judges as per the 9 point Hedonic score card.

Cost analysis of the product manufactured in the SSHE

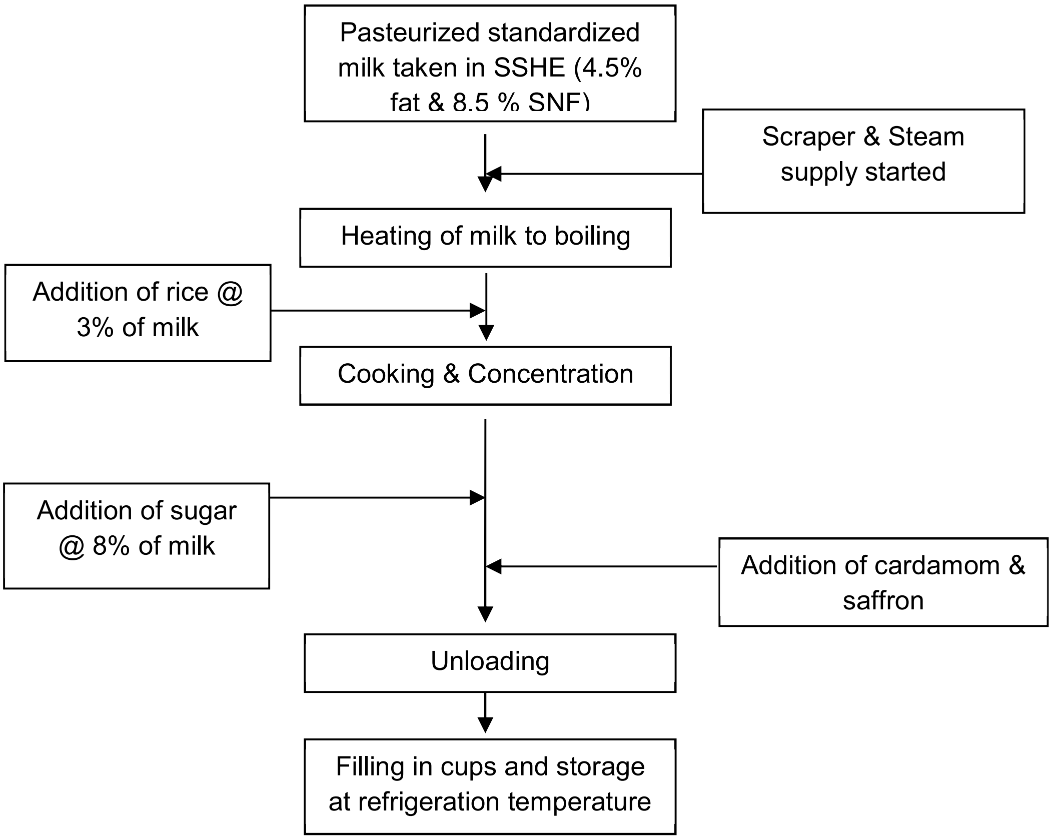


Figure 2. Flow diagram for the manufacture of *Kheer* in the SSHE

Table 1. Statistical Analysis of overall acceptability scores of the *Kheer* samples prepared under various operating conditions of SSHE (Factorial CRD, 3 factors)

	P_1	P_2	P_3	Mean
B_1	7.48 ± 0.10	7.54 ± 0.14	7.02 ± 0.24	**7.35 ± 0.43**
B_2	7.69 ± 0.11	7.56 ± 0.09	7.58 ± 0.14	**7.61 ± 0.17**
B_3	7.99 ± 0.15	7.71 ± 0.02	7.35 ± 0.03	**7.68 ± 0.46**
S_1	7.66 ± 0.28	7.68 ± 0.04	7.18 ± 0.40	**7.51 ± 0.73**
S_2	7.69 ± 0.26	7.59 ± 0.14	7.37 ± 0.23	**7.55 ± 0.41**
S_3	7.82 ± 0.32	7.54 ± 0.17	7.39 ± 0.31	**7.58 ± 0.56**
Mean	**7.72 ± 0.42**	**7.60 ± 0.15**	**7.32 ± 0.46**	

	Result	SE_m	C.D.
Control Vs Rest	*	0.0145	0.0402
P	*	0.0253	0.07
B	*	0.0253	0.07
PxB	*	0.044	0.1212
S	**NS**	0.0253	-
PxS	*	0.044	0.1212
BxS	**NS**	0.044	-
PxBxS	**NS**	0.0758	-
CV%		3.16%	

*Significant, NS-Non significant

Conclusions

The SSHE developed can be successfully used for mechanization of *kheer*. The process parameters which include steam pressure, scraper speed and batch size can be easily controlled in order to obtain desirable attributes in the product. The Teflon edged blades provide efficient scraping of the material adhering on the heat transfer surface and noiseless operation. The operating parameters are required to be standardized to achieve optimum quality product. The quality of the *kheer* prepared in SSHE under the operating conditions $P_1B_3S_3$ was found superior in terms of the sensory attributes as compared to the products prepared at other operating conditions of the SSHE.

Design and Performance Evaluation of CIP System for Three Stage Scrapped Surface Heat Exchanger

Ankit Deep*[1], P. Barnwal[1], Pooja Bhagat[1], S. De[1], Pradip Behare[1], Rajunaik B.[2]
[1] ICAR-NDRI, Karnal, [2] Dairy Science College, Hebbal, Bangalore

Abstract

The designing of CIP system was carried out on the basis of calculated hold-up volume which was depend on some fixed parameters of SSHE .i.e. steam pressure, flow rate and scrapper speed. On the basis of the determined hold-up volume of 45.9 litre, a multi-partition CIP tank with total volume 700 litres was designed and fabricated by using SS-304 as material of construction. All the required component like CIP stand, control panel, Direct Steam Injection, CIP pipeline (forward and return), Inline filter, Fluid level indicators, sensors assembly, motors, starters, pushbuttons, etc. The design of experiment was carried out with response surface methodology and studied the effect of scrapper speed (300, 225, 150 RPM), temperature of solution (80, 70, 60° C) and concentration of solution (2 %, 1.375 %, 0.75%) on CIP performance. The lye time, total CIP time, total plate count (TPC) and coliform count were determined. Optimization of CIP system was carried out using response surface methodology, where concentration, temperature and scraper speed were selected as independent variables. The responses i.e. lye time, total CIP time, total plate count (TPC) and coliform count were determined at optimized solution (concentration 0.85%; temperature, 72.70° C; scraper speed, 150). This CIP system is mobile (wheel mounted) and may be used for other dairy process equipments. The predicted values were compared with experimental value by student's t-test and found non-significant ($p>0.05$).

1. Introduction

Cleaning-in-place (CIP) is a very important unit-operation that is commonly applied throughout the food and dairy industry worldwide. It may be defined as "cleaning of complete items of plant any pipeline circuits without dismantling or opening of equipment and with small or no manual involvement on the part of operator" (Romney,1990). In general, it is carried out by circulating chemical solutions and water by mechanical means onto and over surfaces that needed to be cleaned (Zhao et al., 2009). Initially as a manual process, CIP was developed in 1950's for hygienic cleaning of plant surfaces. It is used not only for microbiological hygiene but also for restoring the heat transfer and pressure drop characteristics of plant. In the dairy industry, CIP is useful daily for all of the processing equipment. The currently applied cleaning procedures are in most cases based on experience. The removal of protein fouling is primarily achieved by cleaning with alkaline solutions. The cleaning solution penetrates into the spongy structure of the deposit layer and causes cracks in the layer. Generally, dairy industry process the milk using various processing equipment and hygiene requirement is necessary for the equipment. During milk processing, fouling of heat exchangers is a major concern in the dairy industry, with a negative impact on operational costs and product quality (Andritsos et al., 2002). In order to get the high quality and sanitisation the cleaning of equipment is a very crucial step. A typical Clean-in-Place (CIP) process requires large amounts of water, chemicals and energy. In the dairy and food industry, manually cleaning is difficult for the process equipments. In order to get the hygienic and good quality products, the proper cleaning is necessary. The manual cleaning process is cumbersome and time consuming. The operation of cleaning to the plant and machinery by disassembling of individual components and again assembling for its operation requires more manpower. CIP helps in saving the resources e.g. time, labour etc. The units of CIP consists of vessels of storage and recovery of cleaning solutions, along with valves, pumps, pipelines and field instrumentation to allow cleaning to take place, usually automatically (Memisi, 2015).

2. Materials and method

2.1 Selection of three stage scraped surface heat exchanger

Three stage scraped surface heat exchanger (TSSSHE) is one of the equipment where high heat transfer rates at high temperature, pressure and flow rate of product co-exist during processing operations/conditions. There is good scope for commercial validation of proposed CIP system. Hence three stage SSHE was selected as model equipment for testing of proposed CIP system. The experimental set up was made using three stage scraped surface heat exchanger developed by Dodeja *et al*. (2005) and the proposed CIP system and modified for manufacture of *Khoa* making.

The TSSSHE consists of following components: Variable speed drives, Balance Tank, Feed Pump, Valves for steam supply, Instrumentation for TSSSHE, Pressure gauge, Magnetic flow meter, I/P converter, Pressure Transmitters, Digital panel meter, Pneumatic valves, Air pressure indicators, Process controller.

2.2 CIP SYSTEM DESIGN

2.2.1 Design consideration for experimental setup

SS304 construction of CIP systems is satisfactory although the non-CIP processing equipment is generally made of SS316L.

2.2.2 Hold up volume studies for TSSSHE

To design the proposed CIP system, experiments were conducted to determine the hold-up volume for SSHE at fixed parameters i.e. steam pressure, flow rate and scrapper speed for water as a process fluid. It was found as 5 to 10 litres for operating parameter range (scrapper speed 200, 175, 40 rpm; flow rates 350 to 528 kg/h and steam pressures 3.5, 2.5, 1kgf/cm^2 for first, second and third stage respectively).

2.2.3 CIP tank and pipelines

Design of multi-partition tank was conceptualised for the proposed CIP system considering savings of resources such as cleaning time, space, water, recirculation and waste water, etc. During manufacturing of product using TSSSHE milk particles falls out of vapour ducts on to nearby equipment's including CIP tank. Making recovered and fresh solutions in tank unsuitable for re-use. To prevent this problem the SS cover for the CIP tank was fabricated which having the thickness of 1.5 mm. The cover is used open from both the side of CIP tank. The forward line was fabricated by the use of 38 mm SS 304 pipe also consisted of a two different sensors i.e. temperature and pH sensor and CIP return line was used to recover the solution when CIP solution was passed through the electrical conductivity sensor. The valves were operated manually to recover the solution, once the motor was started.

2.2.4 Direct steam Injection (DSI) and inline filter

Direct steam injection system was used for heating of forward CIP solution and an inline filter was used before sensor in Return CIP line.

2.2.5 Instrumentation for CIP system

Individual level for each compartment was monitored by using self-replicated level sensing system which included 15 LED indicators three for each compartment for low, medium and high level. Three sensors viz. resistance temperature detector (Pt-100) for temperature of forward line, pH sensor for forward line and Electrical conductivity sensor for return line were calibrated and installed.

Figure1: Fabricated CIP system along with three stage SSHE

2.3 Materials required for experimental trials

Fresh buffalo milk was procured from the Experimental Dairy, ICAR-NDRI Karnal, Haryana, Sodium hydroxide flakes LR (having 80% assay) were diluted in potable water and caustic solution of 0.75 to 2% strength was prepared for CIP of TSSSHE. Potable water available at dairy engineering division was used for cleaning purposes.

Khoa was collected in SS vessels and trays. A one meter Stainless Steel scale was used to observe the fluid level in balance tank and CIP tank (recovery) which was available at dairy engineering workshop.

2.4 Methods followed in experimentation / Experimental procedure

For each trial 40 litre buffalo milk (20-25°C) was procured from experimental dairy, ICAR-NDRI, Karnal, Haryana. Trials were conducted as per flow chart in figure 2.

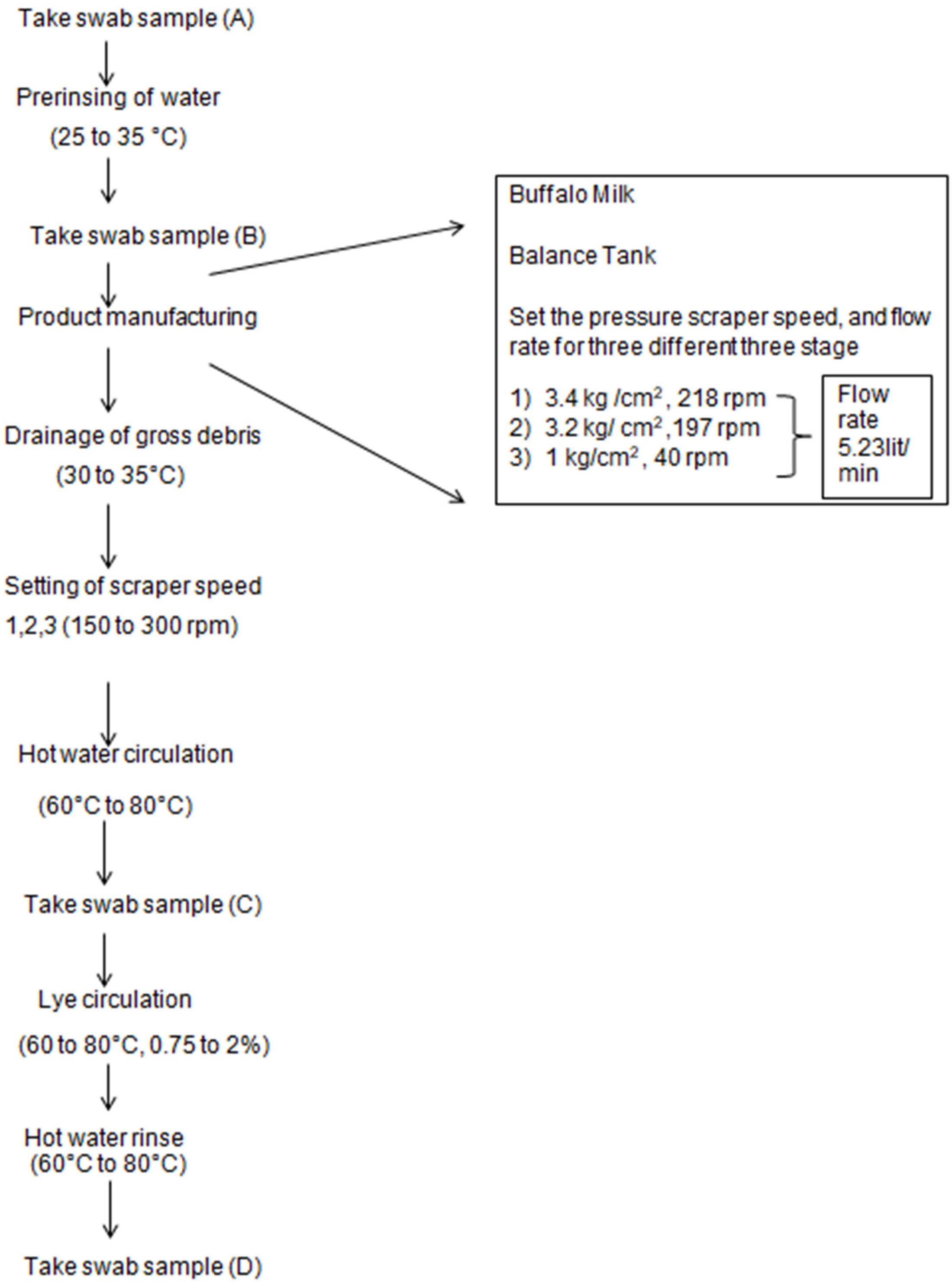


Figure 2: Flow chart for experimental trials

2.5 Experimental design

Optimization of cleaning parameters for TSSSHE obtained from developed CIP system was carried out to achieve desirable cleaning results. Response surface optimization was carried out using Design expert software. Face centred cubic (FCC) design with three independent variable and their responses were used to optimize the cleaning procedure of TSSSHE. The independent variables were chosen for the cleaning experiments were concentration (0.75 to 2%), temperature (60 to 80°C) and scraper speed

(150-300 rpm). The variable levels were selected on the basis of preliminary trails. Lye time, total CIP time, TPC (total plate count), coliform and lye quantity were the responses in this study. The dependant factors and remaining responses were kept within the experimental range.

2.6 Experimental validation

The experimental data were subjected to statistical analysis using response surface methodology (RSM). To test the significance difference between the experimental and predicted value at optimum parameters, student's t-test ($p < 0.05$) was used. The validation RSM and individual effect of different treatment on the corresponding responses were analysed by using the Design expert software v.8.0.7.1

3. Result and Discussion

The present investigation was undertaken to explore the feasibility of CIP of three stage SSHE. It was carried out solely by circulating chemical solutions and water by mechanical means into equipment and over surfaces that are to be cleaned. For its design, experiments were conducted to determine the hold-up volume for TSSSHE by keeping the required fixed parameters i.e. steam pressure, flow rate and scrapper speed. On the basis of the calculated hold-up volume of 45.90 litres, a multi-partition CIP tank with total volume 700 litres was fabricated. The main CIP tank consists of five different partitions in one square block fabricated which was having 231, 178, 178, 56, 56 litres capacity for water, diluted acid, diluted lye, and concentrated acid, concentrated lye, respectively.

Table 1- Specifications for fabricated CIP tank

Purpose	Dimensions				Capacity (litres)
	Thickness (mm)	Length (m)	Width (m)	Height (m)	
Water	2.5	1.000	0.330	0.700	231.000
Lye	2.5	0.760	0.335	0.700	178.220
Acid	2.5	0.760	0.335	0.700	178.220
Conc. Lye	2.5	0.240	0.335	0.700	056.280
Conc. Acid	2.5	0.240	0.335	0.700	056.280
Overall (with partition)	2.5	1.000	1.000	0.700	700.000

3.1 Lye time

It was evident that effects of concentration, temperature, and scraper speed are significant as well as the effects of order two (concentration and temperature). However, interactions of these factors were significant on the lye time. The quadratic model for lye time was obtained through regression analysis. The effect of scraper speed was found to be positive and affects significantly. As the speed increases the lye time also increases. Regression equation on coded factor for lye time was as follows:

Lye time $= +389.26 - 28.80 \times \text{concentration} - 47.90 \times \text{temperature} + 35.90 \times \text{speed} + 58.63 \times \text{concentration} \times \text{temperature} - 53.37 \times \text{concentration} \times \text{speed} - 46.87 \times \text{temperature} \times \text{speed} + 24.59 \times \text{concentration}^2 + 24.09 \times \text{temperature}^2 - 11.91 \times \text{speed}^2$

The model F-value for lye time was more than the table value and found significant ($p \leq 0.05$). Coefficient of correlation R^2 value was 0.86, which indicates that the fitted quadratic model was able to explain 86 per cent of the variation in lye time. The non-significant lack of fit indicated that the model fitted data well.

3.2 Total CIP time

It was evident that effects of concentration, temperature, and scraper speed are significant as well as the effects of order two (concentration and temperature). However, interactions of these factors were significant on the total CIP time. The regression equation obtained for the model of the second degree in terms of coded factors is in the form.

Total CIP time $= +1728.53 - 30.70 \times \text{concentration} - 60.60 \times \text{temperature} + 30.20 \times \text{speed} + 40.63 \times \text{concentration} \times \text{temperature} - 59.12 \times \text{concentration} \times \text{speed} - 56.12 \times \text{temperature} \times \text{speed} - 4.32 \times \text{concentration}^2 + 3.18 \times \text{temperature}^2 - 12.82 \times \text{speed}^2$

The effect of scraper speed found to be positive and/or it affects significantly on the total CIP time. As the scraper speed increases the total CIP time also increases. The model F-value for total CIP time was more than the table value and found significant ($p \leq 0.05$). The high value of R^2 suggests that the second-order model is adequate and R^2 value was 0.85 which indicated that the fitted quadratic model was able to explain 85% of the Total CIP time.

3.3 Optimization of CIP process

The designed goals for each factor and responses were chosen based on the preliminary studies and different weights were assigned to each as per importance in CIP. The program was run to get the optimum process and solutions. The optimization criteria for different factors and response are given in (Table 2). Considering the various responses lye time, total CIP time, TPC and coliform at factors concentration, temperature, speed to be minimum. The optimum concentration of solution, temperature of solution and scraper speed for optimum CIP process was 0.85%, 72.70°C and 150 rpm, respectively.

Table 2 - Optimization criteria for different factors and responses

Factors	Units	Goal	Lower limit	Upper limit	Importance
A:Concentration	%	is in range	0.75	2	3
B: Temperature	°C	is in range	60	80	3
C: Speed	rpm	is in range	150	300	3
Lye time	s	Minimize	333	740	3
Total CIP time	s	Minimize	1549	2004	3
TPC	cfu/cm^2	Target = 0	0	1.15	5
Coliform	cfu/cm^2	Target = 0	0	3.5	5

4. Conclusion:

The findings suggest that optimizing the flow characteristics at a given temperature and concentration and speed is crucial to achieving fast cleaning in all soil cases. These parameters should be optimized in CIP before temperature and or chemical concentration is increased. In the future, minimizing the water load and environmental impact of cleaning will only become more important.

Current issues surrounding novel approaches to cleaning will need to be overcome for application in industrial CIP that will become more important in the future as water becomes less available and/or more expensive.

- The four responses Lye time i.e. 333 to 700s, Total CIP time i.e.1549 to 2004s, TPC i.e. 0.02 to 1.15cfu/cm^2, Coliform i.e.0.02 to 3.5cfu/cm^2 was determined.
- The optimization of CIP of TSSSHE was carried out and four dependent responses were determined at optimized solution was having the concentration of 0.85, temperature was 72.70°C and scraper speed was 150 rpm.
- The model was validated by conducting CIP experiments on TSSSHE from the developed CIP system using the derived optimum CIP conditions and the responses were considered for optimization such as lye time (341.33± 4.04), total CIP time (1648.5 ± 4.5), TPC (0), coliform count (0) were measured.
- Desirability range was varying between 88.48 to 88.90 %
- The predicted values were compared with experimental values by student's t-test and found non-significant (p>0.05).

5. References

[1] Andritsos (2002). Sulphide scale formation and control; the case of lead sulphide. *Geothermics* **20**(5),343-354.

[2] Van Asselt, A. J., Van Houwelingen, G., & Te Giffel, M. C. (2002). Monitoring system for improving cleaning efficiency of cleaning-in-place processes in dairy environments. *Food and Bioproducts Processing*, **80**(4), 276-280.

[3] Darlington, R. 1972. Heat transfer and heat exchangers [in the food industry]. *Food Manufacture,* 47: 33–34.

[4] Dodeja, A.K. and Agrawala, S.P. 2005. Mechanization for large scale production of indigenous milk products. Indian J. Animal Sci., **79**(9), 1118 – 1123.

[5] McDonald, D. P. 1974. Process plant for food is different. Food Manufacture,: 35–37.

[6] Memisi, N., Moracanin, S. V., Milijasevic, M., Babic, J., & Djukic, D. (2015). (2015). CIP cleaning processes in the dairy industry. *Procedia Food Science.*633+ience, 5:184-186.

[7] Romney, A. J. D. (1990). CIP: cleaning in place 2nd Ed. *Society of Dairy Technology*

[8] Zhao, M., Rocha-Alvarez, J. C., Shmurun, I., Sen, S., Lim, M. D., Venkataraman, S., & Lee, J. H. (2009). U.S. Patent No. 7,500,445. Washington, DC: U.S. Patent and Trademark Office.

Technical Article for Oral Presentation Article Code: OP-ED-03

Design, Development and Testing of Thermic Fluid Based Heating System

Srinivasa K.[1], P. Barnwal[2]*, Pritpal Singh[3]
[1,3]Former M.Tech.Scholar, [2]*Principal Scientist
Dairy Engineering Division,ICAR-NDRI, Karnal

Abstract
A thermic fluid based heating system using liquefied petroleum gas (LPG) and electric energy source will replace the boiler and will be helpful in reducing initial cost of the boiler, safety requirements and reliable to use by *halwais*. A study was undertaken to design and develop a thermic fluid based heating system with combined LPG and electric energy source where thermic fluid (Therminol-55) was used as heating transfer medium. The heating system was fabricated by using SS-304 as material of construction. Performance evaluation of the developed system was done in terms of thermal efficiency, energy consumption evaporation rate and overall heat transfer coefficient by heating water as well as sugar syrup under un-stirred conditions. Thermal efficiency, evaporation rate were maximum and energy consumption was minimum in electric heating compared to LPG heating. Integration of the developed heating system with *chhana* ball making machine may be used for *Rasogolla* making.
Keywords: Thermic fluid, Heating system, *Rasogolla* cooking

Introduction

The traditional milk sweets and desserts have great relevance to Indian culture. Traditional milk sweets are value added products with a distinct advantage of having great mass demand. Indian milk sweets have played a vital role in the economic, social, religious and nutritional security and safety aspects of our country people. About 50 to 55 per cent of milk produced, processed by the traditional sector (halwais) into a variety of Indian milk products, using processes such as heat and acid coagulation, heat desiccation, fermentation etc. Basically, *chhana* and *khoa* are the two base/filler materials for a number of *chhana* and *khoa* based sweets. About 6% of the total milk production converted to *chhana* through coagulation (Sahu and Das, 2007). The chhana is used extensively as the base and filler for the preparation of a large variety of Indian delicacies namely, *Rasogolla*, *sandesh*, *cham-cham*, *rasmalai*, *pantoa*, *rajbhog*, *chhana-murki* and many more such products. In India, the market volume of *chhana* based sweets is about 1 million tonnes (Sahu and Das, 2009).

Steam is generally used as a heat transfer medium for making of dairy products. For the steam generation, an additional steam boiler and skilled operator are needed which will add a high initial cost, skill and safety requirements. LPG and electric based heating system will be helpful in replacing the boiler and hence reducing initial cost of the boiler, safety requirements. It may be reliable to use by *halwais*. Liquefied Petroleum Gas (LPG) is used as a conventional fluid for cooking at domestic level. The use of LPG reduces the interior air pollution in comparison to traditional ways of burning biomass etc. A mixture of air and LPG can be ignited if the amount of LPG in the air is between 2 % and 10 % and the ignition temperature is above 380 °C. Its net calorific value may be taken as a 10900 kcal/kg for calculations of thermal-efficiency of burning appliance (IS-4246: 2002). Electric resistance heating converts nearly 100 % of the energy in the electricity to heat. Heat transfer oil also called as thermic fluid is being used for applications of heat transfer in industries. The material shall be a clear fluid free from foreign matter, sediment and visible impurities. High temperature heat transfer oils can be categorized by chemical structure into three primary groups namely synthetic oil, hot oil/mineral oil and others including silicones (NIL, 2010). It shall not contain any ingredients injurious to persons using or handling it. As per guidelines in food process industry, white mineral oil (WMO) can be used in indirect heating loops for deep frying and baking of food products (USFDA, 2013). LPG and Electric based heating system may replace steam / boiler, and then it will be helpful in reducing initial cost as well as safety requirements of boiler. In this paper, a thermic fluid based heating system using liquefied petroleum gas (LPG) and electric energy source has been designed, developed and its performance was evaluated.

Material and Methods

The design and fabrication of the heating system was done at Research and Development (R & D) Workshop, Dairy Engineering Division, ICAR-NDRI, Karnal, Haryana.

Selection of Thermic Fluid: The goal of heat transfer is to move thermal energy from the heating source to the heat requiring process in a uniform and efficient manner. The Therminol series of heat transfer fluids are synthetic aromatic type fluids providing outstanding heat transfer efficiency and fluid stability. Heat transfer fluid i.e. Therminol-55 has high thermal capacity, low viscosity, low-cost, non-toxic, and chemically inert, neither causing nor promoting corrosion of the circulatory system.

Performance benefits of Therminol-55:

(i) **Long Life:** Reliable, cost effective performance, even when operating system continuously at 290°C

(ii) **Excellent resistance to fouling:** Therminol-55 is a synthetic fluid; it resists the effects of oxidation 10 times better than mineral oils, less oxidation and solids formation. For systems without nitrogen inerting, the performance advantages are significant and \
(iii) **Excellent Low Temperature Pumpability:** Therminol-55 is still pumpable at -28°C, compared to some mineral oils that will not pump at temperatures below -7°C.

Design considerations: The heating system for the proposed study consists of the following components: concentric tube heat exchanger, scotch and yoke mechanism, three- phase ac motor, reduction gear box system, electric heating element and horizontal type premixed LPG burner.

Concentric tube heat exchanger: The concentric tube was selected as heat exchanger because of its high heat transfer rate and surface area compared to other heat exchangers. Length of the tube was fixed to 2 m based on the desired volumetric capacity. Heat exchanger consists of two cylindrical tubes having the diameters of 3″ and 5″. These diameters were selected based on the following designs: (i) Selection criteria of inner cylindrical tube of the concentric tube heat exchanger: Inner diameter of inner tube was fixed to 3" (7.62cm) based on the diameter of *Rasogolla* available in the market and (ii) Selection criteria of outer cylindrical tube of the concentric tube heat exchanger:

The volume of inner cylindrical tube,
$V_I = \pi R_i^2 h$, $R_i = 0.0381 m$
$V_I = 3.142 \times 0.0381^2 \times 2$
$V_I = 0.009127\ m^3$
Density of 55º Brix Sugar Syrup At 20 ºC = 1260 kg/m^3
$MASS\ OF\ SUGAR\ SYRUP = VOLUME \times DENSITY$
$MASS\ OF\ SUGAR\ SYRUP = 0.009127 \times 1260$
$MASS\ OF\ SUGAR\ SYRUP = 11.5\ kg$
$Q_{SUGAR\ SYRUP} = M_S \times C_{P(S)} \times (T_{S2} - T_{S1})$
$Q_{SUGAR\ SYRUP} = 11.5 \times 3.098 \times (37 - 103.5)$
$Q_{SUGAR\ SYRUP} = 2369.19\ kJ$
$Q_{SUGAR\ SYRUP} = Q_{THERMIC\ FLUID}$
$2369.19 = M_T \times C_{PT} \times (T_{T2} - T_{T1})$
$2369.19 = M_T \times 1.97 \times (37 - 140)$
$M_T = 11.67\ kg$
Density of therminal-55 =868 kg/m^3 at 38º C
Volume of therminal-55 = $\frac{mass}{density} = \frac{11.67}{868} = 0.01344\ m^3$
Volume of outer cylindrical pipe, $V_0 = \pi(R_o^2 - R_i^2)\ h_o$
Where, $h_o = 1.66\ m$
$0.01344 = 3.142 \times\ (R_o^2 - R_i^2)\ \times 1.66$
$R_o^2 = 0.004028$
$R_O = 0.06346\ m$
$D_O = R_O \times 2 = 0.1269 m = 12.7\ cm = 5"$
Therefore diameter of outer cylindrical tube was fixed as 5″.

Scotch and Yoke mechanism: It is also called as slotted yoke mechanism, where it converts rotational motion into reciprocating/linear motion. For a complete rotation of crank the yoke move s through a length equal to double length of the crank. The shape of motion of the piston is in sine wave. Main parts are crank, pin, yoke, piston and wheel and ram. The yoke moves forward direction, where ram/pusher convey the *Chhana* balls at 3 *Chhana* balls distance i.e. the stroke length of 15 cm at variable time interval and it was driven by 3 phase AC motor.

Three- phase AC motor: Three- phase AC induction motor was used to drive the scotch and yoke mechanism to convey the *Chhana* ball in the cylindrical tube. The speed of the motor is controlled by VFD. Type: induction; Phase: 3; Frequency: 50Hz; Horse power: 0.75 hp; Rating speed: 1425 rpm

Reduction gear box system: The reduction gear system reduces the speed of the AC motor to the reduction ratio of 1: 40 i.e. from 1425 rpm to 35 rpm. The star type couplings connected these systems. The VFD further controlled the speed of the motor.

Electric heating element: Two 1.5 kW electric heating elements were installed at the base of thermic oil cylindrical tube.

Horizontal type LPG burner: Horizontal type burner was fabricated according to the energy requirement at R and D Workshop, Dairy Engineering Division, NDRI, Karnal. The material of construction was mild steel having inner diameter of 254 mm. the burner ports diameter was fixed as 2mm and such 365 ports were drilled on the periphery of the burner. The distance between the each port was 5mm. the burner had to place closed to the bottom of concentric tube heat exchanger with the help of flanges. The gas entered the burner through a pre mixing pipe having a length of 250 mm. provision was made for the entry of primary air by means of a hole on the premixing pipe. The hole was near to entry part of LPG gas entered the burner through a rubber tube from the cylinder. A control valve as well as commercial type regulator was provided to control the mass flow rate of the gas into the burner.

The schematic diagram and photograph of thermic fluid based heating system are shown in Fig.1 and Fig.2, respectively.

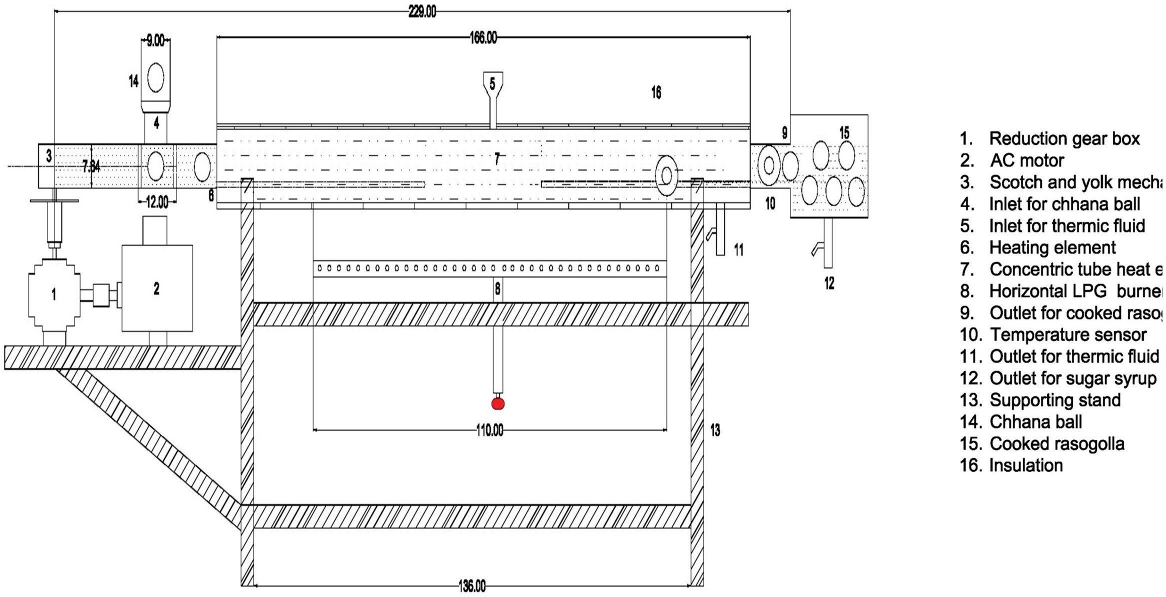


Fig.1: Schematic diagram of thermic fluid based heating system

Fig.2: Photograph of developed thermic fluid based heating system

Performance evaluation parameters

Energy requirement: Energy input constituted the heat energy supplied by the LPG consumed during the trial was estimated by taking the weight of the cylinder at initial and end of the experiment. Total quantity of water evaporated was calculated from the difference between the initial quantity of water taken and final quantity of water remaining at the end of the trial in the developed heating system for *Rasogolla* cooking where as in case of electric heating the energy can be directly measured using digital power analyser.

$$E_R = \frac{M_{LPG} \times CV_{LPG}}{W_{evap}}$$

Where, E_R = kJ/ kg of water evaporated; M_{LPG} = Quantity of LPG consumed ; CV_{LPG}= Net calorific value of LPG (10950 kcal/kg) (BIS) and W_{evap} = Amount of water evaporated.

Evaporation rate: Evaporation rate may be defined as the amount of water evaporated in unit time from unit heat transfer surface area.

$$E_{WR} = \frac{M_W}{T \times A}$$

Where, E_{WR} = Evaporation rate (kg/min. m^2); M_W = Amount of water evaporated; T = Time taken and A = heat transfer surface area

Thermal efficiency: The thermal efficiency of thermic fluid based heating system for *Rasogolla* cooking is calculated by as follows;

$$Q_{SUPPLY} = Q_{1(LPG/ELECTRIC)}$$

$$Q_{1(LPG+ELECTRI\ )} = M_{LPG} \times CV_{LPG} + E_E$$

$$Q_2 = M_T \times C_{PT} \times (T_{T2} - T_{T1})$$

$$Q_3 = [M_{S/W} C_{P(S/W)} (T_{S2/W2} - T_{S1/W1}) + M_{S/W} L_{S/W}]$$

Therefore, $\eta_1 = \frac{Q_2}{Q_1}$ $\quad \eta_2 = \frac{Q_3}{Q_2}$

$$\eta_0 = \eta_1 \times \eta_2$$

Overall heat transfer coefficient: The overall heat transfer for the thermic fluid based heating system is calculated by using following equation:

$$U = \frac{Q_1}{A \times \Delta T_{S/W}}$$

Results and Discussion

Thermal performance of the thermic fluid based heating system was done in terms of thermal efficiency, energy consumption, evaporation rate and overall heat transfer coefficient. Experiments were conducted by heating the fixed quantity of water and 55° Brix sugar syrup under unstirred conditions. The experimental trials were conducted by heating the water as well as the sugar syrup with the help of LPG burner and electric heating element. It was found that the electric heating system has high thermal efficiency, faster evaporation rate of water as well as in the sugar syrup and minimum energy consumption compared to LPG heating system.

Thermal performance of the thermic fluid based heating system for water (without insulation)

Thermal parameters of system without insulation were determined as shown in Table 1 and showed lower thermal efficiency because of excessive heat loss into the atmosphere.

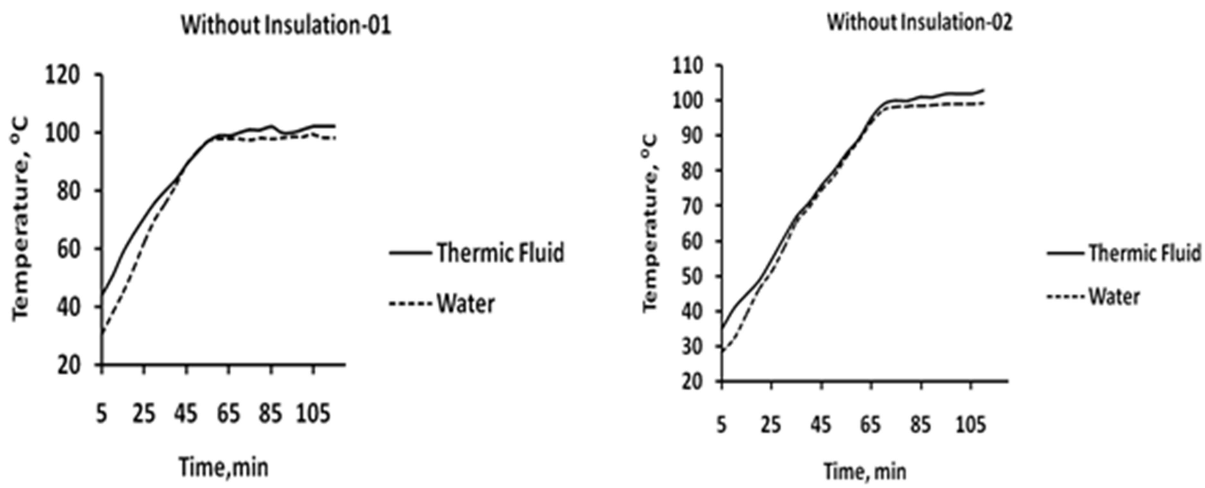


Fig. 3: Variation of temperatures of thermic fluid and water with time

Figure 3 showed that there is no increase in the temperature of thermic fluid above 102°C. Heat given to the thermic fluid was lost into the atmosphere completely because of no-insulation. Later, the equipment was insulated with 10mm glass wool as well as foam sheet enclosed by 1 mm aluminium sheet.

Thermal performance of the fabricated thermic fluid based heating system for water and sugar syrup (with insulation)

The thermal performance of insulated heating system was determined after insulation and observed that the thermal efficiency increased (Table 1).

Table 1: Thermal evaluation of thermic fluid based heating system under undisturbed conditions

Mode of Heating	Total Energy Consumed, kJ	Thermal Efficiency, %	Evaporation Rate ,ml/min	U, W/m^2-K
Electric (without insulation)-01	11370.04	22.54	0.00	300.04
Electric (without insulation)-02	10812.71	24.05	0.00	278.07
Electric (sugar syrup-01)	10302.00	63.92	48.89	299.22
Electric (sugar syrup-02)	9740.73	63.04	46.67	313.46
Electric (water-01)	10830.60	81.12	50.91	290.44
Electric (water-02)	11773.11	80.15	51.67	316.18
LPG (water-01)	20596.95	35.24	43.00	559.78
LPG (water-02)	10985.04	36.13	20.00	300.57
LPG (sugar-01)	14646.72	23.39	30.00	473.43
LPG (sugar-02)	18308.40	22.16	30.00	611.91

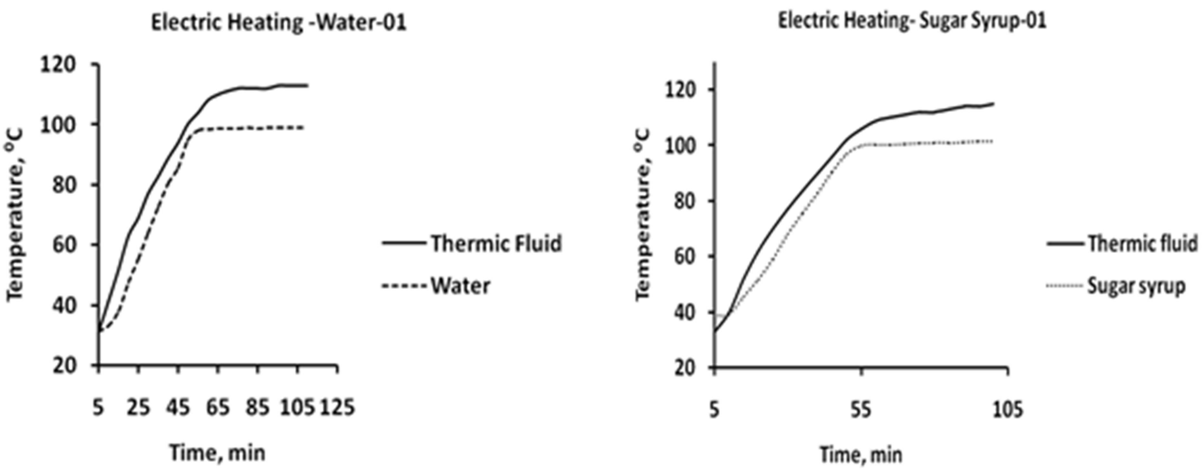


Fig. 4: Variation of temperatures of thermic fluid and water and sugar syrup with time

Figure 4 showed that the uniform heating of water takes place by utilizing the heat of thermic fluid and there was less temperature difference showed in the system and possess high thermal performance. The thermal efficiency of experimental setup with water heated by electric heating was more (Table 1) comparative sugar syrup heated by the same heating source.

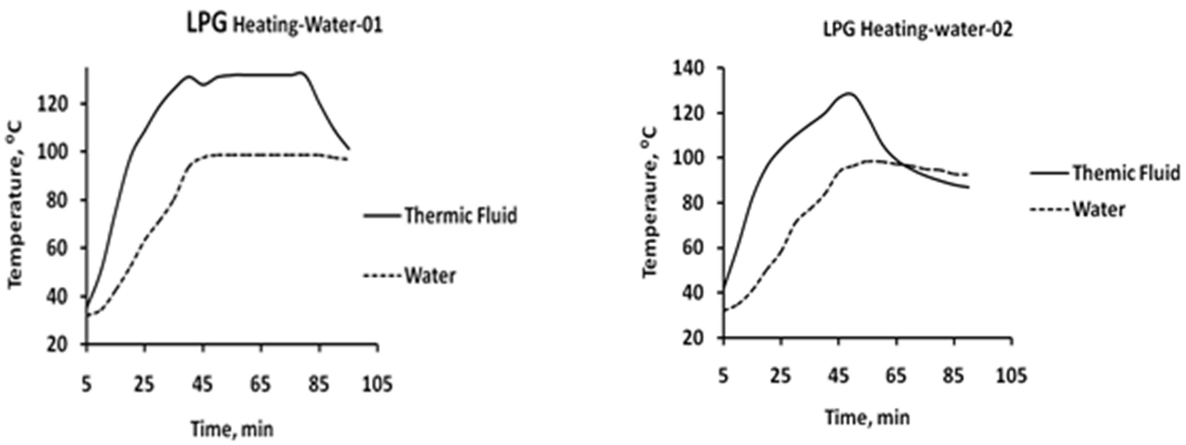
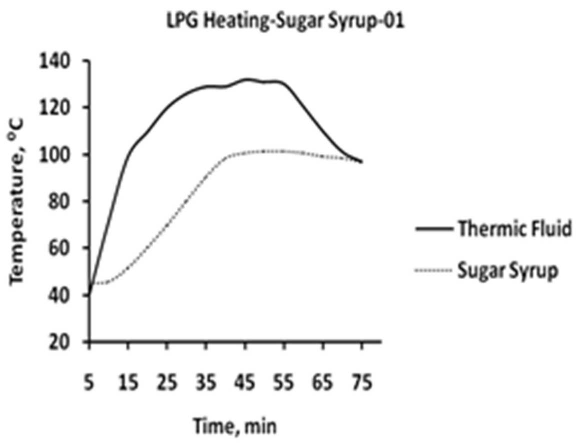


Fig. 5: Variation of temperatures of thermic fluid and water with time (after insulation)



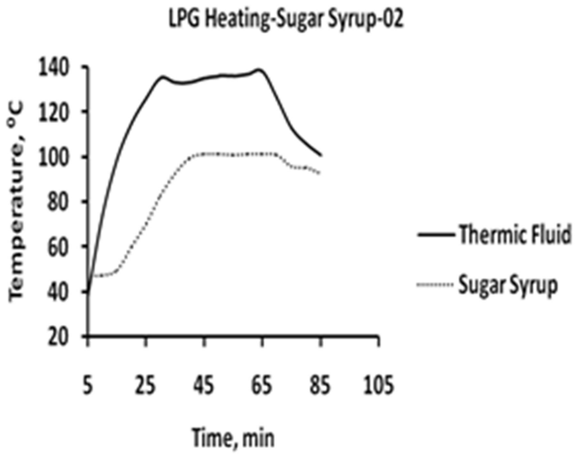


Fig. 6: Variation of temperatures of thermic fluid and sugar syrup with time (after insulation)

It is clear from Figs. 5 and 6 that there is a drastic temperature between the thermic fluid and water/sugar syrup this system showed low thermal performance due to excessive heat loss into atmosphere as a evaporation of water at 100°C.

Conclusion

A thermic fluid based heating system with combined LPG and electric energy source was designed, developed and tested for the fixed quantity of water and 55º Brix sugar syrup under unstirred conditions. Thermal performance of the heating system was done in terms of thermal efficiency, energy consumption, evaporation rate and overall heat transfer coefficient. The electric heating system has high thermal efficiency, faster evaporation rate of water as well as in the sugar syrup and minimum energy consumption compared to LPG heating system. The developed heating system may be integrated with chhana ball making machine for continuous Rasogolla making.

References

[1] IS 4246:2002 (2002) Domestic Gas Stoves for use with Liquefied Petroleum Gases. Bureau of Indian standards, New Delhi.
[2] NIL (2010) Technical investigation into thermal oil technology. Northern innovation limited (NIL), Belfast, Ireland, pp 4-51.
[3] Sahu, J.K. and Das, H (2007) Chhana manufacturing, Indian Dairy Association Monograph, No 3: 1-20.
[4] Sahu, J.K. and Das, H (2009) Continuous Heat-Acid Coagulation Unit for Continuous Production of Chhana. Assam University, Assam University journal 4 (2): 40-45.
[5] USFDA (2013) Indirect food additives: production aids and sanitizers: mineral oils. pp 36.

Technical Article for Oral Presentation Article Code: OP-PO-01

Performance Evaluation and Energy Saving in Boiler of a large Dairy Plant

H. R. Patel, Vivek Koshta, A. R. Chaudhari, B. P. Shah, B. M. Patel
Dairy Engineering Department, Mansinhbhai Institute of Dairy and Food Technology, Mehsana

Abstract
Boilers have a larger share (about 60 %) in thermal energy consumption in dairy plants. While dealing with such a large energy share, the performance of the boilers should be optimized by adopting newly developed energy saving methods for profitability of a dairy plant. Numerous methods viz. controlling excess flue gas due to excess oxygen (Air) supply-using Variable Frequency Drive (VFD) for the air blower, controlling blow down, installing economizer, use of biomass pellet as a fuel, etc. have been suggested for energy saving to improve the boiler thermal efficiency. The existing boiler of a large dairy plant having capacity of 10 Tonnes per hour steam generation was studied to reduce the Furnace oil consumption by controlling the excess air supply to the boiler to reduce the excessive heat losses in flue gas leaving the boiler by installing VFD for the air blower. It was found that the pay-back period i.e. return on investment for VFD for air blower was about 37 months. This results into savings of the Furnace oil of about 14707 litres, amounting Rs. 323554 (considering price of FO @ Rs 22/Litre) per anuum.

Key words: Boiler performance, Excess air control, Air Blower with Variable Frequency Drive and Energy Saving.

Milk handling in the organized dairy sector has witnessed a prominent growth in our country with increase in annual milk production. India has reached to annual milk production of 165 million tonnes by the year 2016-17 with a per capita milk availability of 355 grams per day (NDDB, 2018). It has resulted in expansion of dairy plants and thereby, increasing the energy usage in dairy processing.

One of the large organized milk handling dairy plant in Gujarat under Amul pattern using thermal energy in the form of furnace oil and natural gas for heating and power generation application was evaluated for the thermal energy management.

The dairy plant under study has 4 boilers, of which, one boiler is working on furnace oil, while the rest uses Furnace Oil and Natural gas. The total thermal energy is utilized for boilers, hot air generators and gas generators. The consumption and distribution of the thermal energy for boilers, hot air generators and gas generators are given in table-1 and figure-1 respectively.

Table 1. Annual Fuel Energy Consumption details, Year 2016

Annual natural gas consumption in SCM	113,65,281
Annual natural gas cost, RS.	12,59,57,266
Annual furnace oil consumption in Litres	19,02,650
Annual furnace oil consumption cost, RS.	4,18,58,300
Total cost of energy, Rs.	29,66,87,405

The boiler having steam generation capacity of 10 TPH using furnace oil as a fuel was evaluated for furnace oil consumption and other parameters for the whole year-2016. The consumption of furnace oil during the year-2016 is given in figure-2.

Table 2 shows the data for performance evaluation of the boiler carried out by Petroleum Conservation Research Association (PCRA), western Region, and Mumbai in the year-2017.

There are different factors affecting the performance of the boiler. All energy losses in boilers can be categorized into five broad categories.viz., (1) Heat carried away by dry flue gasses (2) Heat carried away by hot water vapour, including both sensible and latent heat (3) Heat loss due to unburnt carbon in fuel i.e. incomplete combustion, (4) losses from the outside surface by conduction, radiation and convection (5) Blow-down loss. (Barma *et.al.* 2017). Amongst which, one of the important factor is to provide the correct amount of excess air for complete combustion of fuel. The average amount of Oxygen (O_2) in flue gas (%, dry) of the boiler is found to be 13%.Therefore; the excess air corresponding to the O_2 present in flue gas is estimated to be about 162 %, using the following relation.

$$\text{Excess Air supplied (EA)} = \frac{\%O_2}{21 - \%O_2} \times 100$$

(source: $BEE_{b.}$)

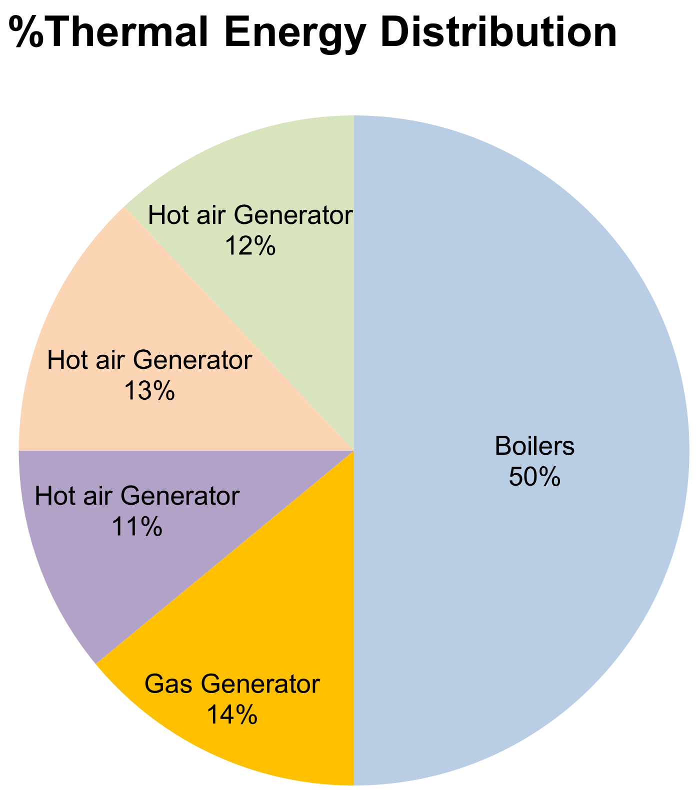


Figure 1. Percentage distribution of Thermal Energy

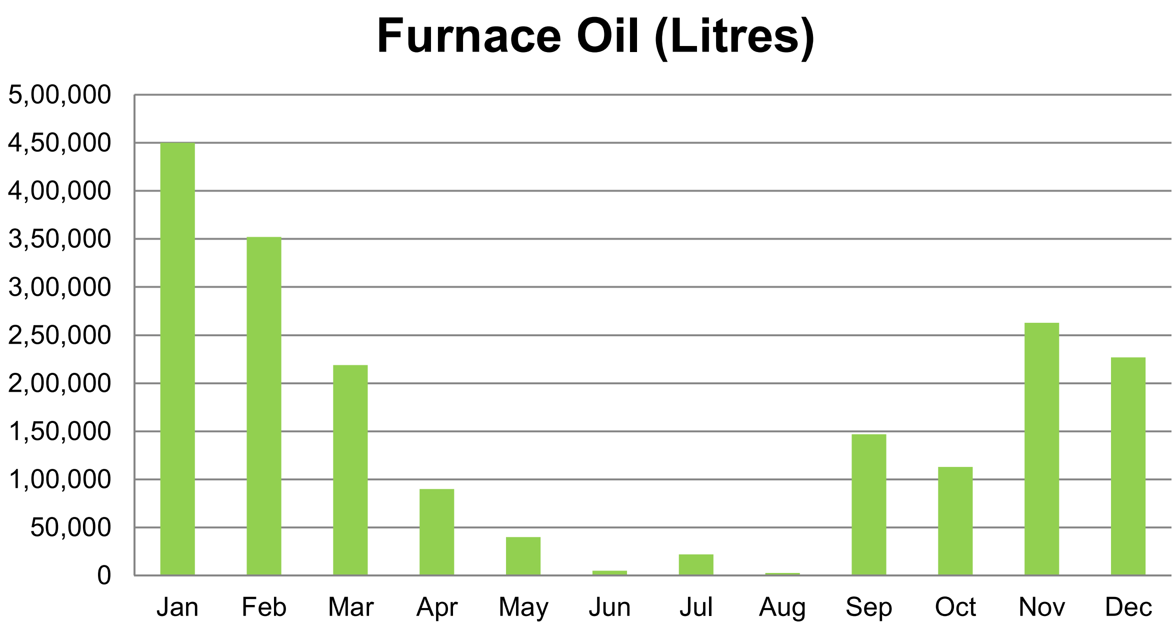


Figure 2. Monthly Furnace oil Consumption in litres -Year 2016

Table 2. Boiler performance Evaluation

Boiler Parameters	**10 TPH**
Annual Furnace Oil Use (litres per year)	19,02,650
Temperature and % Oxygen Inputs	
Flue gas temperature in ° C	177
Oxygen (O_2) in flue gas (%, dry)	13
Combustion air temperature (° C)	140

Controlling excess air to an optimum level always results in reduction in flue gas losses. This can be achieved by reducing the flow of excess air in the burner through air blower. As the temperature of the flue gas leaving a boiler typically ranges from 150 to 250 °C, about 10–30% of the heat energy is lost

through the flue gas due to higher temperature (Barma *et.al*, 2017). It is reported that about 1% fuel can be saved by reducing 22° C flue gas temperature (PCRA, 2018; BEE, 2018).Therefore, about 0.772 % fuel, which is about 14707 litres can be saved during the year. This is amounting to Rs. 323554(Considering Furnace oil price @ Rs. 22/litre) lost during the year due to higher flue gas temperature. The flue gas temperature can be reduced by reducing the supply of excess air using Variable Frequency Drive for controlling speed of air blower.
Considering, the cost of VFD about Rs 10,00000; the payback period for VFD cost to save the fuel will be about 37 months as shown in table 3.

Table 3. Possible Savings and Payback period

Possible Savings and Payback period	
Excess air (%)	162
Savings by Flue Gas Heat Recovery	
Recommended reduction in flue gas temperature,° C (PCRA,BEE_a)	17
Expected fuel saving @ 1% per 22°C reduction,%	0.773
Saving of Furnace Oil per annum, Liters	14,707
Monetary Saving per annum @ Rs. 22/liter of Furnace oil, Rs.	**3,23,554**
Investment needed to install VFD for Air blower in Rs.	**10,00,000**
Payback in a year	**3**
Payback in a months	**37**

Conclusion: Correcting the excess air by installing Variable Frequency Drive integrated with the boiler blower can achieve a significant saving in furnace oil.

References:

[1] M.C. Barmaa, R. Saidurb,c, S.M.A. Rahmand, A. Allouhie, B.A. Akashf, Sadiq M. Saitg (2017) 'A review on boilers energy use, energy savings, and emissions reductions', Renewable and Sustainable Energy Reviews. Elsevier Ltd, 79(May), pp. 970–983. doi: 10.1016/j.rser.2017.05.187.
[2] BEE_a. Bureau of Energy Efficiency : CHECKLISTS & TIPS FOR ENERGY EFFICIENCY IN THERMAL UTILITIES. Available online at https://beeindia.gov.in/sites/default/files/2ChAnnexure.pdf. Accessed on 30th july, 2018.
[3] BEE_b. Bureau of Energy Efficiency 2. Boilers. Available online at: https://beeindia.gov.in/sites/default/files/2Ch2.pdf. Accessed on 30th july, 2018.
[4] NDDB. National Dairy Development Board: Statistics. Available online at http://www.nddb.org. Accessed on 30th july, 2018.
[5] PCRA. Petroleum Conservation Research Association: Conservation tips. Available online at http://www.pcra.org/pages/display/59--Conservation-Tips-/22. Accessed on 30th july, 2018.


THE TRUSTED BRAND IN
DAIRY INDUSTRY
KK
KOTHARI GROUP
SINCE 1975
KK SS MILKCANS (AISI 304)
KK ALUMINIUM MILKCANS
THE MOST CONVENIENT
AUTOMATIC PASTEURISER
MILK COOLING TANK
CLOSED TYPE
MILK COOLING TANK
OPEN TYPE
HEAT RECOVERY UNITS
MILK COLLECTION
ACCESSORIES
KHAMBETE KOTHARI CANS AND ALLIED PRODUCTS PVT. LTD.
B-5, MIDC, Ajanta Road, Jalgaon - 425 003. Tel. : +91-257-2210750, 6451444,
Fax : +91-257-2210950. E-mail :info@kkcans.net
www.malhar.org
Spreading Healthy Smile - Globally


SINCE 1977
राजहंस दूध
मालकी शेतकऱ्यांची, विश्वास ग्राहकांचा
मा.आ. बाळासाहेब थोरात
मा.आ.डॉ. सुधीर तांबे
मा. रणजीतसिंह देशमुख
दर्जेदार दूध आणि
दुग्धजन्य उत्पादने
संगमनेर तालुका सहकारी दूध उत्पादक व प्रक्रिया संघ मर्यादित
अमृतनगर(घुलेवाडी), पोस्ट- संगमनेर साखर कारखाना, ता.संगमनेर, जि.अहमदनगर (०२४२५) २२५४१०, २२५५१०, २२६१६१, २२६१६२ www.rajhansmilk.com rajhansmilk@gmail.com

Technical Article for Oral Presentation Article Code: OP-PO-02

Engineering interventions in refrigeration system for milk cooling applications

Shubham Thakare[1], Chitranayak[2], P.S. Minz[3], J.K. Dabas[4], Amita D. Vairat[3], Khushbu Kumari[3]
[1]M Tech Scholar, [2]Senior Scientist, [3]Scientist, [4]ACTO,
Dairy Engineering Division, ICAR-NDRI, Karnal

Introduction

India is the largest milk producing country in the world achieving an annual output of 165.4 MT (million tons) during the period of 2016-17 (Department Of Animal Husbandry, Dairying and Fisheries, Ministry Of Agriculture, GOI). In most of the developed countries, production of milk is confined to rural areas, while demand is mostly urban in nature. Hence, the milk has to be collected and transported from production points to processing including chilling centres and distributions points in cities. In India small quantities of milk are produced, in a scattered manner all over the country. This situation makes the task of milk collection complex. Raw milk generally has a low microbial load as it comes out of the animal's udder. However, the temperature of raw milk at the time of milking, generally about 30-35°C, is most conducive for the growth of microorganisms. Subsequent holding of raw milk at ambient temperatures for longer periods (4-6 hours), till it reaches a processing plant, provides conducive environment and enough time for microorganisms to proliferate extensively. Thus, by time raw milk is received at a dairy plant the number of bacteria has already increased manifold, resulting in souring and other quality deterioration. Therefore, if milk cannot be delivered to the processing plant within 2-3 hours of milking, it is necessary to chill it to around 4°C, at which temperature microbial growth is greatly retarded. Milk could be chilled at farms at the village collection Centre itself or at the raw milk chilling centres. If the dairy plant is far away from the collection centre, then the collected milk is first brought to a centralized chilling centre/ bulk milk cooling unit. Here, milk is cooled to 4°C and stored in insulated storage tanks of 5000-20,000 L capacity. Subsequently, the chilled milk is transported in insulated Road milk tanker to the dairy plant. The transportation of milk from the chilling centre to the dairy plant usually takes place once a day. Chilling of milk means rapid cooling of raw milk to sufficiently low temperature so that the growth of micro-organisms present in milk is checked. In chilling process the temperature of milk should be reduced to less than 10 °C preferably 3 - 4°C. Chilling, therefore, is considered necessary soon after it is received at the chilling centres. The most effective means of controlling the growth of microorganisms without affecting the physico-chemical properties and nutritive value of milk is to chill it at the earliest. Lower temperatures inhibit the growth of most of the microorganisms. It should be clearly understood that chilling process does neither kills microorganisms nor it renders milk safe for human consumption. It is only a means of checking the growth of microorganisms for some time. But during chilling of milk in bulk milk coolers the rate of chilling is very slow (chills milk from 35°C to 4°C in 2 to 3 hours) and bulk milk coolers are higher in cost so that these cannot be installed at farm level. Hence there is an urgent necessity of improving performance of current refrigeration system of milk cooling. For this purpose there is need of searching new innovations in refrigeration system and to develop new advanced refrigeration system which will increase the rate of cooling of milk and will lower the price of cooling system. So there is urgent necessity of advanced refrigeration system for milk cooling by applying new advanced and innovative techniques to refrigeration system for milk cooling. In this paper we are going to discuss about conventional refrigeration system for milk cooling system (BMC) and the scope of applying new technologies to the refrigeration system.

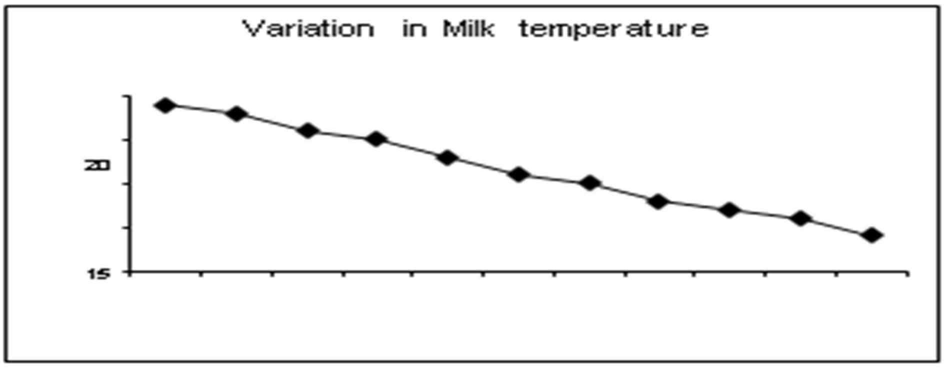
Review of Literature

The Operational Behaviour of BMC

The conventional system used for milk cooling is Bulk milk cooler. Ghewade *et.al*. (2007) studied the operational behaviour of this bulk milk cooler. Bulk milk coolers are basically designed to operate at milk farms or dairy cooperative societies and are built in capacities ranging from 500 litres to 5000 litres. Small sized BMCs are with one vapour compression system and medium to large sized BMCs consists of two vapour compression systems both operating simultaneously. These are designed to chill the given quantity of milk to 4°C within three hours.

The chillers operate under two conditions
1. First Milking condition
2. Second Milking condition.

First milking condition requires three hours to cool the milk from 35°C to 4°C wherein tank is filled to its half capacity. Second milking condition requires three hours to cool the milk from 19°C to 4°C when the tank is completely filled.



Operation of BMC is shut down when the milk temperature reaches 4°C. The temperature is further maintained by insulating the tank by polyurethane foam of sufficient thickness. Small amount of heat leak takes place from top cover since it is single walled and not insulated. Milk is continuously churned to maintain the homogeneity and avoid fatting. Agitator is directly attached to low rpm motor supported on top cover. Stirring also contributes somewhat to increase the heat transfer and maintain the uniform temperature throughout the BMC. The temperature gradient from top to bottom and from front to back side should be less than 0.5°C. The experimental data on a 2000 litre and 3000 litre capacity BMC has been recorded at the time of its performance testing in industry. The cooling load varies reasonably along with compressor input power, which varies by 15% with 30% variation in cooing load.

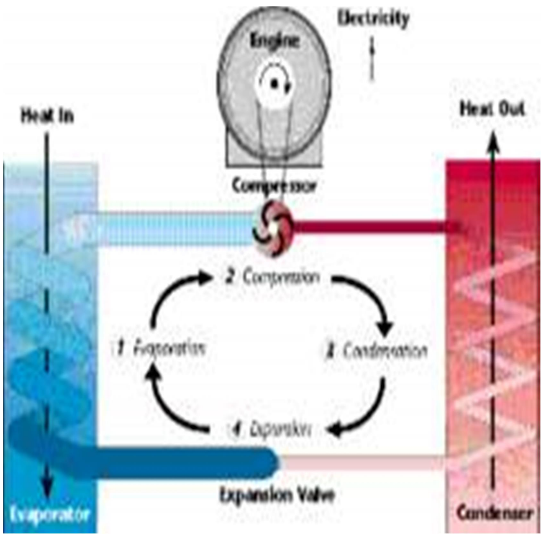


Fig.1: VCRS

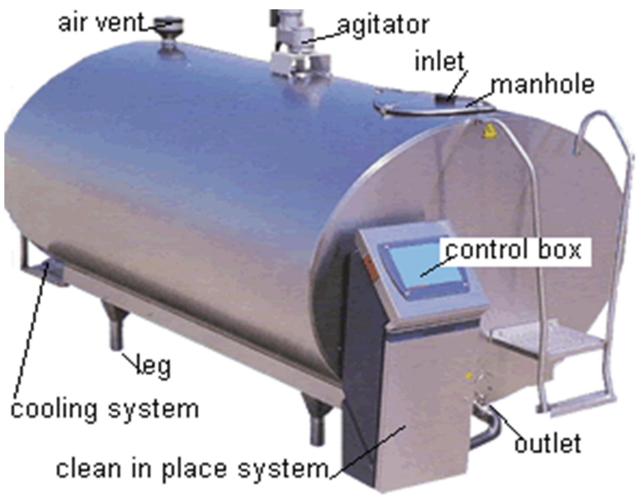


Fig.2: Bulk milk coolers

The Bulk milk cooler uses the conventional refrigeration system i.e. the VCRS (Vapour Compression Refrigeration System) which contains compressor, condenser, evaporator and expansion devices. A compressor is the heart of the refrigeration system on which the working of the refrigerator depends. The compressor used by the traditional refrigeration system is of single speed type which only operates at one speed. In a day, a traditional compressor goes through a cycle of on and off. You might have noticed this cycle in your traditional refrigerator that at one point the unit gets quiet and then compressor works again.

The new innovative and advanced technologies are to be implemented in order to improve the performance of conventional refrigeration.

Materials and methods

New Advanced Technologies Used in Refrigeration System

1. VFD System:

A variable-frequency drive (VFD) also termed as adjustable-frequency drive,"variable voltage/ variable-frequency (VVVF) drive", AC drive, micro drive or inverter drive, variable is systems to control AC motor speed and torque by varying motor input frequency and voltage.

VFDs are used in applications ranging from small appliances to large compressors. About 25% of the world's electrical energy is consumed by electric motors in industrial applications, which can be more efficient when using VFDs in centrifugal load service; however, VFDs' global market penetration for all applications is relatively small.

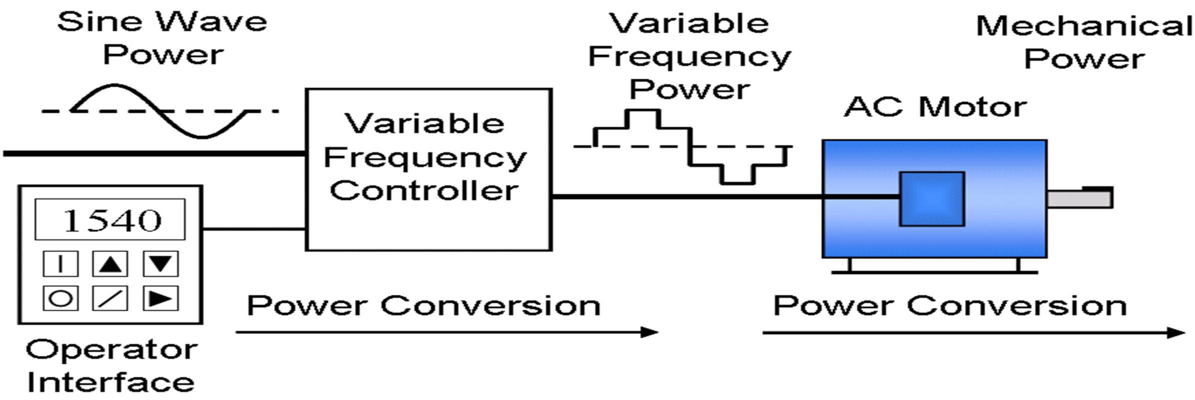


Fig.3: Block diagram of VFD system

The use of variable-frequency drives (VFDs) is to control compressor and fan motors has become a key factor in reducing energy costs, enhancing product life and stability, and improving equipment service life. For outdoor condensers, drives utilizing variable-speed operation have made important contributions to noise reduction.

2. Inverter Technology for Refrigeration

An inverter compressor is a gas compressor that is operated with an inverter. In the hermetic type, it can either be a scroll or reciprocating compressor. This type of compressor uses a drive to control the compressor motor speed to modulate cooling capacity. Capacity modulation is a way to match cooling capacity to cooling demand to application requirements. According to the statistical data, the household refrigerator/freezer takes up with 17% of the total household energy consumption as 38 billion KWH per year in Taiwan. To improve energy utilization and minimize carbon dioxide emission, some governments around the world are tending to establish increasingly strict regulation on energy consumption for household appliances. Some strategic methods were proposed to reduce energy consumption for household refrigerators/freezers, including with increase of thermal insulation thickness for walls, improvement of thermal insulation material or applying vacuum insulation panels, using a high-efficient compressor, and optimization of the refrigeration system etc. To reduce energy consumption greatly for refrigerators/ freezers, novel inverter controlled technology for the variable speed compressor with a brush-less DC (BLDC) motor is paying attention in recent years, especially in Asia area. The inner structure diagram and disassembled photo of a four-pole BLDC motor is shown in **Fig.4**. The DC motor inside the variable-speed compressor is driven by a digital signal processing (DSP) controller, one sensor-less power electronic circuit with pulse width modulation (PWM) regulation vs. its driving machine codes, a switching power supplier, and some peripheral communication circuits. The control sequence diagram for one six-step driving inverter is indicated in **Fig.5** and the PWM waveform is described in **Fig.6.** This type of controller described previously is implemented as an inverter, and the product is generally named as variable frequency refrigerators/freezers in Asia area. The compressor rotation speed is modulated through power frequency feedback control, what helps to realize intellectual control, increase power efficiency and energy saving. The rotation speed of compressor is usually controlled within 1600~4800 rpm for normal operation. At high speed, the refrigerator/freezer can reach the setting storage temperature during a short time; so the rapid cooling function can be achieved. Sometimes, the refrigerator/freezer would not be opened for a long time, and the low speed operation methodology can reduce the energy consumption and also ensure low noise. Therefore, temperature stability is improved by smart feedback control, and so food freshness is maintained. Besides, as the on/off switching frequency of the compressor is reduced, the running life of the electric appliance can be also improved.

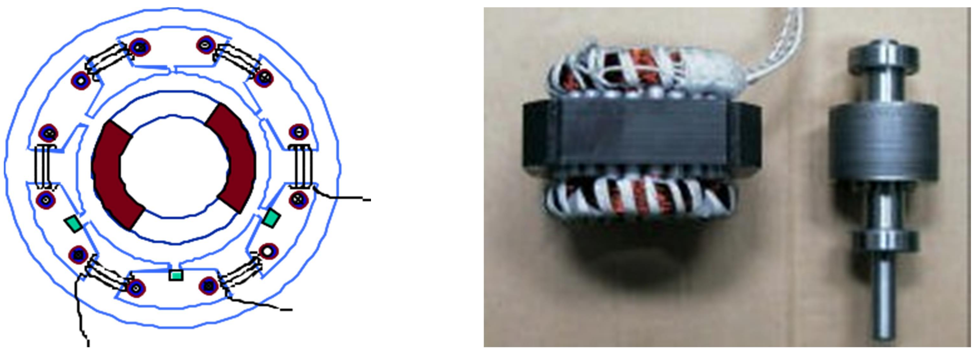


Fig.4. Inner structure and photo of four-pole brush-less DC motor.

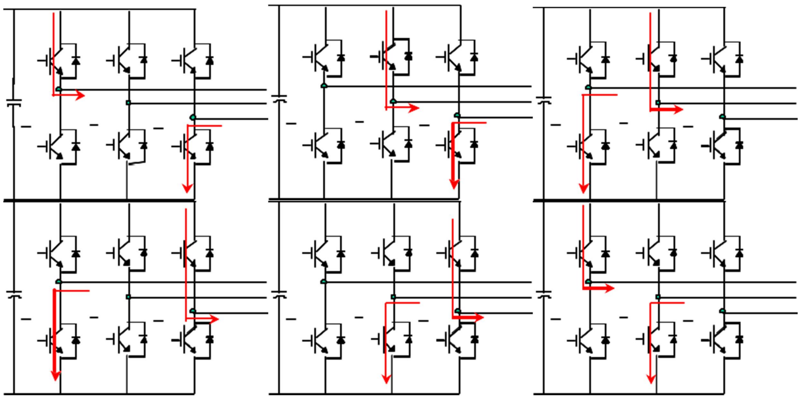


Fig.5: Control sequence diagram for 6 step inverter

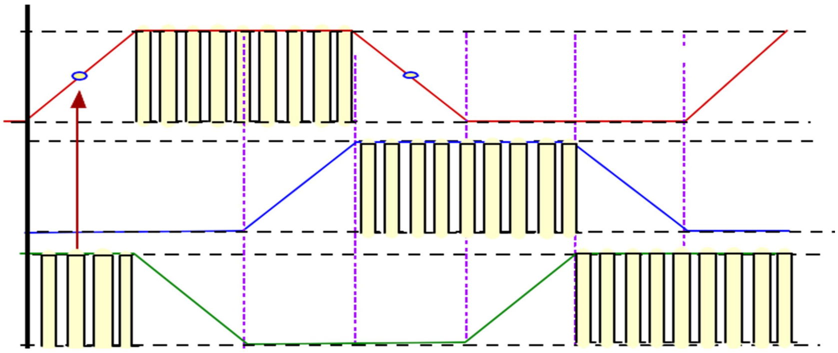


Fig.6: Pulse width modulated voltage waveform

Advantages and Energy saving Potential for inverter controlled Refrigerator/freezer

From the second law of thermodynamics, the coefficient of performance for one refrigeration system can be improved as by continuous running, if possible, compared to intermittent on/off operation under the same condition. The whole summation of each cycling loss could occupy a large percentage of household energy consumption. The percentage running time R', defined as d'/D'×100, is usually 40 to 50% for apparatus with on/off control for the refrigerating source, where d' is the duration of the refrigerating system operation during an operation cycle, and D' is the total duration of operation cycle minus the duration of the defrosting cycle for refrigerators/freezers. In general, the storage temperature of refrigerator/ freezer is maintained by turning on/off for thermostat relay of AC compressor/motor. Such control method causes cycling loss and reduces its energy efficiency. Under off-cycle state, refrigerant inside pipeline of refrigeration system will flow through capillary tube from condenser at high pressure vs. temperature into evaporator at low state. As the motor stops and refrigeration system is in equilibrium, evaporator temperature will increase due to pressure balance. Although the natural convection heat quantity is small inside refrigeration cabinets, it does not affect food preservation. But when the system is turning on again, warmer refrigerant vapour in the evaporator of freezer compartment will exhaust additional refrigeration capacity during starting instance. The system needs to re-establish the pressure potential between condenser and evaporator, for the refrigerant reaching normal conditions. Coulter et al. (1997) studied the starting and steady state cycling losses of refrigerators/freezers experimentally at room temperature from 60 to 100°F. The starting operation caused refrigeration loss of system by 3 to 17%, the energy consumption increased by 1 to 9% and the COP reduced by 5 to 25%. Wicks' study (2000) indicated that the variable speed control of compressor would reduce temperature variation than that by on/off control for a refrigerating system. For one system with refrigeration capability rated by 12000 Btu/h operating under partial load of 6000 Btu/h, variable speed control would save more energy than that by on/off control by 41% from the analysis of thermodynamic second law. On the other hand, energy consumption of refrigerators/freezers would be decreased by reduction of pressure potential cross compressor's discharge and suction lines. From the study by Woodall et al. (1997), the energy efficiency of refrigerators/freezers improved by 10.5% due to decrease of temperature difference between the condenser and evaporator, as the rotation speed of compressor decelerating from 3600 rpm to 2400 rpm under steady-state operation.

Results and Discussion

The energy efficiency potential was also studied experimentally by with one variable frequency refrigerators/freezers, with BLDC motor/compressor noted by 'B', compared to one fixed frequency type, installed with AC induction motor/compressor noted by 'A'. The fixed frequency sample, 'A' was made on 2001 by local manufacturer in Taiwan with storage volume rated 480 litres. The inverter type 'B' with 470 litres of rated storage volume was imported from Japan, manufactured on the same year. The testing procedure used here is following CNS-2062 standard (2001) used in Taiwan, similar to ISO 8561 (1995) and ANSI/AHAM HRF-1-1988 (1988). The room ambient temperature is fixed at 15 and 30°C, standing for winter and summer condition respectively. The relative humidity is controlled at 75%, and the storage temperature is set at -18±0.5°C for frozen food compartment and 3±0.5°C for fresh food compartment. Refrigerators/Freezers 'A' and 'B' were tested under the same condition concurrently in an environmental controlled room. From the testing results, variable speed product 'B' had higher energy efficiency than that of fixed frequency product 'A' by 22% at room temperature of 30°C. As the room temperature was set down to 15°C, the energy efficiency potential was raised up to 34%.

Control methods for controlling inverter controlled refrigerator /freezer

In digital era, intellectual control function is the inevitable trend for home appliance development. The controller of variable frequency refrigerator/freezer can adjust some rotating components, including the BLDC motor/compressor, to fit the best operation under discrepant environment condition and customer's propensity. This smart controller should be including with digital signal processor with PWM modulation, sensor-less control circuits and driving machine codes for refrigerant compressor, power supply and transformer with power factor correction, ability to defence of electromagnetic interference, and some peripheral analog sensors or communication.

Table 1: Energy Consumption Comparison of Refrigerators at Ambient Temperature of 15 and 30°C

Ambient Temperature	30°C		15°C	
Type	Energy consumption (KWH per year)	(B-A)/A	Energy consumption (KWH per year)	(B-A)/A
Fixed Frequency Product 'A'	932.5	-	474.0	-
Variable Frequency Product 'B'	725.8	22.15%	311.9	34.2%

The controller's methodology provides flowchart of physical information and corresponding judgment of inter devices for smart appliances. Better control methods could serve with optimal performance and behave friendly for any kind of consumers of household appliances. The control methods applied in variable frequency refrigerators/freezers are described in Figure 4, where the input signals are coming from temperature transducers, electro-switches like doors or function bottoms, and timer for defrosting or adaptive control. The output signals, which are processed by DSP controller with smart methodology, could regulate suitable actions for the BLDC compressor, Fan/motor, chilled flow electro-damper, and defrosting heater. Sometimes, the amplitude of these control signals is decided following consumer's propensity, especially for homemakers, e.g. quick freeze for meat or fresh sea food after market. These normal control parameters or special functions should be built as a database from a lot of performance testing data and electro-mechanical debug consideration.

Conclusion

Development for inverter-controlled refrigerator might be considered as a revolutionary advancement for refrigeration appliances. It not only has low noise, constant temperature control, fast cooling and energy saving. Variable frequency control even makes refrigerator intellectual. It adjusts compressor speed and puts control over other components according to various conditions. Variable frequency refrigerator needs proper control method to obtain good performance. It also needs integration among all components to achieve optimization in speed and temperature control under different input conditions. Variable frequency control method uses designer's framework and works with system simulation. To verify or adjust control parameters, it usually needs a long-term performance test under different ambient conditions to establish the database for reliable control or empirical formula for parameter control. Inverter controlled refrigerator adopts digital control, so refrigerator temperature control becomes more accurate than before. So these types of new Engineering interventions improve the performance of conventional refrigeration system and make it more accurate and advanced in terms of performance and economy.

References

[1] Chang, W. R., Liu, D. Y., Chen, S. G., and Wu, N. Y. (2004). The Components and Control Methods for Implementation of Inverter-Controlled Refrigerators/Freezers.
[2] Ghewade, D. V., Sapali, S. N., & Kajale, S. R., (2007). Dynamic modeling of bulk milk cooler. HEFAT
[3] Wicks, F. (2000). 2nd law analysis of on/off vs. frequency modulation control of a refrigerator. In Energy Conversion Engineering Conference and Exhibit, 2000. (IECEC) 35th Intersociety (Vol. 1, pp. 340-344). IEEE
[4] William H. Coulter and Clark W. Bullard, (1997) Experimental analysis of cycling losses in domestic refrigerator-freezers, ASHRAE Transactions, Vol.103, No.1, 587-596
[5] Woodall, R. J., & Bullard, C. W. (1997). Simulating effects of multispeed compressors on refrigerator/freezer performance (No. CONF-970668-). American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc., Atlanta, GA (United States).

Technical Article for Oral Presentation Article Code: OP-PO-03

Fouling in Heat Exchangers of Dairy Industry

A. D. Patel*[1], A. M. Rathva[1], I. A. Chauhan[1], S. M. Patel[2]
1 Assistant Professor, 2 Professor and Head
Dairy Engineering Department, SMC College of Dairy Science, AAU, Anand

1. Introduction

India is leading milk producer around the world. Milk and related milk-derived liquid products are usually heated so that the resultant product poses no risk of food safety for human consumption and also possibly to impart some desirable functional property to the finished product. One important practical problem resulting from the heating of milk is fouling where, during processing, a layer of milk derived components is progressively deposited onto surfaces that are in contact with the milk. The formation of these fouling layers can have important consequences. For example, fouling can reduce product flow, and extreme fouling may result in shorter runs times before shut down for the purposes of cleaning with an obvious impact on productivity, as well as increased cleaning costs (Bansal & Chen, 2006; Burton, 1968). This limits processing time and increases plant downtime and costs. Monitoring fouling and cleaning requires high demands for the measuring and analysing system having heat exchangers.

2. Fouling

Fouling is classified into macro and micro fouling. The first plays no major role in food industry. The micro fouling is divided into precipitation, particulate fouling (colloidal particles) or sedimentation (larger particles), corrosion, chemical reaction fouling, solidification, and biofilms (Bott, 1993) which are summarized in Table 1. Cleaning is conducted due to the diminished heat transfer with fouling and the risk of unsafe food (Changani *et al*., 1997; Fryer 2009).

Table 1 Comparison of different fouling types and their occurrence.

Fouling kind	Short description	Occurrence	Example
Precipitation	Precipitation/crystallization of salts, oxides etc.	Heat exchangers Water treatment, desalination	Dairy fouling type B Calcium, other salts
Particulate/sedimentation	Deposition/accumulation of particles on surfaces	Combustion systems Food processing industry	Colloids Dust
Corrosion	Corrosion deposits on metal surfaces	Water treatment	Rust
Chemical reaction	Decomposition/polymerization of proteins, hydrocarbons on heat transfer surfaces	Heat exchangers in dairy, crude oil industry, Food processing industry	Dairy fouling type A, Crude oil fouling
Solidification	Freezing of components on a cooled surface	Food processing industry, Fine mechanical manufacture	Ice Paraffin wax
Biofilm	Growth of algae, bacteria	Water treatment	Bacterial growth on membranes

3. Factors Affecting Milk Fouling

Fouling depends on various parameters such as heat transfer method, hydraulic and thermal conditions, heat transfer surface characteristics, and type and quality of milk along with its processing history. These factors can be broadly classified into 5 major categories: milk composition, operating conditions in heat exchangers, type and characteristics of heat exchangers, presence of microorganisms, and location of fouling.

3.1 Milk Fouling

Milk fouling can be classified into 2 categories known as type A and type B (Burton 1968; Lund and Bixby 1975; Changani *et al*.1997; Visser and Jeurnink 1997). Type A (protein) fouling takes place at temperatures between 75 °C and 110 °C. The deposits are white, soft, and spongy (milk film), and their composition is 50% to 70% proteins, 30% to 40% minerals, and 4% to 8% fat. Type B (mineral) fouling takes place at temperatures above 110 °C. The deposits are hard, compact, granular in structure, and gray in color (milk stone), and their composition is 70% to 80% minerals (mainly calcium phosphate), 15% to 20% proteins, and 4% to 8% fat.

3.2 Milk Components causes fouling

Milk consists for the most part of water (approx. 87 %), lactose (4.6 %) fat (4.0 %), protein (3.5 %), and salts (0.7 %). It can be considered as a dispersion of fat globules and proteinaceous particles (casein micelles and serum proteins), in a continuous phase, which includes lactose and dissolved salts. Heating causes many changes to occur in milk, like denaturation of serum proteins, precipitation of calcium phosphate and, at high temperatures, some aggregation of casein micelles. These reactions may cause milk to become less stable and this colloidal instability will lead to fouling.

The turbidity and viscosity of skim milk were found to increase with temperature and time of heating. The denaturation of *serum proteins*, in particular *β-lactoglobulin* (β -lg), is responsible for the increase in turbidity and viscosity. Denatured β.-1g molecules associate with the casein micelles, leading to an increase in the size of the micelles and in their mutual attraction. Experimental results are presented to demonstrate that the *heat stability of milk*, i.e. the resistance to coagulation during heating, is related to its fouling behaviour. If the stability of milk is lowered, e.g. by renneting or lowering the pH, the coagulation of casein micelles will cause extreme fouling.

Aged milk was found to cause more fouling than fresh milk: due to the action of proteolytic enzymes, produced by psychrotrophic bacteria during cold storage, part of the caseins are broken down. Consequently the heat stability of the milk is decreased so that additional protein deposition takes place. Either increasing or decreasing the *calcium concentration* in normal skim milk led to a lower heat stability and to more fouling. Changing the calcium concentration produced a shift from serum protein to casein in the composition of the deposit. Apparently calcium ions alter the structure of the casein micelles in milk in such a way (albeit for low- and high-calcium milk in different ways) that their mutual interaction increases and fouling is enhanced.

Fouling increases with increasing *serum Air bubbles*, which form in the milk on heating and stick to the stainless steel wall, appear to act as nuclei for the formation of an additional deposit. They influence the composition of the deposit through drying of the membrane that forms around a bubble, which comprises predominantly casein.

If *serum proteins* are (nearly) absent in the milk, fouling reduces by two-thirds. Although the calcium content remains unaltered, calcium deposition also reduces by two-thirds, indicating that the deposition of calcium is coupled to that of proteins. Not only β -l_g but also α-lactalbumin, bovine serum albumin and caseins contribute to the deposit.

The cleaning rate for milk and whey deposits: After processing milk, whey or concentrated whey the equipment can be cleaned completely in a short time. The cleaning mechanism involves penetration of the alkaline cleaning solution (mainly through cracks) into the deposit layer, thereby altering its structural properties, breaking up of the layer, and removal of deposit by carrying it away in large lumps, followed by dissolution of the remaining deposit, mainly mineral, in the subsequent acid cleaning solution. However, if in evaporators the flow rates during cleaning are too small or the alkali concentrations are too high, or both, then cleaning will be slow and incomplete. In that case the remaining deposit layer becomes covered with a brown rubber-like layer of polymerized protein. Since a whey deposit contains considerably more mineral compounds than a milk deposit it is better to alter the sequence of the cleaning stages after processing whey, i.e. to start with acid cleaning, followed by alkaline cleaning.

Studying the cleaning process revealed that if the following cleaning conditions are applied - (i) optimum temperature and detergent concentration, (ii) disposal of the first alkaline and acid flush in the case of heavy fouling and (iii) flow conditions in which all parts of the equipment are well reached by the cleaning solution - milk deposits in a heat exchanger can be readily removed by alkaline cleaning followed by acid cleaning.

3.3 Operating conditions in heat exchangers

Important operating parameters that can be varied in a heat exchanger are air content, velocity/ turbulence, and temperature.

Fouling is enhanced only when the *air bubbles* are formed on the heat-transfer surface, which then act as nuclei for deposit formation (Burton 1968; de Jong 1997). The solubility of air in milk decreases with heating as well as a reduction in the pressure (de Jong 1997; de Jong *et al* 1998). Also, the formation of air bubbles is enhanced by mechanical forces induced by valves, expansion vessels, and free-falling streams (de Jong 1997). It is usually reported that the presence of a deaerator will reduce fouling,

Fouling decreases with increasing *turbulence* (Belmar-Beiny *et al* 1993; Santos *et al* 2003). According to Paterson and Fryer (1988) and Changani *et al* (1997), the thickness and subsequently the volume of laminar sublayer decrease with increasing velocity and as a result, the amount of foulant depositing on the heat-transfer surface decreases.

Temperature of milk in a heat exchanger is probably the single most important factor controlling fouling (Burton 1968; Kessler & Beyer 1991; Belmar-Beiny *et al* 1993; Toyoda *et al* 1994; Corredig and Dalgleish 1996; Elofsson *et al* 1996; Jeurnink *et al* 1996b; Santos *et al* 2003). Increasing the temperature results in higher fouling. Beyond 110 °C, the nature of fouling changes from type A to type B (Burton 1968). the absolute temperature and temperature difference are important for fouling. This means that it is feasible to have fouling in coolers where the wall temperature is lower than the bulk temperature. Preheating of milk (often termed *forewarming*) causes denaturation and aggregation of proteins before the heating section, which then leads to lower fouling in heat exchangers (Bell & Sanders 1944; Burton 1968; Mottar & Moermans 1988; Foster 1989).

4.0 Type and characteristics of heat exchangers

Due to numerous distinct processing features PHE is widely used in Dairy industry. The plate heat exchangers are prone to fouling because of their narrow flow channels (Del place *et al* 1994) and contact points between adjacent plates (Belmar-Beiny *et al* 1993). Also, milk fouling in a heat exchanger is difficult to completely eliminate, because the temperature of the heat-transfer surface needs to be considerably higher than the bulk temperature to have efficient heat transfer. Complex hydraulic and thermal characteristics in plate heat exchangers make it very difficult to analyze milk fouling.

The heat-transfer surface to which the deposits stick affects fouling (Wahlgren and Arnebrant 1990, 1991). It influences the adhesion of microorganisms as well (Flint *et al* 2000). The surface characteristics are generally important only until the surface gets covered with the deposits. The surface treatment can be of great benefit in case fouling occurs after a time delay and the strength of the adhesion of the deposits onto the metal surfaces is weaker, giving way to an easier cleaning process.

Stainless steel is the standard material used for surfaces that are in contact with milk. Factors that may affect fouling of a stainless-steel surface are presence of a chromium oxide or passive layer, surface charge, surface energy, surface microstructure (roughness and other irregularities), presence of active sites, residual materials from previous processing conditions, and type of stainless steel used (Jeurnink *et al* 1996a; Visser and Jeurnink 1997). Modifications of the heat-transfer surface characteristics through electro-polishing and surface coatings can reduce fouling by altering the surface roughness, charge, and wettability (Yoon and Lund 1994; Santos *et al* 2001, 2004; Beuf *et al* 2003; Rosmaninho *et al* 2003, 2005; Ramachandra *et al* 2005, Rosmaninho and Melo 2006). It is generally reported that hydrophobic surfaces adsorb more protein than hydrophilic surfaces (Wahlgren and Arnebrant 1991). Increasing the surface roughness provides a larger effective surface area and results in a higher effective surface energy than a smooth surface (Yoon and Lund 1994). As a result, the adhesion of deposits with a rough surface would be comparatively stronger. The effect of different surface coatings tends to be less on the deposit formation but more on their adhesion strength (Britten *et al* 1988). Magnetic field treatment has been observed to have no effect on the milk fouling rate (Yoon and Lund 1994).

5.0 Bio fouling

Bio-fouling takes place through 2 different mechanisms: deposition of microorganisms directly on the heat-transfer surfaces of the heat exchanger, and deposition/attachment of microorganisms on/in the deposit layer forming on the heat-transfer surfaces (Bott,1993). With the supply of nutrients by the deposits, microorganisms multiply. The presence of micro-organisms in the process stream and/or deposit layer not only affects the product quality, it influences the fouling process as well (Flint *et al* 1997, 1999; Yoo *et al* 2005).

6.0 Prevention methods

From the various mechanisms of fouling and observations as given above, the following conclusions can be drawn:

- ✓ Fouling in heat exchangers can be reduced by controlling the formation of activated serum protein molecules and by preventing the precipitation of calcium phosphate. This can be achieved by introducing a holding section with a high volume-to-surface ratio.
- ✓ For some milk products, desalting, addition of calcium binders or pH adjustment may be ways to reduce fouling.
- ✓ Degassing of milk and application of high flow rates will prevent air bubbles from sticking to the wall, resulting in less fouling.
- ✓ Upon heating milk there is a region in the heat exchanger where fouling is most severe. This critical region is determined by the concentration of activated serum protein molecules.

Fouling in heat exchangers can be reduced by controlling the formation of these activated molecules. Possible ways of achieving this include:

- ❖ Installing a holding section with a high volume to surface ratio: By using a stirred tank as a holder, the amount of deposit was reduced by more than 50 % (De Jong 1997);

- Applying steam injection/infusion to shorten the period during which the concentration of activated molecules is high;
- Introduction of a coating on those plates where fouling is most severe;
- Applying such high shear stresses in the critical region that deposition of foulants will be prevented;
- Applying a temperature profile in such a way that fouling is evenly spread over the various passes of a plate heat exchanger to prevent one pass being so rapidly fouled that it blocks the whole equipment. A similar effect is achieved by applying a preheating of milk before pasteurization; in practice, the selection of preheating temperatures is a matter of compromise between reducing downstream fouling without causing overmuch deposition in the preheating section.

Other ways to reduce fouling include:

- Degassing the milk, applying high operational pressures and high shear rates; these procedures may prevent air bubbles from sticking to the wall, resulting in less fouling;
- Preventing psychrotrophic bacteria from producing extracellular proteolytic enzymes in milk by applying thermalization to raw milk, by avoiding dead spaces in the processing lines and by draining tanks and pipelines completely;
- Desalting, adding Ca^{2+}-binders and pH adjustment; in certain milk products these may be tools to diminish fouling.

7.0. Summary of detection of fouling

A combination of different methods may enhance both detection stability and the probability of fouling. It is important for industry to have a non-invasive, fast, reliable, robust and not expensive method. Thus, the different methods according to their applicability are summarized in table 2.

Table 2 Comparison of different methods of fouling detection with advantages and limitations

Method	Short Description	Advantages	Limitations
Pressure drop	Pressure between inlet and outlet measured	No extra equipment Usually measured Caution of excessive pressures	Not very Sensitive More sensitive for PHE Fouling place unknown
Temperature	Product outlet/heating medium temperature measured	No extra equipment Usually measured	Not very Sensitive Thein layers not monitored Fouling place unknown
Heat transfer parameters	Heat flux, heat transfer coefficient, thermal resistance measured	No extra equipment (despite heat flux) Flow/temperature usually measured	Certain thickness necessary Heat flux sensors not usable at high temperature
Electrical Parameters	Electrical resistance, conductivity measured Electrical behaviour of heater monitored	Very sensitive to thin layers Fouling thickness determinable	Invasive Electrical heating not popular
Acoustic/Ultra sound/QCM. QCM-D	Acoustic parameters measured Frequency change and energy dissipation monitored	Non-invasive Very sensitive to material changes, thin fouling Fouling and cleaning monitored Movable clamp-on sensor	Scattering can occur Parameters temperature dependent One transducer only one point monitored QCM.QCM-D invasive
Numerical method/ANN	Clean/fouled heat exchangers modelled Parameters combined in ANN	No extra equipment Very sensitive when appropriate parameters and models used	Due to parameters errors may occur First validation with other methods required

8.0 Conclusions

Fouling of heat exchangers in the dairy industry is a complex phenomenon and the mechanisms are not completely understood. It is believed that fouling is controlled by the aggregation reaction of proteins and the formation of protein aggregates reduces fouling. Fouling can be controlled and mitigated by increasing the flow rate and decreasing the temperature reduces fouling. Plate heat exchangers tend to have lower fouling compared with tubular heat exchangers because they have higher turbulence and the surface temperature is also comparatively lower. Microwave heating and ohmic heating also result in less fouling; however, the information available about these technologies is limited. Bio-fouling aggravates the problem and raises concerns about the product quality as well. Finally, it is important that a holistic approach is taken to mitigate fouling because controlling fouling within the heat exchangers may be of little use in case it shifts to other parts of the plant. Further concentrated and joint efforts among industry, research institutes, and academia are required to combat this serious problem.

References

[1] Arnebrant T, Barton K, Nylander T. 1987. Adsorption of α-lactalbumin and β-lactoglobulin on metal surfaces versus temperature. *J CollInterf Sci* 11 9(2):383–90.

[2] Bansal B, Chen XD, Lin SXQ. 2005. Skim milk fouling during ohmic heating. Heat exchanger fouling and cleaning: challenges and opportunities. Engineering Conferences Intl.; KlosterIrsee, Germany; June 5-10: Engineering Conferences International, New York, U.S.A.

[3] Bell RW, Sanders CF. 1944. Prevention of milk stone formation in a high temperature short-time heater by preheating milk, skim milk and whey. *J Dairy Sci* 27:499–504.

[4] Belmar-Beiny MT, Fryer PJ. 1993. Preliminary stages of fouling from whey protein solutions. *J Dairy Res* 60:467–83.

[5] Belmar-Beiny MT, Gotham SM, Paterson WR, Fryer PJ, Pritchard AM. 1993. The effect of Reynolds number and fluid temperature in whey protein fouling. *J Food Eng* 19:119–39.

[6] Beuf M, Rizzo G, Leuliet JC, Müller-Steinhagen H, Yiantsios S, Karabelas A, Benezech T. 2003. Potency of stainless steel modifications in reducing fouling and in improving cleaning of plate heat exchangers processing dairy products. In: Proceedings of heat exchanger fouling and cleaning—fundamentals and applications.

[7] Bott TR. 1993. Aspects of biofilm formation and destruction. Corrosion Rev 11(1/ 2): 1 –24.

[8] Bradley SE, Fryer PJ. 1992. A comparison of two fouling-resistant heat exchangers. *Biofouling* 5:295–314.

[9] Britten M, Green ML, Boulet M, Paquin P. 1988. Deposit formation on heated surfaces: effect of interface energetics. *J Dairy Res* 55:551–62.

[10] Burton H. 1967. Seasonal variation in deposit formation from whole milk on a heated surface. *J Dairy Res* 34:1 37–43.

[11] Burton H. 1968. Deposits from whole milk in heat treatment plant—a review and discussion. *J Dairy Res* 35:31 7–30.

[12] Changani SD, Belmar-Beiny MT, Fryer PJ. 1997. Engineering and chemical factors associated with fouling and cleaning in milk processing. *Exp Thermal Fluid Sci* 14:392–406.

[13] Christian GK, Changani SD, Fryer PJ. 2002. The effect of adding minerals on fouling from whey protein concentrate—development of a model fouling fluid for a plate heat exchanger. Trans IChemE C 80:231–9.

[14] Corredig M, Dalgleish DG. 1996. Effect of temperature and pH on the interactions of whey proteins with casein micelles in skim milk. Food Res Int 29(1):49–55. Dalgleish DG. 1990. Denaturation and aggregation of serum proteins and caseins in heated milk. *J Agric Food Chem* 38(11):1 995–9.

[15] deAlwis AAP, Fryer PJ. 1990. The use of direct resistance heating in the food industry. *J Food Eng* 11:3–27.

[16] de Jong P. 1997. Impact and control of fouling in milk processing. *Trends Food SciTechnol* 8:401–5.

[17] de Jong P, Bouman S, van der Linden HJLJ. 1992. Fouling of heat transfer equipment in relation to the denaturation of 3-lactoglobulin. *J Soc Dairy Technol* 45:3–8.

[18] de Jong P, l'Ammie PFJ, van der Linden HJLJ. 1994. Mathematical optimization of heat treatment equipment with respect to fouling and product quality. Fouling and Cleaning in Food Processing; Jesus College, Cambridge, England; March 23-25. p 43–50.

[19] de Jong P, van der Horst HC, Waalewijn R. 1998. Reduction of protein and mineral fouling. Fouling and Cleaning in Food Processing; Jesus College, Cambridge, England; April 6-8, p 39–46: Office for Official Publications of the European Communities, Luxembourg.

[20] de Jong P, van der Linden HJLJ. 1992. Design and operation of reactors in the dairy industry. ChemEngSci 47(13/14):3761–8.

[21] Elofsson UM, Paulsson MA, Sellers P, Arnebrant T. 1996. Adsorption during heat treatment related to the thermal unfolding/aggregation of β-lactoglobulin A and B. *J CollInterfSci* 183:408–15.

[22] Flint S, Hartley N. 1 996) A modified selective medium for the detection of pseudomonas species that cause spoilage of milk and dairy products. *Int Dairy J* 6(2):223–30.

[23] Flint SH, Brooks JD, Bremer PJ. 2000. Properties of the stainless steel substrate influencing the adhesion of thermo-resistant streptococci. *J Food Eng* 43(4):235–42.

[24] Flint SH, Brook JD, van den Elzen H, Bremer PJ. 1997. Biofilms in dairy manufacturing plant—a threat to product quality. *Food Technol* NZ 27(2):61–4.

[25] Flint SH, van den Elzen H, Brooks JD, Bremer PJ. 1999. Removal and inactivation of thermo-resistant streptococci colonising stainless steel. *Int Dairy J* 9(7):429–36.

[26] Fonterra Co-Operative Group. 2004. Available from:www.fonterra.com. NewZealand. Date Accessed: April 10, 2005.

[27] Foster CL, Britten M, Green ML. 1989. A model heat-exchanger apparatus for the investigation of fouling of stainless steel surfaces by milk I. deposit formation at 100°C. *J Dairy Res* 56:201–9.

[28] Fox PF. 1989. The milk protein system. In: Fox PF, editor. Developments in dairy chemistry. New York: Elsevier Applied Science. p 1–53.

[29] Fryer PJ, Belmar-Beiny MT. 1991. Fouling of heat exchangers in the food industry: a chemical engineering perspective. *Trends Food SciTechnol*, Volume: Feb 1991, p 33–7.

[30] Fryer PJ, de Alwis AAP, Koury E, Stapley AGF, Zhang L. 1993. Ohmic processing of solid-liquid mixtures: heat generation and convection effects. *J Food Eng* 18:101–25. Fung L, McCarthy OJ, Tuoc TK. 1998. The effect of fat globule membrane damage on fouling of whole milk. In: Wilson DI, Fryer PJ, Hasting APM, editors. Fouling and Cleaning in Food Processing '98. Cambridge, U.K.: Jesus College. p 33–8.

[31] Gillham CR, Fryer PJ, Hasting APM, Wilson DI. 2000. Enhanced cleaning of whey protein soils using pulsed flows. *J Food Eng* 46:1 99–209.

[32] Gotham SM, Fryer PJ, Pritchard AM. 1992. 3-lactoglobulin denaturation and aggregation reactions and fouling deposit formation: a DSC study. Int J Food SciTechnol 27:31 3–27.

[33] Gough MJ, Rogers JV. 1987. Reduced fouling by enhanced heat transfer using wire matrix radial mixing elements. AIChESympSer 257:16–21.

[34] Jeurnink TJM, de Kruif KG. 1995. Calcium concentration in milk in relation to heat stability and fouling. Netherlands Milk Dairy J 49:151–65.

[35] Jeurnink T, Verheul M, Stuart MC, de Kruif KG. 1996a. Deposition of heated whey proteins on a chromium oxide surface. Colloids Surf B Biointerf 6:291–307. Jeurnink TJM, Walstra P, de Kruif CG. 1996b. Mechanisms of fouling in dairy processing. *Netherlands Milk Dairy J* 50:407–26.

[36] Karlsson CAC, Wahlgren MC, Trägårdh AC. 1996. 3-Lactoglobulin fouling and its removal upon rinsing and by SDS as influenced by surface characteristics, temperature and adsorption time. *J Food Eng* 30:43–60.

[37] In: Melo LF, Bott TR, Bernardo CA, editors. Fouling science and technology. Amsterdam, The Netherlands: Kluwer. p 557–73.

[38] Lund DB, Bixby B. 1975. Fouling of heat exchanger surfaces by milk. *Proc Biochem* 10:52–5.

[39] Mottar J, Moermans R. 1988. Optimization of the forewarming process with respect to deposit formation in indirect ultra high temperature plants and the quality of milk. *J Dairy Res* 55:563–8.

[40] Paterson WR, Fryer PJ. 1988. A reaction engineering approach to the analysis of fouling. *Chem Eng Sci* 43(7):1 714–7.

[41] Rosmaninho R, Melo LF. 2006. Calcium phosphate deposition from simulated milk ultrafiltrate on different stainless steel-based surfaces. *Int Dairy J* 16:81–7.

[42] Rosmaninho R, Rizzo G, Müller-Steinhagen H, Melo LF. 2003. The influence of bulk properties and surface characteristics on the deposition process of calcium phosphate on stainless steel. In: Proceedings of heat exchanger fouling and cleaning—fundamentals and applications. Santa Fe, New Mexico, U.S.A.; May 18-22. New York, U.S.A.: Engineering Conferences International.

[43] Rosmaninho R, Rizzo G, Müller-Steinhagen H, Melo LF. 2005. Anti-fouling stainless steel based surfaces for milk heating processes. Heat exchanger fouling and cleaning: challenges and opportunities, engineering conferences intl. KlosterIrsee, Germany; June 5-10: New York, U.S.A.: Engineering Conferences International.

[44] Santos O, Nylander T, Paulsson M, Trägårdh C. 2001. Adsorption behavior of 3-Lactoglobulin on different types of stainless steel surfaces. In: Proceedings of heat exchanger fouling—fundamental approaches & technical solutions. Davos, Switzerland; July 8-13: New York, U.S.A.: United Engineering Foundation, Inc.

[45] Santos O, Nylander T, Rizzo G, Müller-Steinhagen H, Trägårdh C, Paulsson M. 2003. Study of whey protein adsorption under turbulent flow rate. In: Proceedings of heat exchanger fouling and cleaning—fundamentals and applications; Santa Fe, New Mexico, U.S.A.; May 18-22. New York, U.S.A.: Engineering Conferences International.

[46] Santos O, Nylander T, Rosmaninho R, Rizzo G, Yiantsios S, Andritsos N, Karabelas A, Müller-Steinhagen H, Melo L, Boulangé-Petermann L, Gabet C, Braem C, Trägårdh C, Paulsson M. 2004. Modified stainless steel surfaces targeted to reduce fouling—surface characterization. *J Food Eng* 64:63–79.

[47] Toyoda I, Schreier PJR, Fryer PJ. 1994. A computational model for reaction fouling from whey protein solutions. Fouling and Cleaning in Food Processing, Jesus College, Cambridge, England; March 23-25. p 222–229.

[48] vanAsselt AJ, Vissers MMM, Smit F, de Jong P. 2005. In-line control of fouling. Proceedings of heat exchanger fouling and cleaning—challenges and opportunities; KlosterIrsee, Germany; June 5-10: New York U.S.A.; Engineering Conferences International.

[49] Visser J, Jeurnink TJM. 1997. Fouling of heat exchangers in the dairy industry. ExpTherm Fluid Sci 14:407–24.

[50] Visser H, Jeurnink TJM, Schraml JE, Fryer P, Delplace F. 1997. Fouling of heat treatment equipment. Fouling and cleaning of heat treatment equipment. IDF bull 328:7–31. Brussels: Intl. Dairy Federation.

[51] Wahlgren M, Arnebrant T. 1990. Adsorption of 3-lactoglobulin onto silica, methylated silica, and polysulfone. *J CollInterfSci* 136:259–65.

[52] Wahlgren M, Arnebrant T. 1991. Protein adsorption to solid surfaces. Tibtech 9:201 – 8.

[53] Yoon J, Lund DB. 1994. Magnetic treatment of milk and surface treatment of plate heat exchangers: effect on milk fouling. *J Food Sci* 59(5):964–9, 980.

Technical Article for Oral Presentation Article Code: OP-NT-01

Bio-packaging for Indian Dairy Products

Khojare A. S.
Department of Dairy Science and Technology, Vivekanand College, Aurangabad Maharashtra

Introduction:

With an increasing concern towards environment due to over use of plastics in packaging of dairy foods, the bio-packaging is emerging as a viable alternative for plastics. Bio-packaging involves use of bio-degradable, edible and environment friendly packaging materials which can protects the food product from environmental parameters as well as enhance its shelf life due to its antibacterial properties. In near future bio-packaging may offer the complete solution to replace the plastic or minimize use of it by giving added internal protection to food. With changing dimension of Indian dairy industry it is necessary to use and incorporate the necessary technologies for shelf life enhancement, product monitoring and packaging of dairy products. As far as Indian milk products are concerned, it is mostly confined to unorganized and small scale industries. Very few Indian dairy products have been taken up in the past by bigger dairy brands in India. The reason behind this is non standardization of production processes and unavailability of reliable scale-up data to upgrade the production at mass level. There is a real need to generate rational data on bio-packaging and shelf life extension of indigenous dairy products. This paper communicate some of the work that author has reviewed on bio-packaging of paneer using chitosan.

Chitosan

Chitosan is a nontoxic, biodegradable, and biocompatible natural polymer and the second most important natural polymer in the world. Chitosan is prepared from chitin, the second most abundant natural polymer in the world. It is primarily composed of glucosamine and N-acetyl glucosamine residues with a 1, 4-b-linkage. It can be obtained by deacetylation of chitin, which is produced from shells of crustaceans, insects, and other sources. Chitosan can be used in a wide range of applications such as in the areas of biomedicine, membranes, drug delivery systems, hydrogels, water treatment, food packaging, etc.

Film Forming Ability of Chitosan

Chitosan with higher molecular weight have good film forming properties as a result of intra and intermolecular hydrogen bonding (Muzzarelli, 1977). A patent was granted to form film from chitosan to G.W. Rigby in 1936, describing the film as flexible, tough, transparent, and colourless with tensile strength of about 9000 psi and prepared by a solvent casting method.

Film forming Methods

A wet or dry mechanism is used for the preparation of edible film of chitosan. A wet process mechanism is based on film forming dispersion or solution in which chitosan are first dispersed or solubilized into a liquid phase and then dried. Peressini and others (2004) reported that the wet process permits application of film as coatings in liquid form directly onto food products by dipping, brushing, and spraying.

Film forming Mechanisms

Chitosan solutions form films through a series of phases. Banker (1996) reported that when the polymer solution i.e. chitosan solution is cast on a surface cohesion forces form a bond between the polymer molecules.

Film Morphology

Polymeric films should be uniform and free from defects for their applications. Uniformity of the films is critical for their functionalities. It was reported that the processing variables involved in conversion of chitin into chitosan greatly influence the properties of chitosan and hence the uniformity of films produced.

Properties of Chitosan and Chitosan Films

Safety:

Chitosan is safe in terms of inertness and low or no toxicity has been demonstrated by in vivo toxicity studies and its oral LD_{50} (median lethal dose) in mice was found to be in excess of 16 g/day/kg body weight (Singla and Chawla, 2001). According to Rao and Sherma (1997) chitosan films were nontoxic and free from pyrogens and can be sterilized by autoclaving, although the processes lead to some degradation of the films.

Biological Properties

a) Biodegradation:

Chitin and chitosan are biodegradable polymers and most susceptible to hydrolysis by Lysozyme at pH 5.2 and optimum range of pH value is between pH 5.2 -8.0. Sashiwa et al., (1990) studied the relative rates of degradation of six chitosan varying in degree of deacetylation (45%, 66%, 70%, 84%, 91%, & 95%) and reported that 70% deacetylated chitosan degraded most quickly.

b) Biocompatible

i) Natural polymer

ii) Biodegradable to normal body constituents and Chitosan is well tolerated by living tissues including skin, ocular membrane, and nasal epithelium

c) Transport Properties:

The edible film coatings of chitosan provide the potential to control transport of moisture, oxygen, aroma, oil, and flavor compounds, in food systems depending on the nature of film forming materials.

Chitosan films exhibits gas barrier properties. Webber (2000) studied that oxygen permeability of chitosan is as low as many conventional plastic films such as poly vinylidene dichloride (PVdC) and ethyl vinyl alcohol (EVOH) Since chitosan obtained from various sources and methods vary in their characteristics, barrier properties of film made of various chitosan also vary.

d) Antimicrobial Properties:

The interaction between negatively charged microbial cells and positively charged chitosan molecules leads to the leakage of proteinaceous and other intracellular constituents (Shahidi et al., 1999). Chitosan selectively binds trace metals i.e. it acts as chelating and inhibits microbial growth and toxins. It also activates several defence processes in the host tissue acts as water binding agent and inhibits various enzymes. Binding of chitosan with DNA inhibits the mRNA synthesis through penetration of chitosan in the nuclei of microorganisms and interferes in protein synthesis.

Application of chitosan in dairy products:

Chitosan had a great potential for a wide range of application in dairy products due to its biodegradability, biocompatibility, antimicrobial activity, Nontoxicity and versatile chemical and physical properties. Chitosan has high antimicrobial activities against a wide variety of pathogenic and spoilage microorganisms including fungi and Gram-positive and Gram-negative bacteria and used as a packaging material for the quality preservation of variety of foods. There are no studies available on use of chitosan for bio-preservation of Indian milk products.

Inhibitory effect of chitosan with different molecular weight and their complexes with casein on the growth of three milk-fermentative bacteria have been studied by Honarkarand & Barikani (2009). In addition to molecular weight and concentration of the polymer, the concentrations of the bacteria and casein micelles or milk fat are important. The inhibiting effects of chitosan were greatly reversed when the biopolymers were incubated with milk before interaction with bacteria, because casein micelles or milk fat can prevent the inhibitory activity of these biopolymers on bacterial growth.

Paneer is one of the traditional dairy products of India. Chitosan is the edible bio polysaccharide and extensively studied for its bio preservative properties. Studies were undertaken to check an effect of chitosan coating on paneer for its shelf life improvement (Waghchaure et al., 2016). Paneer was prepared as per the procedure recommended by Sachdeva et al (1991).

Different concentrations of chitosan solutions were prepared and coated on the paneer cubes of equal size. The shelf life of these chitosan coated paneer was determined on every alternate day by microbial and physical analysis. The paneer samples coated with different concentration of chitosan and stored at 20^{o}C are shown in figure 1. It was concluded that the paneer sample having 0.8% chitosan concentration showed good shelf life and sensory acceptability.

Effect of chitosan in acetic acid as edible coating for precooked pizza (0.079g/100g pizza) delayed the growth of *Alternaria sp*, *Penicillium sp*, and *Cladosporium sp* (*Deuteromycetes*) (Rodriguez and Anullo, 2003). Agullo et al., (1998) evaluated the capacity of chitosan films extend the shelf life of precooked pizza and showed increased shelf life properties of chitosan due to its antifungal properties instead of its action as a water vapour barrier.

Evdokimov et al., (2015) studied the sorption properties of various forms of chitosan: granulated, as cryogels, as well as part of calcium tartrate gel. Using the chitosan containing sorbents allows them to select proteins from the milk serum and obtain purified preparations of β-lactoglobulin and lactoferrin. Inclusion of the chitosan in the milk beverages and dairy desserts allows them to create a functional food, where the polysaccharide acts as a technological, bactericidal and fungistatic agent.

Savant and Torres (2000) studied Chitosan-Polyanion complexes for treating the cheddar cheese whey. Complexation and coagulation time played a significant role in adsorption, whereas polymer concentration was significant only for chitosan – alginate complexes. Complexes of chitosan with Alginate (ALG), pectin (PEC), and carragenan (CAR) used at 30 mg complex/ L. This study successful demonstrated the effectiveness of Chi-Pol complexes in flocculation of suspended solid waste in cheese whey with over 705 protein recovery.

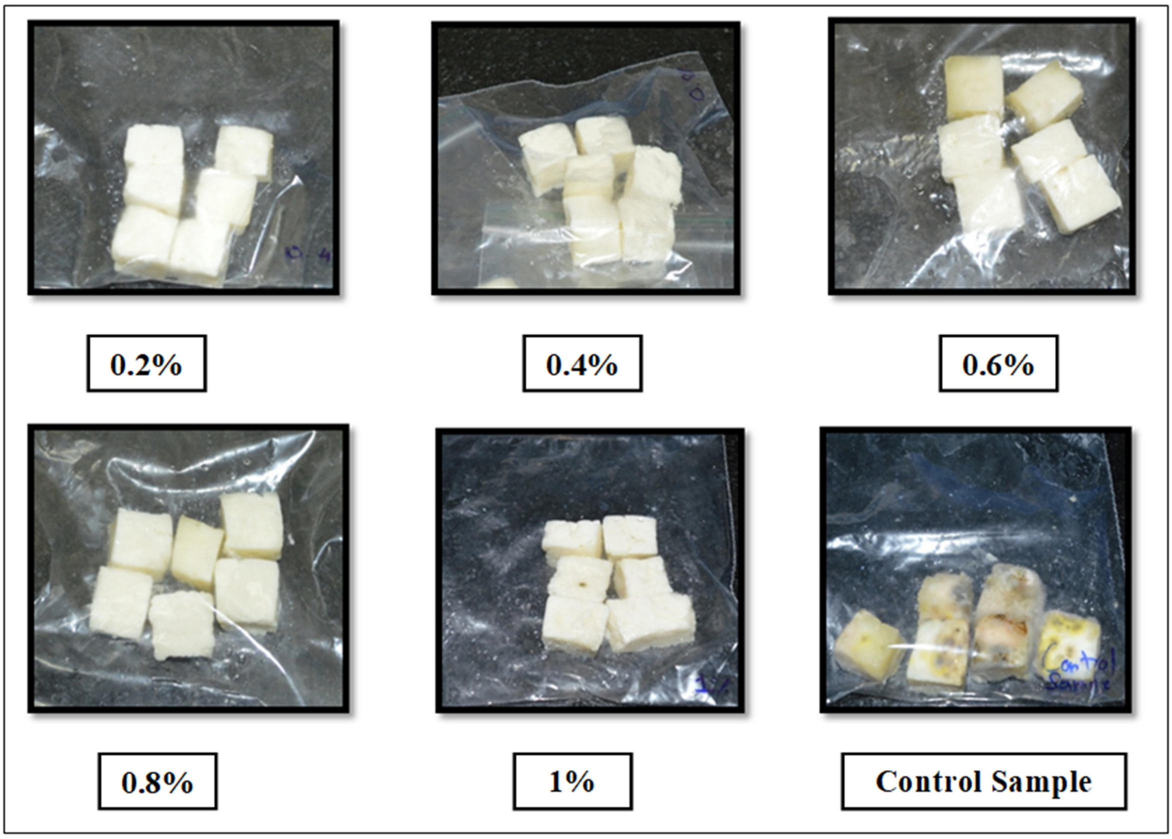


Fig 1 - Paneer samples coated with chitosan stored at the temperature 20°C

Conclusion

Chitosan is one of the emerging innovative materials for preserving food and increasing shelf life of food. It is safe and biocompatible for the use to increase the shelf life of dairy product. With increasing concern over the use of plastic for packaging in food industry, the use of biodegradable materials gives the new way for sustainable development. As chitosan is nontoxic and safe it is beneficial and having promising future in preserving the dairy food products. It is required to explore more studies to understand the use of such bio-degradable and antimicrobial materials in Indian dairy products.

References

[1] Agullo E., Schulz P. C., Rodriguez M. S., Del Blanco L. F., Pistonesi M. (1998). Emulsification properties of chitosan. Colloid Polym. Sci., vol 276, Issue 12, pp 1159-1165.

[2] Altieri C., Scrocco C., Sinigaglia M., and Del Nobile M. A. (2005) "Use of Chitosan to Prolong Mozzarella Cheese Shelf Life" J. Dairy Science 88:2683-2688 American Dairy Science Association, 2005

[3] Coma V., Deschamps, and Martial-Gros A. (2002) "Bioactive Packaging Materials from Edible Chitosan Polymer- Antimicrobial Activity Assessment on Dairy related Contaminanats"

[4] Dutta P. K., Dutta J., and Tripathi V. S. (2010) "Progress in antimicrobial activities of chitin, chitosan and its oligosaccharides: a systematic study needs for food applications" Food Science and Technology International 18(1) 3-34

[5] Evdokimova I. A., Alievaa L. R., Varlamovb V. P., Kharitonovc V. D., Butkevichd T. V., and Kurchenkod V. P. (2015) "Usage of Chitosan In Dairy Products Production" Foods and Raw Materials Vol. 3, No. 2, 2015, ISSN 2308-4057.

[6] Honarkar H. and Barikani M. (2009) Springer-Verlag, 140:1403-1420 DOI 10.1007 /S00706-009-0197-4

[7] Muzzarelli R. A. A., (1977). Depolymerization of chitin and chitosan with hemicelluloses, Lysozyme, papain, and lipase, Eds. Chitin handbook, European chitin society 153- 85

[8] Rodriguez M. S., Anullo E. (2003). Antimicrobial action of chitosan against spoilage organism in precooked pizza, J. Food Sci., 68(1):271-4

[9] Sashiwa H., Saimoto H., Shigemasa Y. (1990). Lysozyme susceptibility of partially deacetylated chitin, Int. J.Biol. Macromol. 12:295-6.
[10] Savant V. D. and Torres J. A. (2000) “Chitosan Based Coagulating Agent for Treatment of Cheddar Cheese Whey” Biotech Prog. 2000 16, 1091-1097, Department of Food Science and Technology, Oregon State University, Corvalis, Oregon 97331
[11] Shahidi F., Jeon Y. J., and Archchi J.K.V. (1999) “Food Application of Chitin and Chitosans” Trends in Food Science and Technology 10 (1999) 37-51
[12] Tripathi S., Mehrotra G.K., and Dutta P. K. (2008) “Chitosan based antimicrobial films for food packaging applications”, e- Polymers 2008, no.093, ISSN 1618-7229
[13] Waghchaure R.S., Khojare A. S., Jadhav A.B., Bobade H.P (2016) “Biopreservation of Indigenous Milk Products” in the Book ‘Recent Trends in Dairy and Food Processing’ Edited by Khojare A.S. Paithani Prakashan Aurangabad.
[14] Webber C. J. (2000). Biobased packaging materials for the food industry: Status and perspectives. The report of Food Biopack Project. The Royal Veterinary and Agricultural University, Frederiksberg C, Denmark. Retrieved from www.mli.kvl.dk/foodchem/special/biopack/.

Technical Article for Oral Presentation Article Code: OP-NT-02

Advancement and Application of Automation Technique in Process Engineering

Chitranayak*, J. K. Dabas, Amita D. Vairat, Khushbu Kumari, Pavan Kumar, Ankit Deep
Dairy Engineering Division, ICAR-NDRI, Karnal

1.0 Introduction:

In the method of automated evaluation of food quality various sensors and supporting equipments are required and they all should be in proper synchronization starting from sensing the process variable to be evaluated up to the final display of the numerical values of the process variable. Often, evaluation detects component adequacy and documents mechanical, chemical, and microbiological changes over the shelf life of food items. Both qualitative and quantitative evaluation can provide the basis for determining if a food product meets target specifications. This quality information also provides feedback for adjustments to processes and products needed to achieve target quality. There are two methods for evaluation of food quality. One is subjective, based on the judgment of human evaluators. The other is objective, based on observations excluding human evaluators' opinions. Subjective methods require the human evaluators to give their opinions regarding the qualitative and quantitative values of the characteristics of the food items under study. These methods usually involve sensed perceptions of texture, flavour, odour, colour, or touch. However, even though the evaluators are highly trained, their opinions may vary because of the individual variability involved. Sensory panels are a traditional way to evaluate food quality. Although highly trained human evaluators are intelligent and able to perceive deviation from food quality standards, their judgments may not be consistent because of fatigue or other unavoidable mental and physical stresses. The output of food quality evaluation is the primary basis for establishing the economic value of the food products for farmers, manufacturers, and consumers, and it can be useful for quality control of food products. Because traditional manual quality control is time-consuming, can be error prone, and cannot be conducted in real time, it has been highly desirable for the food industry to develop objective methods of quality evaluation for different food products in a consistent and cost-effective manner. The objective methods of food quality evaluation are based on scientific tests rather than the perceptions of human evaluators. They can be divided into two groups:

1. Physical measurement methods are concerned with such attributes of food product quality as size, texture, colour, consistency, and imperfections. There are several sensors adapted for the physical evaluation of food product quality.
2. Chemical measurement methods test for enzyme, moisture, fibre, pH, and acidity. In many cases, these tests can be used to determine nutritive values and quality levels.

The development of computer and electronics technologies provides strong support to fast, consistent signal measurement, data collection, and information analysis. The greatest advantage of using computer technology is that once the food quality evaluation systems are set up and implemented, the system will perceive deviation from food quality standards in a consistent way and not experience the mental and physical problems of human evaluators. Another major benefit of using computer technology in food quality systems is that it is possible to integrate a large number of components to automate the processes of food quality evaluation. This automation can result in objective, fast, consistent food quality evaluation systems, a significant advancement for food engineering and industry. In the past twenty-twenty five years, electronics and computer technologies have significantly pushed forward the progress of automation in the food processing industry. Research, development and applications of computerized food quality evaluation and automatic control of various process variables such as, temperature, pressure, humidity, flow, consistency and viscosity etc. have been accomplished time after time during the period and further, much advancement have also been taken place in the overall food processing technology simultaneously.

Fig.1.1: HMI (Human Machine Interface) for process control

These recent advancements in the technology of automatic process control (APC) minimized the human interventions, due to which the chances of contamination have been reduced drastically in the processed food items. At the same time the shelf life of the processed food items have also been increased due to these technological advancements in the processing techniques. Automation or automatic control can be defined as the use of various control systems for operating equipment such as machinery, processes in factories, boilers and heat treating ovens, switching in telephone networks, steering and stabilization of ships, aircraft and other applications with minimal or reduced human intervention. Some processes have been completely automated. The biggest benefit of automation is that it saves labour; however, it is also used to save energy and materials and to improve quality, accuracy and precision. The term *automation*, inspired by the earlier word *automatic* (coming from *automaton*), was not widely used before 1947, when General Motors established the automation department. It was during this time that industry was rapidly adopting feedback controllers, which were introduced in the 1930s. Automation has been achieved by various means including mechanical, hydraulic, pneumatic, electrical, and electronic and computers, usually in combination. Complicated systems, such as modern factories, airplanes and ships typically use all these combined techniques. One of the simplest types of control is *on-off* control. An example is the thermostats used on household appliances. Electromechanical thermostats used in HVAC may only have provision for on/off control of heating or cooling systems. Electronic controllers may add multiple stages of heating and variable fan speed control.

1.1 Instrumentation and measurement systems in a food processing plant

Apart from the instrument characteristics, construction and working, it is pertinent to understand the various ways in which the measuring instruments are put into use in food processing. Different classification of applications of the instruments and measurement system in a food processing plant are as follow:

i) Monitoring a process / operation,
ii) Control a process / operation and
iii) Experimental engineering analysis

1.2 Basic elements in the measurement and process control system

1. The *primary element* or the *Transducer Element* that senses and converts the desired input to a more convenient and practicable form to be handled by the measurement system.
2. *The Signal Conditioning* or Intermediate Modifying Element for manipulating/processing the output of the transducer in a suitable form.
3. The *end device* i.e. the *Data Presentation Element* for giving the information about the measurement or measured variable in the quantitative form.

The transducer element senses and converts the desired input to a more convenient and practicable form. The input variable could be pressure, acceleration or temperature and the output may be displacement, voltage or resistance change depending on the type of transducer element. It converts the input physical variable to usable form, mostly in the form of electrical signal. It senses and converts the desired input to a more convenient and practicable form to be handled by the measurement system, which further is modified by the conditioning element. Finally, the results are shown and presented by the data presentation element for giving the information about the measurement or measured variable in the quantitative form.

2.1 Automatic Process control (APC)

The industrial processes need certain variables such as temperature, consistency, flow, level or pressure and concentration, remain at or near some reference value (set-point). The reference value or the set-point is a value for a process variable that is desired to be maintained during the entire processing duration. The system that serves to maintain a process variable at the set point is called controller which is the part of a control system. A process variable is a condition of the process fluid that can change the manufacturing process in some way. In an automatic process control (APC) system, controller performs the basic operation used by many systems providing regulation or command to the process variable to be controlled. Goal of control is to determine the value or state of some physical quantity and often to maintain it at that value, despite variations in the system or the environment.

Basic objectives of *automatic process control (APC):* Mainly there are four basic objectives of automatic process control (APC) in the food processing, which are as under:

(i) Suppressing the influence of external disturbances,
(ii) Optimizing the performance,
(iii) Increasing the productivity and
(iv) Cost effective

Principles of automatic process control (APC): Most processes will perform well and efficiently only when the values of certain process variables are held within given limits. Theses process variables will change unless energy or material input equals output. Thus the fundamental function of process control is to manipulate the energy (or material) input to output relationship so as to keep the process variables within desired limits. An automated controller can be defined as a mechanism that measures the values of a process variable and operates to limit the deviation of that variable for desired value. A process variable that is held within limits termed as controlled variable. The automatic controller regulates the controlled variable by correction to another variable of the process which is termed as the manipulated variable.

Here, dynamic or controlled variable is the temperature of the hot water. The desired value is the desired hot water temperature. The manipulated variable or controlling variable is the rate of steam flow. Any change in steam value opening as dictated by the automatic controller comprises a correction to the manipulated or controlling variable. Thus, it is possible to hold or change the output hot water temperature by manipulating the balance of energy input to energy output as shown in the fig.2.1.

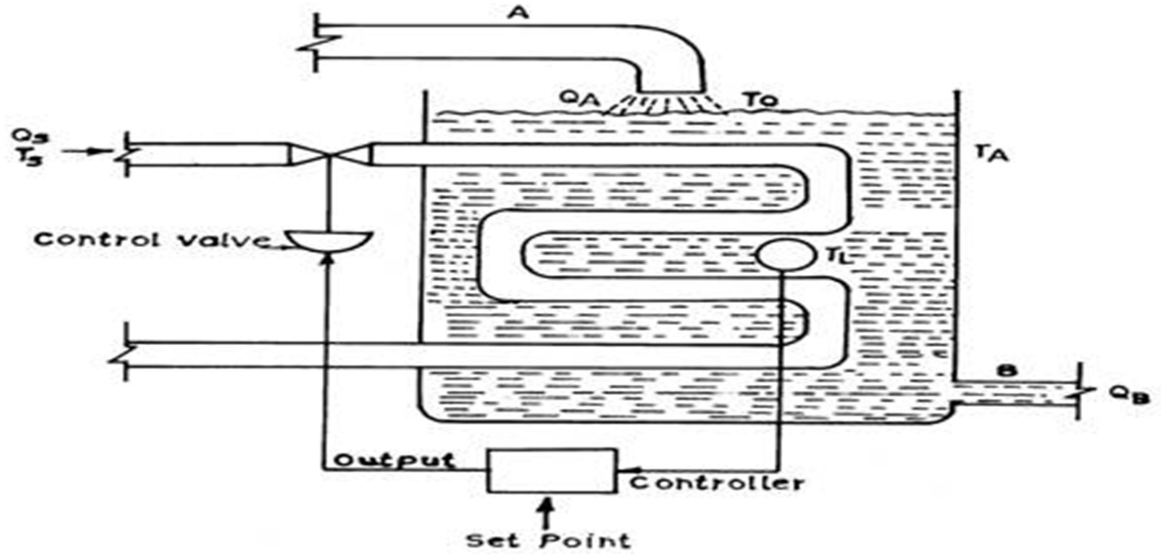


Fig.2.1: Automated hot water temperature control system

2.1.1 Types of Control System

Mainly there are two types of control system:

1) Open-loop systems and
2) Closed-loop systems

The *open-loop system* is also called the non-feedback system. It utilizes an actuating device to control the process directly without using feedback as its block diagram is shown in fig.2.2. Gas geyser, electric geyser etc. used for heating of water are few examples of open-loop control system. This is the simpler of the two systems. However, since it is not possible to achieve desired accuracy of control of the parameter and its use is limited in the industry. In open- loop control system there is only a forward action from the input to the output.

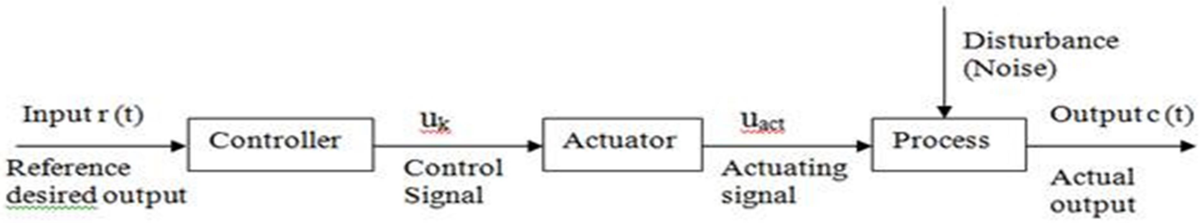


Fig.2.2 Block diagram of an open loop control system

The *closed-loop system* is also called the feedback system. Feedback control system is to control the process by using the difference between the output and reference input. A closed-loop control system uses a measurement of the output and feedback of this signal to compare it with the desired output (reference or command). Usually, the output, as measured by the sensor is subtracted from the input (which is the desired output). That forms an error signal that the controller can use to control the process as shown in the fig.2.3.

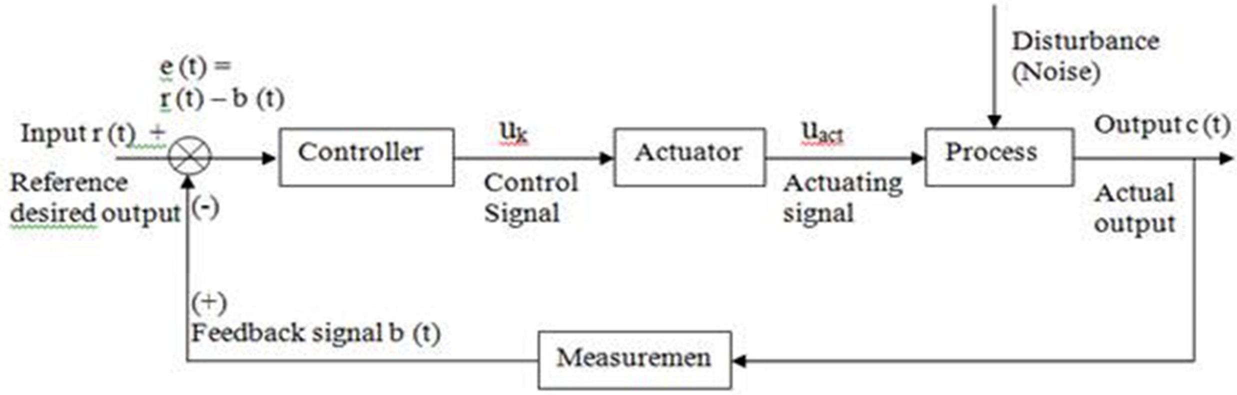


Fig.2.3: Block diagram of a closed loop control system

In the *automatic process control (APC),* four basic elements are normally involved:
(i) Process,
(ii) Measurement,
(iii) Evaluation (with a controller) and
(iv) Control element.

The term *Process* as used in relation to *process control* refers to the methods of converting raw materials into the end product(s). In general, a measurement refers to the transduction of the variable into some corresponding *analog* of the variable, such as a pneumatic pressure, an electrical voltage, or current. Further transformation or *signal conditioning* may be required to complete the measurement function. The result of the measurement is a transformation of the dynamic variable into some proportional information in a useful form required by the other elements in the process-control loop. The evaluation consists of a *comparison* of the controlled variable measurement and the set point and a determination of action required to bring the controlled variable to the set point value. The *correcting* or *final control element* is the part of the control system that acts to physically change the manipulated variable. This element accepts an input from the controller, which is then transformed into some proportional operation performed on the process. In any process control loop, final control elements are typically used to correct a variable that is out of set-point.

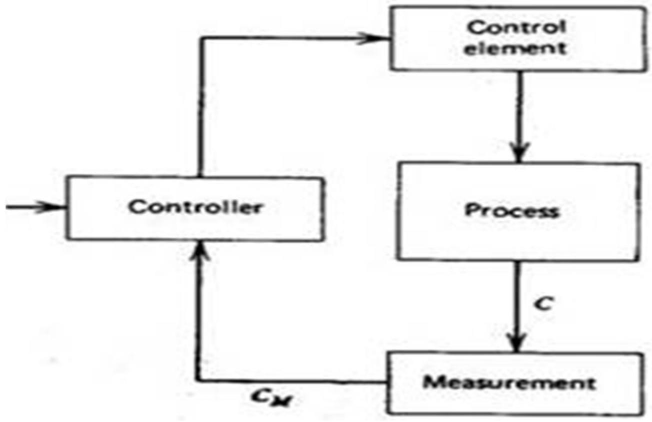


Fig.2.4: Basic Elements of Generalized Process Control

2.1.3 Control system parameters:

A control system monitors and determines a difference between a desired and measured parameter values, applies a weighting factor to the difference and selects a control strategy based on the weighted difference. The weighting factor generally reflects the confidence in the accuracy of the parameter value determined by the parameter monitor. The weighting factor may be determined based on one or more ambient operating conditions or parameters, or on statistical analyses of monitor values and/or control system parameter values. These are error, variable range, control parameter (output) range, control lag and dead time. Several aspects must be considered when designing a dairy. Therefore, the final production solution of a plant is always a compromise between product-related, process-related and economic aspects, in which external demands on the plant must be satisfied. These external requirements relate to factors such as legislation, type and amount of product, product quality, hygiene, production availability, flexibility, labour and economy. The product-related aspects include raw materials, product treatment and quality of the end product, while the process-related aspects include selection of process equipment to satisfy external demands. Even if the processing units in a plant are chosen primarily to achieve the stated product quality, various compromises must be made, particularly if many

different products are to be manufactured. Such considerations apply, for example, to the cleaning requirements of the equipment and its suitability for connection to the proposed cleaning system. Compromises must also be made on other matters, such as the consumption of energy and service media, and the suitability of the equipment to be controlled. When selecting process equipment, it is important to remember that the process control solution should also be considered.
Correctly applied process control, in which a thorough knowledge of products processes and process equipment guides the design, has many advantages. The most important advantages of automation are:

- Food safety
- Consistent product quality
- Reliability
- Production economy
- Flexible production
- Production control
- Traceability

Food safety is secured by the control system through the continuous supervision of equipment and processes. A malfunctioning machine will be brought to a safe status if a serious fault occurs, and a process fault will stop the related process. This system ensures the prevention of unwanted mixing of products, overfilling of tanks and other faults, which might cause product losses and production disruptions. The process is monitored in exactly the same way during each production run, which means that the finished product will always have the same high quality after fine-tuning of all processing variables for an optimum outcome. Precise control of the process means that product losses and consumption of service media, cleaning solutions and energy are kept to a minimum. As a result, the production economy of a well-designed and adapted control system is very good. Flexible production can be achieved by programming the control system with various production alternatives and production recipes. Changes in production can be implemented simply by altering a recipe, instead of modifying the actual program. The control system can also provide relevant production data and information in the form of reports, statistics, analyses, etc. The data becomes a tool for more precise management decisions. A plant design is always a compromise between: Product, Process, Economy and the External factors.

Control levels
The following definitions have been adopted to describe the level of control in the system:

- Manual control
- Unit control and supervision
- Line control and supervision
- Production management

Manual control: All operations in the plant are carried out manually. Control modules are manually operated, but normally they are started or stopped from panels with push buttons, with no interlocking function. Some single valves, such as the diversion valve in a manual pasteurizer, may be automatically controlled, but the plant or line is still considered to be manual.

2.1.4 Controller modes
The method used by the controller to correct the error is the control mode. Controller modes are an expression of relation between controller output and dynamic variable deviation from the set point. The actions of controllers can be divided into groups based upon the functions of their control mechanism. Each type of controller has advantages and disadvantages and meets the needs of different applications. Grouped by control mechanism function, the two types of controllers are: Discontinuous controllers, continuous controllers and combined controllers.

1. Discontinuous controller mode
2. Continuous controller mode: In this mode there is a possibility of smooth variation in control parameter and the controllers automatically compare the value of the process variable to the set-point to determine if an error exists. If there is an error, the controller adjusts its output according to the parameters that have been set in the controller. When there is an error, the controller makes a change in its output. It determines:
How much? – (A) Proportional Mode,
How long? – (B) Integral Mode and
How fast? – (C) Derivative Mode

3. Composite Control Modes
Due to offset error, proportional mode is not used alone. Similarly, integral and derivative modes are not used individually in practice. Thus, to take the **advantages of various modes together**, the composite

control modes are used. Composite modes of controller operation combine advantages of each 'pure' mode. The various composite control modes are:

1. Proportional + Integral mode (PI)
2. Proportional + Derivative Mode (PD)
3. Proportional + Integral + Derivative Mode (PID)

Proportional Integral Derivative (PID) Controller (Three Mode Controllers)

The three mode controller uses proportional, integral and derivative **(PID)** action and is the **most versatile** of all controller actions. The proportional part of this controller multiplies the error by a constant. The integral part integrates the error. Finally, the derivative part differentiates the error. The functions of the individual proportional, integral and derivative controllers complement each other. If they are combined it is possible to make a system that responds quickly to changes (derivative), tracks required positions (proportional), and reduces steady state errors (integral). The output of the controller is the sum of the previous three signals as given in the following equation:

$p(t) = K_p\ e(t) + K_p\ K_i \int e(t)\ dt + K_p\ K_d\ \ + p(0)$

Where, K_p, K_i and K_d are the proportional, integral and derivative gains respectively.

The proportional, integral and derivative terms must be individually adjusted or 'tuned' to a particular system.

Advantages

1. This mode eliminates the offset of proportional mode and provides the most accurate and stable control of the three controller types.
2. It is recommended in systems where compensation is required for frequent changes in load, set point, and available energy and can help to achieve the fastest response time and smallest overshoot

2.2. Final control elements:

Final control elements are devices that complete the control loop. They link the output of the controlling elements with their processes. The final control element is the last element of the closed control loop that implements the control action. It receives the output signal (control or actuating signal) from a process controller and adjusts accordingly the value of the manipulated variable by changing the amount of matter or energy entering the process in a way to bring the controlled variable (process variable) to its set point. The final control element is probably the most important because it exerts a direct influence on the process. This is accomplished by positioning valves or dampers, varying the speed of a pump, or regulating the current through electric heater. There are many options to a process control. Out of the final control elements, the most widely used in power plants are valves. Valves can be easily adapted to control liquid level in a tank, temperature of a heat exchanger, or flow rate. Control valves are the single most common type of final control element in process.

2.2.1 *Control valves and actuators*

***Control valves**:* A control valve is a valve with a pneumatic, hydraulic, electric or other externally powered actuator that automatically, fully or partially opens or closes the valve to a position dictated by signals transmitted from controlling instruments.

Types of Actuator: An *actuator* is the part of a final control device that causes a physical change in the final control device when signalled to do so. The most common example of an actuator is a valve actuator, which opens or closes a valve in response to control signals from a controller. There are *four* principal types of actuator: *Pneumatic, Hydraulic, Solenoid and Electric Motor.*

Pneumatic actuator with valve: The pneumatic valve is an air-operated device which controls the flow through an orifice by positioning appropriately a plug.

Hydraulic actuators: Pneumatic actuators are normally used to control processes requiring quick and accurate response, as they do not require a large amount of motive force. However, when a large amount of force is required to operate a valve (for example, the main steam-stop valves), hydraulic actuators are normally used. Hydraulic actuators use fluid displacement to move a piston in a cylinder positioning the valve as needed for 0-100% fluid flow.

Electric motor actuators: An electric motor is composed of a rotating centre, called the rotor and a stationary outside, and called the stator. These motors use the attraction and repulsion of magnetic fields to induce forces, and hence motion. Equipped with limit switches and/or torque limiters, the electric motor actuator has the capability of 0-100% control and has not only a motor but also a manual hand wheel, and a clutch and gearbox assembly. Most electric motor actuators are equipped with limit switches, torque limiters, or both. Limit switches de-energize the electric motor when the valve has reached a specific position. Torque limiters de-energize the electric motor when the amount of turning force has reached a specified value. The turning force normally is greatest when the valve reaches the fully open or fully closed position. This feature can also prevent damage to the actuator or valve if the valve binds in an intermediate position.

Electric solenoid actuators: Solenoid actuators are used on small valves and employ an electromagnet to move the stem which allows the valve to either be fully open or fully closed. A major advantage of solenoid actuators is their quick operation. Also, they are much easier to install than pneumatic or hydraulic actuators. However, solenoid actuators have two disadvantages. First, they have only two positions: fully open and fully closed. Second, they don't produce much force, so they usually only operate relatively small valves.

References:

[1] Chitranayak and M Manjunatha (2014), "Instrumentation and Process Control", Teaching-cum-practical manual, Southern Regional Station of ICAR-NDRI, Bangalore

[2] Chitranayak, M Manjunatha, IK Sawhney, Mahesh Kumar G., PS Minz, Amita Vairat and Pavan Kumar (2018), "Introduction and Basic Concepts of Instrumentation, Measurement and Process Control", Teaching-cum-practical manual, Dairy Engineering Division, ICAR-NDRI: Publication no. 160/2018, Karnal

[3] B C Nakra and K K Chaudhry (2009), "Instrumentation Measurement and Analysis", third edition, Tata McGraw Hill Education Private Limited, New Delhi

[4] Yanbo Huang, A. Dale Whittaker and Ronald E. Lacey (2001), "Automation for Food Engineering", CRC Series in contemporary food science, CRC Press LLC, Florida 33431, US.

[5] Ernest O Deobelin and Dhanesh N Manik (2011), "Deobelin's Measurement Systems", sixth edition, Tata McGraw Hill Education Private Limited, New Delhi

[6] Erika Kress-Rogers and Christopher J. B. Brimelow (2001), "Instrumentation and sensors for the food industry", second edition, CRC Press, WOODHEAD PUBLISHING LIMITED, Cambridge, England

[7] A. Hugi and E. Voirol (2000), "Instrumental measurements and sensory parameters", Nestle Research Centre, Lausanne

Technical Article for Oral Presentation Article Code: OP-NT-03

E-Sensing Technology: New Approach towards Artificial Sense

Ravi Prajapati[1]*, Shreyash Patel[2], Arun Patel[3], G. Gopikrishna[4], Ashish Shendurshe[5]
[1, 3, 4, 5] Assistant Professor, GN Patel College of Dairy Technology, SDAU-Dantiwada
[2]Assistant Professor, SMC College of Dairy Science, AAU-Anand

Abstract

Food testing and tasting is a critical task in the food manufacturing process. Food analysis includes qualitative and quantitative measurement of physical, chemical and microbiological parameters that can be easily sensed and measured. However, the sensory analysis of food materials varies from person to person which counts for a major lacuna in sensory analysis of food. Moreover, recruiting and maintaining an expert sensory panel is an additional investment. These limitations could overcome using E-sensing technologies. Such technology involves electronic sensors which measures the basic five sense of human and replaces the human discrepancy in food tasting. The major components of E-sensing technology are mainly E-nose, E-tongue, E-eye, E-ear and E-fork. These technologies are faster, precise and comparatively economical. Further, these technologies have high reproducibility and repeatability which required in case of routine analysis of food materials.

Key words: Metal oxide semiconductor (MOS), Nanocomposite, Mechanoreceptors

Introduction

Development of electronic systems from routine life activities of human to its industrial applications has already transformed our world. Immense attention given to E-sensing technologies owing to the possibility of electronic systems to solve tasks of a broad spectrum of applications in various industries i.e. food & beverage, plastics & packaging, flavours & fragrances, cosmetics, pharmaceutical industry and environmental sector. In food industry, electronic systems are used in the form of E-sensors for measuring various parameters of unit operations, research & development and quality control. Further, some electronic systems are being used from offset analysis via lab instruments to onset analysis of product at the production spot. Above that, sensory analysis is increasingly being supplemented by electronic system based sensory analysis. Electronic nose (E-nose), Electronic tongue (E- tongue), Electronic eye (E-eye), Electronic ear (E-ear) and electronic fork (E-fork) are the major electronic systems which are recognized for their wide applications as E-testing and E-tasting in the food industry.

The concept of electronic system can overcome the disparity of using human senses which varies from individual to individual. Along with inconsistency, it may sometimes be unpleasant or even dangerous tasks. In near future the sight, taste and smell sensors will be available to industries to incorporate into their own products, or for individuals directly (1). E-nose, E- tongue, E-eye, E-ear and E-fork replaces five human basic senses. Further, it detects odours or flavours, taste, colour, auditory signals as well as body and texture attributes, respectively. The major electronic systems with their concept of working, advantages, limitations and applications are discussed below:

1. Electronic nose (E-nose):

Electronic nose is an instrument designed to analyse odour and volatile organic compounds that are either gaseous or evaporated from liquid or solid surfaces of food materials. It is basically an array of non-specific chemical sensors, electronically analysed, which mimics the action of the mammalian nose by distinguishing patterns of response to vapours (2). Metal oxide semiconductor (MOS), conducting polymer, and surface acoustic wave (transducers) are the most common e-nose sensors (3, 4). Some sensors used as conduct metric chemical sensors which change resistance when exposed to vapours. These sensors are not specific to any one vapour; it is in the use of an array of sensors, each with a different sensing medium, that mixture of gases can be identified by the pattern of response of the array. The arrangement of sample testing setup for the proposed E-Nose system is schematically presented in **Figure 1**.

E-nose is a device that identifies the specific components of an odour and analyses its chemical make up to identify it. An odour stimulus generates a characteristic fingerprint from the sensory array. The fingerprint (or smell-print) is classified and identified with suitable pattern recognition engine for declaration of odour (5).

The system was tested with the smell of fruit samples in the breakers sealed with a cover. The set recipe (8051) was set in to testing or training mode in the program. If the system is in training mode, sensor value is shown on the LCD as Set value (SV). If the system is in testing mode, classification result of the target fruit is shown on the LCD as Present value (PV). The sensor array gets the gas through valve (V1), which is normally closed. The vacuum pump is turned on for predefined time to pump the gas out of the sensor array. The valve (V1) was closed and the sensor resistance was given time to reach a study state mode. The classification result of sensors characteristic value appeared on the LCD as Result. The sensor array chamber was disconnected from the fruit sample breaker and the valve (V1) was opened to turn fresh air, the valve (V2) was opened so that the smells were pumped out. The chamber was aired out with fresh air for quite a few minutes for next analysis (6).

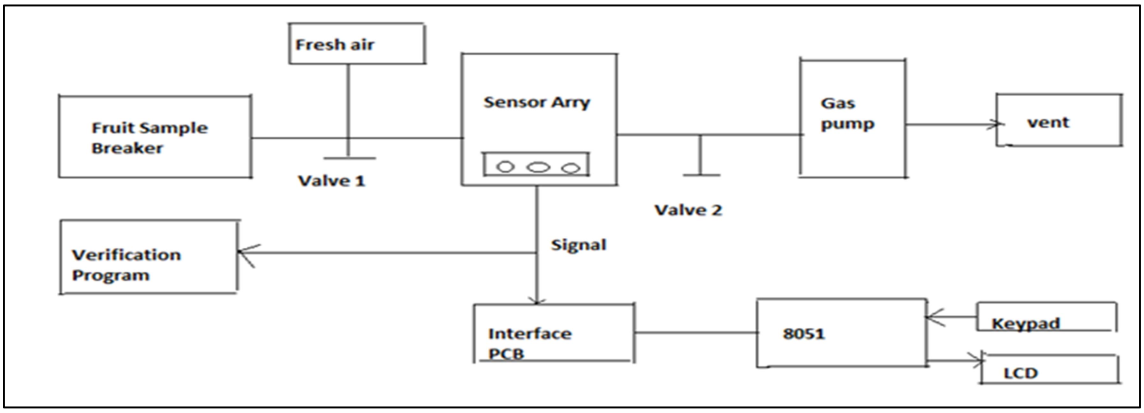


Figure 1. The diagram on of sample testing setup for E-Nose system (6)

Electronic noses have been established from several years but they are large and expensive. Hence, the use of such devices is limited. Current scenario is focused on comparatively small devices, cheaper and having more accuracy and precision during sensing.

Ramamoorthy (2014) has reported that electronic noses were at first used for quality control applications in the food, beverage and cosmetics industries (7). But, current application includes detection of odours specific to diseases for medical diagnosis, detection of pollutants and gas leaks for environmental protection. Now a day, E-nose can be useful tool for offset analysis of dairy and food products by their sensory analysis. Further, field applications of E-nose include the maturity check-up of seasonal fruits, tea quality tasting, decide cheese ripening stages and quality of edible oils can be determined using E-nose.

2. Electronic tongue (E- tongue):

The taste of food materials is one of the most important criteria which decide the acceptance of consumers towards the product. The taste can be electronically measured via E- tongue. The principle for the E-tongue is to combine signals from specific, non-specific and overlapping sensors with pattern recognition as described for the E-nose. For amperometric sensors there are four classes that includes metal, conducting polymer, phtalocyanine film and biosensors. Nanocomposite materials are in developing stage. Three different detection modes are described including fixed potential preferred in flow systems and for biosensors, step pulse potential and sweeping potential of which the last two are preferred in batch systems (8, 9). Further, Professor Fredrik Winquist of Linköping University, Sweden has invented the E-tongue that not only assesses basic tastes (sweet, bitter, sour, salty, umami) but also all other gustatory components (metallic, pungent, astringent, etc.). It can identify, classify and analyse the multi-component mixtures in a qualitative and quantitative way by comparing their mixture profiles with those of standards.

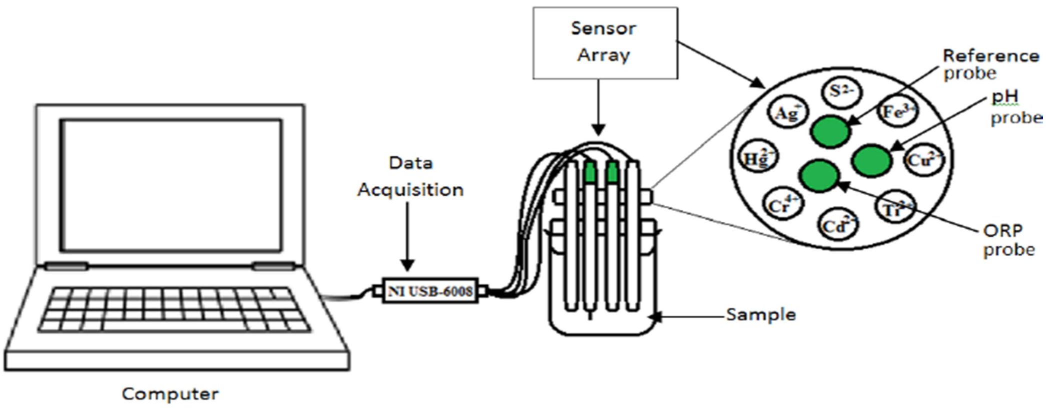


Figure 2. Setup for E-tongue system with data acquisition (10)

The main benefits of E-tongue are that it can also provide information related to microbial species classification, liquid properties and quality of food and water by employing different metals like rhodium, rhenium, platinum, palladium, iridium and gold as electrodes. But, effectiveness of E-tongue shall be better when E-tongue and E-nose are jointly used. The wide applications include classification of cultivars, tomatoes on the basis of various parameters mainly flavour, apples and apricots during storage. Further, to discriminate between freshwater and marine fish species, this technology is widely accepted. It is also used to monitor fermented milk and milk products. An experiment was conducted to discriminate honey on the basis of geographical and botanical origin via E-tongue, and can be used for other such commodities like milk, fish and meat, etc.

Generally combination of E-nose and E-tongue system is widely used for determination flavour and taste as they are finding fused as a group. E-nose and E-tongue system combined and set for dataset from both the sensor systems. The system is explained flow diagram (Figure-3). Due to the presence of innumerable chemical components, food classification is much more complicated problem than any other pure sample.

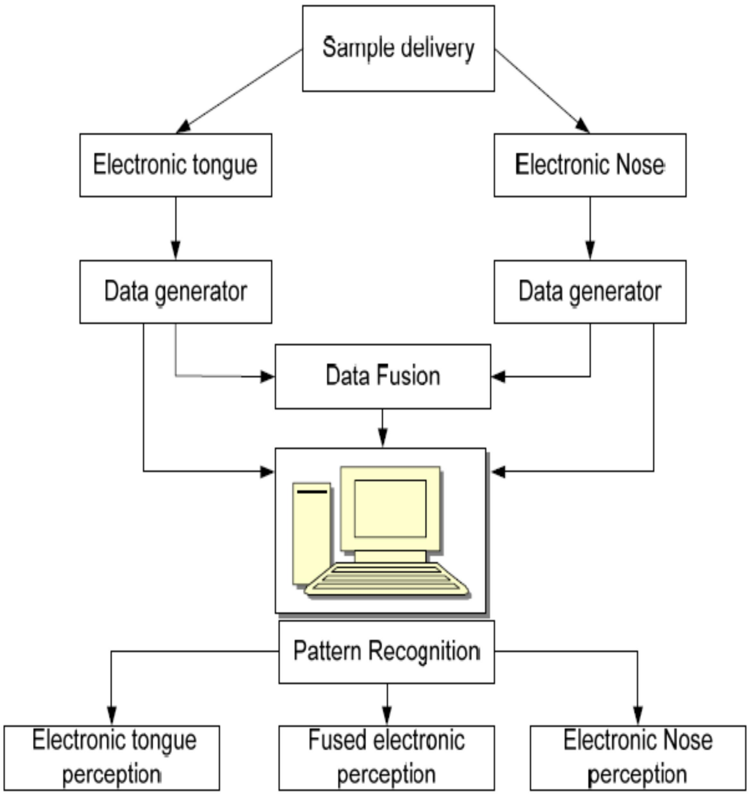


Figure 3: Flow diagram on working of combined System (11)

3. Electronic eye (E-eye):

The next sense which itself has got a significance in the recognition of food material via its colour is sight. The colour of food and other material can attract customers to accept the particular food product by creating interest in their mind. E-eye can be in the form of computer vision technology or image analysis or ultra-imaging technology and several others. Computer vision is a process that includes acquisition, processing and analysis of images captured during various stages of food handling. It also gives real time analysis of food material based on the logic created for progressive analysis. The main component of E-eye technology consists of five elements - lighting, camera, computer with software, and high-resolution monitor. The standard curves of food material can be drawn by pre-experimental analysis or are available off the rack, which are further used to compare the data obtained during time to time study (2). The similar technologies like image analysis, food scanning and ultra-imagining also works on the same principle but the work of action is either interior or exterior surface of food materials.

The advantages of E-eye include simple, easy to set up and real time monitoring. There is no reagent, pre- treatment of sample required when analysed. The testing gives high sensitivity, selectivity and rapid response as images can be captured within short span of time. Additionally, it can be possible to store the data, data acquisition and benchmarking with programmed software. But, the limitations are operating conditions need to be maintained (sampling procedure, air flow, temperature, humidity, lighting). The shape and size of sample are also important when the offset analysis is carried out. The potential applications of E-eye are quality testing of raw materials, especially the fruit deterioration during transportation and storage, end product judging by colour identification and proportionate mixing of ingredients based colour comparison. The cleaning efficiency of equipment surfaces can be examined using E-eye technology which avoids the microbiological and chemical testing and thereby reducing the cost and time saving.

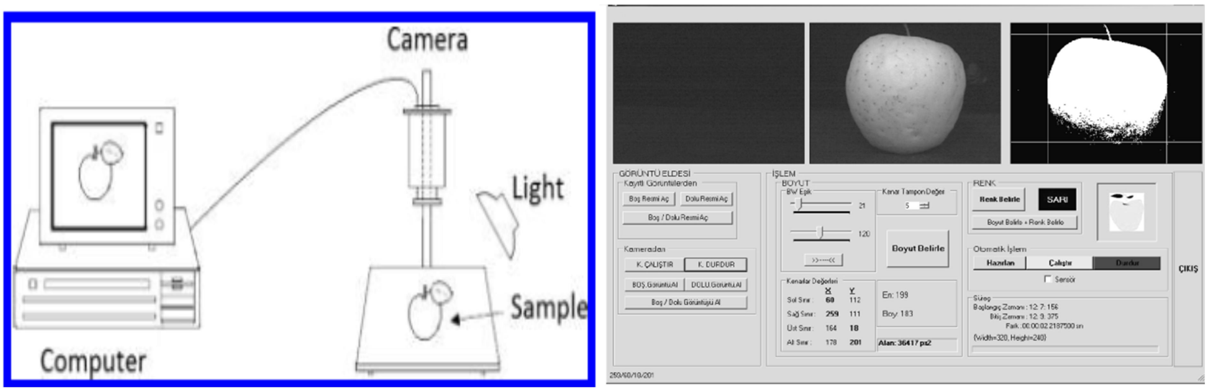


Figure 4-5: Diagram and sample observation of E-eye System (12, 13)

4. Electronic ear (E-ear):

E-ear is less likely to be used singly. However, the role of E-ear is sound recognition. The ear can be jointly used for analysing the textural parameters in combination with E-tongue. It works on principle that the food material when crushed or bitted between the involuntary jaws, the material crushing sound can be recorded with respect to its firmness, chewiness, hardness and other textural properties. It is similar to Instron- Textural Profile Analyser. However, the parameter of measurement is sound waves instead of mechanical force. Acoustic sensors replace the work of mechanoreceptors of human body which responds to the movement, pressure, and tension in the E-ear.

The advantages of E-ear are simple working, high accuracy and precision. The limitations can be conditioning of surrounding environment is compulsory, hearing threshold limit shall be pre-defined, data conversion and amplification is also required during the measurement.

The probable applications include quality analysis of food having textural uniqueness. The major examples here are the crispy noise heard when consuming potato crisps or sponge fingers, or the crunching of biscuits, Vienna-type sausages or chocolate, when pieces are bitten off (14). Furthermore, combine assessment of E-ear and E-nose gives an idea about the sensory quality of food which are having high moisture content and their textural properties varies in wide range.

5. Electronic fork (E-fork):

The food materials have sensory attributes like odour, flavour, colour and appearance, body and texture which direct the consumers to accept one product over another. From all these attributes, major attributes could be sensed and analysed by the above discussed four devices. However, researchers have built a device that imparts the food a salty taste, but without actually adding the salt. A battery powered fork electrically shocks taste buds to stimulate the taste of salt, as well as sourness and different food textures. According to Hiromi Nakamura It is a technology that allows electricity to be used as seasoning. It works with soft electrical current which is then sent to the tongue (1). E-fork appliance is not used singly; instead the combination of E-fork with other electronic devices can give better results.

The advantages of such tool are smaller size, variety of range and require small power to operate. However, it must be used in the combination with other such electrical device. The applications include the body and texture analysis of various solid and semi solid materials. It also helps to measure the secondary sensory properties like gumminess, chewiness, etc.

Current Scenario of E-senses

E-sensing technologies used globally for analysis of food and agriculture products. These technologies are comparative economic and have high degree of precision in results. Different supplier with their instrumental working with advance applications has been listed below;

E-Sense	System working & Technology	Technology / Instrument Suppliers	Food applications
E-nose	An array of non-specific chemical sensors which deliberately analyse odour and volatile organic compounds via GC or GLC.	HERACLES Flash GC-Alpha MOS, Toulouse, France., HIGUCHI INC.	Odour, smell and aroma sensing of volatile and semi-volatile compounds in food
E- tongue	Electronically measures the combine signals from specific/non-specific sensors with pattern recognition.	Norlab, Finland, HIGUCHI INC. ASTREE- Alpha MOS, Toulouse, France.	Testing the food taste for five basic taste of the food and analysis

E-eye	Measurement of colour, shape and size and accordingly compare with reference and std. curve	DigiEye System- United Kingdom, Hunter Lab Reston, VA. Konica Minolta Sensing Americas-USA,	Colour, size and shape including internal structure of food
E-ear	Sound recognization via acoustic sensors in combination with tongue.	Food Tech Corp, Virginia	Crispiness and chewiness and sound when food is consume
E-fork	Analysing the textural parameters by physical work and compare with std. results	INSTRON, Brookfield, DUH- Shimandzu	Body and texture analysis of various solid and semi solid materials

Conclusion and future prospects

The development of artificial sensing technologies replaces human exertion during testing and tasting. The technologies are used widely, with established ability to differentiate basic tastes of food and other materials. The working process of such technologies are rapid, have high sense of reproducibility and repeatability. Further, the use of novel food sensors in such technologies plays a significant role in the detection and identification of contaminants during the food manufacturing processes and can monitor the process flow throughout. In future, "in-line" or as "stand-alone" sensors can be integrated in conjunction to Wi-Fi technologies and could be used for real-time transmission of data with alarms and/or test results to remote servers. The comparable technologies can likewise customize with latest intervention and innovation which will extend the effectiveness of technology.

References

[1] Bhajekar, D., Ghosh, D., Halde, P., Basu, A. (2018) E-testing and e-tasting : the frontiers of food safety, Commemorative Edition, FSSAI: Regulatory and Legislative Framework (inner-page/1/)
[2] Ramasamy, R., (2018), *E-Sensing Techniques in Food Quality Analysis.* Technical presentation in Department of Sensory Science, CSIR-CFTRI
[3] Deisingh, A. K., Stone, D. C., & Thompson, M. (2004). Applications of electronic noses and tongues in food analysis. *International journal of food science & technology*, *39*(6), 587-604.
[4] Ghasemi-Varnamkhasti, M., Mohtasebi, S. S., Siadat, M., & Balasubramanian, S. (2009). Meat quality assessment by electronic nose (machine olfaction technology). *Sensors*, *9*(8), 6058-6083.
[5] Chaudhari, P. R., & Judal, A. L. (2015). Sensory Instruments and Its Application in Dairy and Food Industry.
[6] https://www.elprocus.com/electronic-nose-work.
[7] Ramamoorthy, H. V., Mohamed, S. N., & Devi, D. S. (2014). E-nose and e-tongue: Applications and advances in sensor technology. *Journal of NanoScience and NanoTechnology*, *2*(1), 370-376.
[8] Baldwin, E. A., Bai, J., Plotto, A., & Dea, S. (2011). Electronic noses and tongues: Applications for the food and pharmaceutical industries. *Sensors*, *11*(5), 4744-4766.
[9] Scampicchio, M., Ballabio, D., Arecchi, A., Cosio, S. M., & Mannino, S. (2008). Amperometric electronic tongue for food analysis. *Microchimica Acta*, *163*(1-2), 11-21.
[10] Zakaria, N. Z. I., Masnan, M. J., Shakaff, A. Y. M., Zakaria, A., Kamarudin, L. M., Yusuf, N., & Aziz, A. H. A. (2013, December). Electronic Flavour Assessment Techniques for Orthosiphon Stamineus Tea from Different Manufacturer. In Proceedings of the 2013 IEEE Conference on Wireless Sensor (ICWISE), Kuching, Malaysia (pp. 2-4).
[11] Roy, R. B., Modak, A., Mondal, S., Tudu, B., Bandyopadhyay, R., & Bhattacharyya, N. (2013). Fusion of electronic nose and tongue response using fuzzy based approach for black tea classification. *Procedia Technology*, *10*, 615-622.
[12] Tonguç, G. and Yakut, A. K. (2009). Fruit Grading Using Digital Image Processing Techniques. *Tarım Makinaları Bilimi Dergisi*, *5*(1).
[13] Sliwinska, M., Wisniewska, P., Dymerski, T., Namiesnik, J., & Wardencki, W. (2014). Food analysis using artificial senses. *Journal of agricultural and food chemistry*, *62*(7), 1423-1448.
[14] Ralf-André, W., Lisa, D., Bianca, SH., (2015) DLG-Expert report 3/2015: Instrumental sensory testing in the food industry. PP- 3

Technical Article for Oral Presentation Article Code: OP-NT-04

Rheology Applied to Development of Dairy Products

Subhash Prasad[1]*, Ankit Deep[2]
[1]College of Dairy Science, Kamdhenu University, Amreli, Gujarat
[2] Dairy Engineering Division, ICAR-NDRI Karnal

Introduction:

Food rheology is the science that studies the solids deformation and the liquids fluidity by the influence of applied mechanical forces. Food rheology parameters are directly related to the acceptance of the final product by consumers. For these reasons, the rheology is an important analytical tool to evaluate dairy products quality. However, owing to the complexities of the product texture, progress made in this regard is rather limited. Nevertheless, recent developments in rheological instruments hold out a definite scope for generating valuable information on the basic rheological parameters of dairy products. In dairy products, the rheological proprieties can be influenced mainly by three factors, raw material quality; type and characteristics of ingredients used; and the technological process.

Methodology:- Rheological properties of dairy product are done by Texture Analyser (model TA XT Plus, Stable Micro Systems Ltd.,UK), available instrument's at C.D.S., Amreli (Fig.1).

Fig.1 TA XT Plus, Stable Micro Systems Machine.

Rheological characteristics of Dairy products mainly cream, butter, cheese, *dahi*, ice-cream and frozen desserts, paneer, and *chhana* & *khoa* based Indian sweets are characterize through various textural attributes like hardness, adhesiveness, springiness, cohesiveness, gumminess and chewiness of the dairy products by Texture profile analysis (TPA) shown in Fig 2.

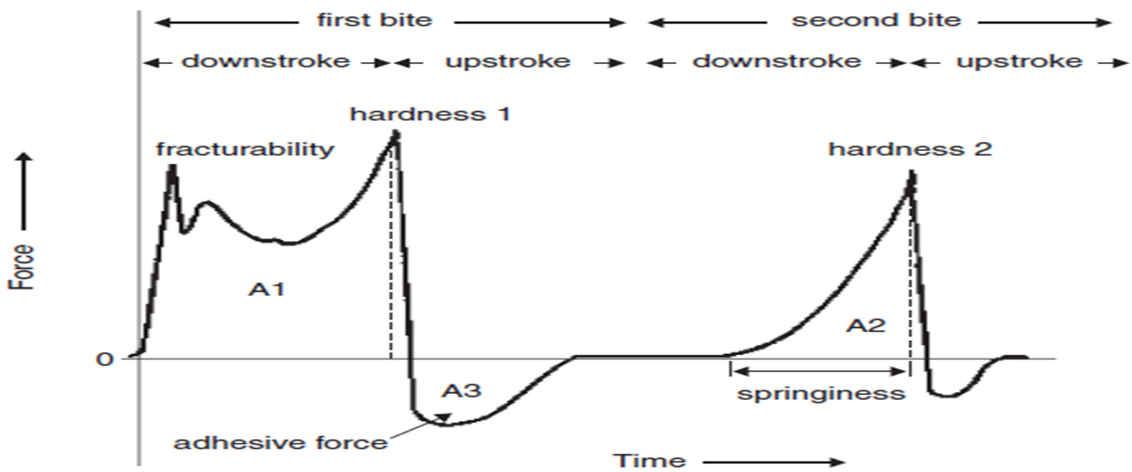


Fig.2 Generalized Texture Profile Analysis (TPA) curve by TA-XT Plus, Stable Micro Systems.

Texture profile Analysis (TPA) is originally carried out using double-bite compression tests (Fig. 2). In practice, force (stress) and deformation (strain) are the two fundamental parameters for texture characterization.

Hardness (N): The force necessary to attain a given deformation, i.e. the highest point of peak in the first bite curve.

Brittleness (N): Force with which the sample crumbles crakes or shatters.

Adhesiveness: It is the work necessary to overcome the attractive forces between the surfaces of the sample and the other materials with which sample come in contact. It is negative force area for the first bite curve. Adhesiveness = A_3

Cohesiveness: The extent to which a material can be deformed before it ruptures

Cohesiveness = A_2/A_1

A_1 = Area under the first bite curve before reversal of compression

A_2 = Area under the second bite curve before reversal of compression

Springiness (mm): The height sample recovers between the first and second compression, on removal of the deformation force

Gumminess (N): It is the energy required to masticate a sample to a state ready for swallowing a product of hardness and cohesiveness

Gumminess **=** Hardness x Cohesiveness

Chewiness (N-mm): It is the energy required to masticate a sample to a state ready for swallowing. It is a product of hardness, cohesiveness and springiness

Chewiness = Hardness x Cohesiveness x Springiness.

Results:

The rheological and textural characteristics evaluation of dairy products can be applied for selection of raw materials and process type, beyond the quality control of the final product. In cream, the rheological behaviour is similar to emulsions and suspensions in general. Both can exhibit Newtonian or non-Newtonian behaviour depending on the composition, conditions or processes to which it may be subjected [1]. The fat content has a greater effect on dairy rheology i.e. products with high concentration of fat have different behaviours. The milk protein mainly casein also influences the viscosity of dairy products.

The butter is a dairy derivative which may be defined as an emulsion of water droplets in a semisolid matrix of milk fat. The milk fat matrix is mainly responsible for the texture of butter, consisting of a three-dimensional network of fat crystals enmeshed in a liquid oil medium. Beside fat, temperature and other related factors such as moisture SNF, salting, ripening etc. have been found to influence the rheological behaviour of butter. The processing parameters in conjunction with the physical properties or milk fat in butter govern the structure of butter (believed to be a dispersion of fat globules and aqueous phase in a continuous phase of liquid fat) which is responsible for the typical rheological behaviour of the butter. Rheology measurements of butter are important from two main points, Spreadability of butter as a functional texture attribute (Fig. 3), and its pump ability or handling convenience.

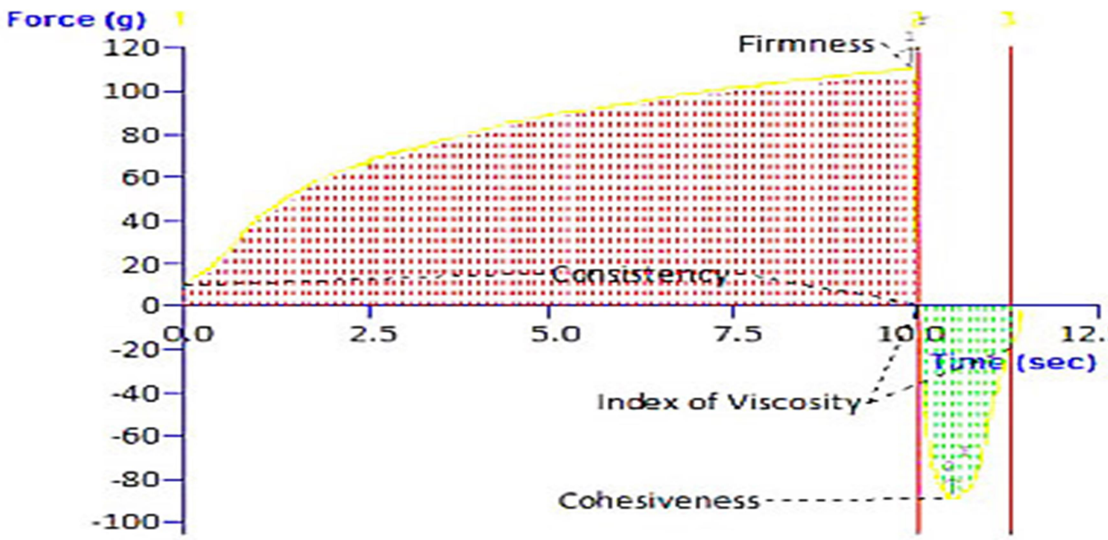


Fig.3:- Spreadability of butter

The most relevant factor in this connection is the high temperature coefficient for the consistency of this 'plastic' product, which necessarily needs to be stored under refrigeration in plants or in homes. The most common parameter that is sought to be measured by those methods is hardness of the product. Other less important texture measurements made on butter include its stickiness, oiliness and brittleness.

Cheese is a composite material. Its major constituents para-casein, fat and the aqueous phase, contribute each in a specific way to the structure and hence to the rheology of cheese. The para casein matrix imparts the product solidity though formation of 3-dimension structure. Thus composition is among the most important factors influencing cheese rheology. The moisture, fat and protein contents are major compositional variables in cheese. Fat is a key contributor of the temperature-caused variation in the rheological properties of cheese.

Fermented milk, as *dahi*, exhibits a viscoelastic behaviour and highly time-dependent shear thinning behaviour, presenting a complex rheology. Its rheological behaviour depends on the concentration, composition, and pre-treatment of the milk, starter culture and incubation conditions [4]. The fermentation process of also influences the rheological behaviour mainly when are used strains that produce exopolysaccharides can be used to increase the viscosity of the *dahi* and decrease susceptibility to syneresis. Measurement of rheological properties allows the characterizing and predicting the effects of variables involved in the manufacturing process on the sensory aspect of the final product, especially its texture [2].

The ice cream consists in a dispersion of milk fat and vegetable fat in an aqueous phase containing non-fat milk solids, carbohydrate sweeteners, and a stabilizer (usually a hydrocolloid). It is thus essentially a dilute oil-in-water emulsion and in this aspect, is similar to cream. However, it presents viscosity and rheological behaviour variable, because they depend on both mix formulation and processing conditions [2]. The ice cream is a frozen dairy product consumed in the frozen state; therefore the freezing and whipping processes are factors that considerably influence the development of the desired structure, texture, and palatability [3]. Stabilizers, as polysaccharides, are one such ingredient, which, in spite of the low level in the formulation, impart specific and important functions to the finished ice cream, influencing its texture and acceptability.

Paneer is widely used in all vegetable dishes as well as for preparation of special foods, which requires having textural properties. The control of processing parameters during manufacture of paneer like temperature, pressure of press, control of pH, chilling and freezing during storage etc. are critical parameters, which requires study of its effect on the textural properties of paneer.
Chhana is basic ingredient of *chhana* based Indian sweets like *rasogolla* and *sandesh*. Textural attributes of *chhana* made from cow and buffalo milks are given in table 1.

Table-1: Texture Profile Properties of Chhana

Attributes	Cow milk *chhana*	Buffalo milk *chhana*
Hardness, mN	11.60	19.50
Cohesiveness	00.59	00.67
Springiness, mm	03.60	05.00
Gumminess, mN	06.48	13.06
Chewiness, mN. mm	24.64	65.32
Adhesiveness mN	00.35	00.38

It is evident that all the textural values were less for cow milk *chhana* compared to that of buffalo milk *chhana*. The secondary parameters such as gumminess and chewiness for buffalo milk *chhana* were more than two times to those values for cow milk *chhana*. However there was not much difference between cow milk and buffalo milk *chhana* as for as the adhesiveness was concerned.

Rasogolla is an Indian traditional dairy product, stored and served in sugar syrup. In size and shape it resembles a ping-pong ball. It is snow white in colour, possesses a spongy, chewy body and smooth texture. Texture of *rasogolla* depend upon Moisture and fat content in *chhana*, Sugar syrup concentration for cooking and soaking and time and temperature for cooking.
Textural attributes of *rasogolla* are shown in table-2 & TPA curve of cow milk *rasogolla* in Fig. 4.

Table- 2: Texture profile properties of rasogolla

Attributes	Cow milk rasogolla	Buffalo milk rasogolla
Hardness, mN	05.85	16.82
Cohesiveness	00.61	00.70
Springiness, mm	04.80	06.40
Gumminess, mN	03.57	12.17
Chewiness, mN. mm	17.15	77.88

As the consequence of higher hardness and springiness in buffalo milk *rasogolla*, their gumminess and chewiness values also increased remarkably than that of cow milk *rasogolla*. No adhesive force, however, has been recorded for either of the *rasogolla*.

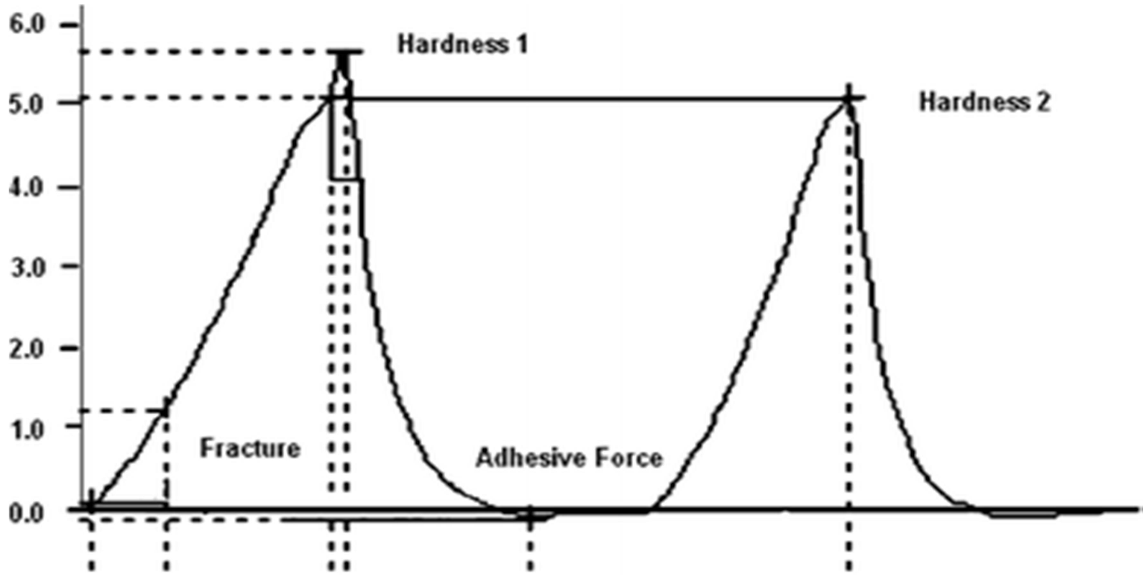


Fig.4: Typical TPA Curve of cow milk *chhana* based *rasogolla*.

Sandesh is the oldest and most popular sweet in our country because of its high palatability. It is popular in West Bengal and some parts of Assam, Myanmar, Orissa and Tripura and other parts of India. TPA of *sandesh* (Fig.5) were analysed using Texture Analyser (TA.XT plus texture profile analyser, Stable Micro Systems, UK).

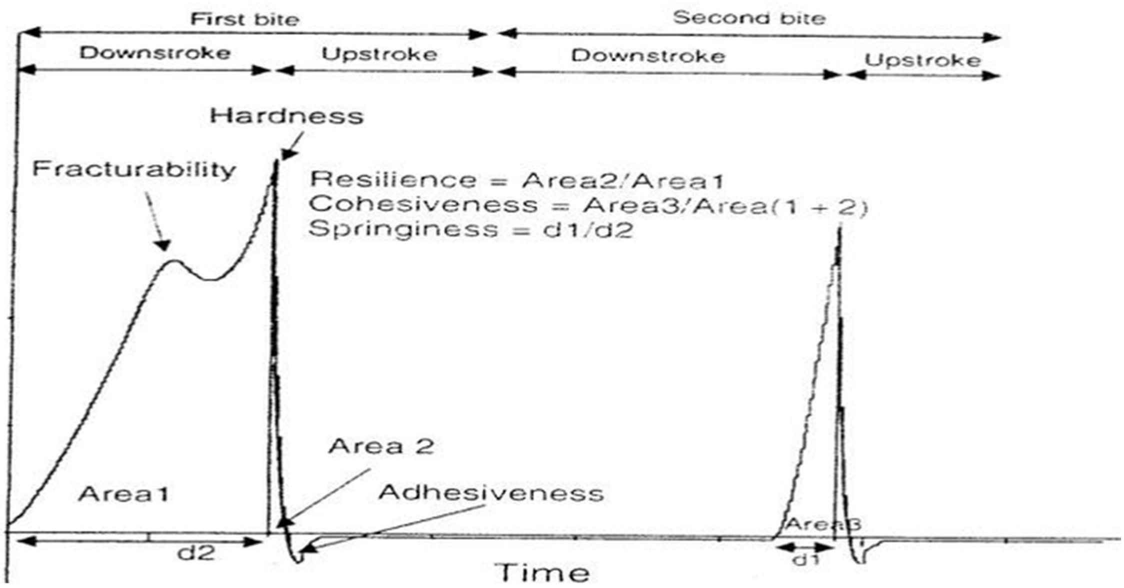


Fig.5: Typical TPA Curve of *Sandesh*

Khoa, also called *Mawa*, is a food product indigenous to India, prepared by partial dehydration of milk. The milk is boiled in an open pan while the pan walls are being manually scraped using a blade. The evaporation process is terminated when the dehydrated milk becomes semi-solid. Texture of *Khoa* plays an important role in its suitability for the production of sweets. *Pindi Khoa* (26-34% moisture) has a smooth-grained texture and a firm body and is extensively used as an ingredient [5], where these properties are important, as for example, in *Peda*.

Texture profile parameters of *Peda* determined as a function of composition have been studied and Texture Profile Analysis (TPA) hardness has been found to exhibit a significant correlation with the corresponding sensory attribute of the product (Fig.6).

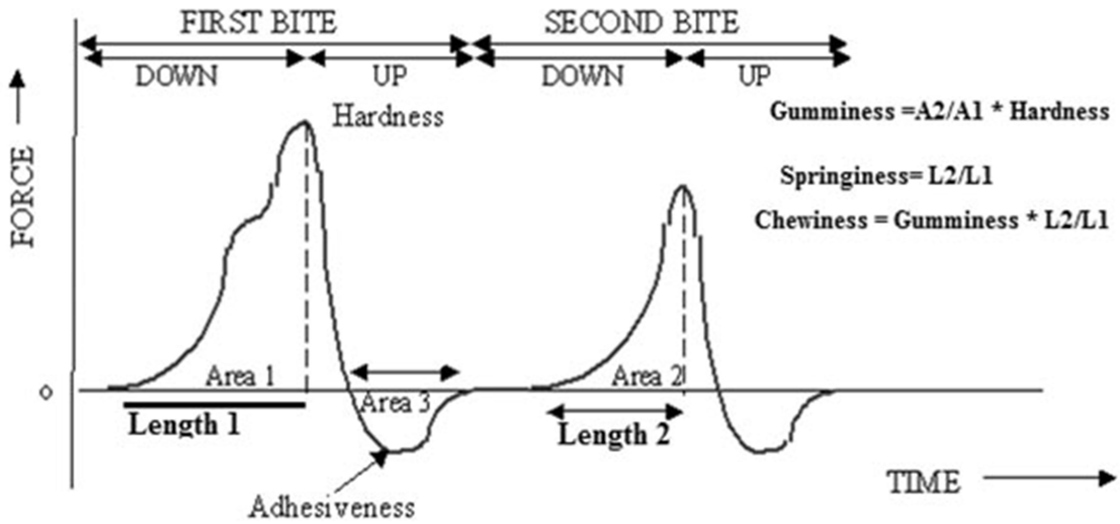


Fig.6 : TPA of *Peda*

Conclusion:-Rheological properties interfere with the final dairy product and how the steps in the manufacturing process significantly influence these derivatives. Thus, we perceived how each stage, from beginning to end of production is important to obtain a final product with rheological characteristics compatible with the type of dairy products.

References:-

[1] McCarthy OJ (2011) Rheology of liquid and semi-solid milk products. Elsevier.

[2] McCarthy OJ (2011) Rheology of liquid and semi-solid milk products. Elsevier.

[3] Bahramparvar M, Tehrani MM (2011) Application and functions of stabilizers in ice cream. Food Rev Int 27: 389-407.

[4] Delgado KF, Frasao BS, Costa MP, Conte-Junior CA (2017) Different alternatives to improve rheological and textural characteristics of fermented goat products: A review. Rheol Open Access 1: 1-6.

[5] Rajorhia GS, Srinivasan MR. (1979). Technology of Khoa- a review. *Indian J. Dairy Sci.* 32(3), 209-216.

MANUFACTURES OF PREMIUM QUALITY PRODUCTS UNDER THE BRAND NAME "White Star"

- GHEE AGMARK SPECIAL GRADE
- SKIMMED MILK POWDER ISI MARK
- WHITE BUTTER
- PANIR

AND BULK SUPPLIER OF
PASTURISED MILK

WHITE STAR MILK & MILK PRODUCTS

85-A, Industrial Area No.1
A.B.Road, DEWAS (M.P.) 455001
Phone :- 9425919289 | E- Mail : wsdairy@yahoo.in

VED Engineering

ISO 9001:2008 CERTIFIED COMPANY

COMPLETE TURN KEY SOLUTION FOR

DAIRY , BEVERAGE , FOOD & PHARMA INDUSTRY

CUP FILLING MACHINE

CUP FILLING MACHINE IS SUITABLE FOR FILLING FLUIDS LIKE DAHI / LASSI / MILK / JUICE / YOGHURT / WATER & NON CARBONATE BEVERAGE WITH CAPACITY 1200 , 2000 , 3000 CPH. IT ALSO AVAILABLE MANUAL , SEMI AUTOMATIC & FULLY AUTOMATIC TYPE.




ICE CREAM FILLING MACHINE

ICE CREAM CUP - CONE FILLING MACHINE FOR 2400 CUPS / CONES PER HOUR. AUTOMATIC MACHINE WITH STATION FOR SYRUP & CHOCLATE SPRAY , NUTS ADDITION , PENCIL INSERTION IN CONE.

PASTEURIZATION SYSTEM

PASTEURIZATION SYSTEM RANGING 300 LPH TO 20,000 LPH SUITABLE FOR MILK , CREAM , DAHI , PANEER , JUICE , & BEVERAGE.THIS SYSTEM IS OFFERED WITH TUBLAR HOLDING RANGING FROM 20 SEC. TO 10 MIN. DEPENDS ON APPLICATION. IT IS ALSO PROVIDED PRECISE OUTPUT TEMP. COMTROL OF THE PRODUCTS.



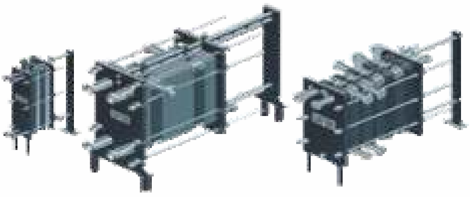


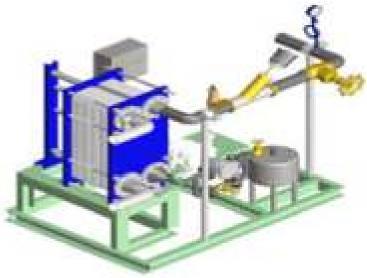
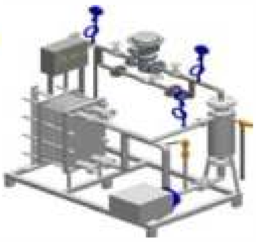
PLATE HEAT EXCHANGER

PHE USED FOR HEATING / COOLING OF MILK , CREAM , ICE CREAM MIX , SUGAR SYRUP , JUICE MIX , BEVERAGES , SODA WATER , PHARMA CHEMICALS & FOOD PRODUCTS.

CLEAN-IN PLACE

CLEAN-IN PLACE (CIP) SYSTEM USED TO CLEAN THE PIPELINES & EQUIPMENT USING CIRCULATION OF HOT WATER , LYE & ACID AFTER EVERY SHIFT OF PROCESSING PRODUCT.



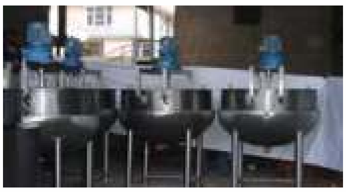



HOT WATER GENERATON SYSTEM

FOR SUPPLY HOT WATER AT PRECISE TEMP. USED FOR HEATING OF PHARMA SOLUTION , MILK , CREAM , JUICE , SUGAR SYRUP , BEVERAGE , CHEMICAL SOLUTION , SWIMMING POOL & HOT WATER SUPPLY TO HOTE & HOSPITAL.


INSULATED & DIMPLE JACKETED TANK

USED FOR HEATING / COOLING OF DAIRY , BEVERAGE , FOOD , PHARMA PRODUCTS WITH REGULAR AGITATION WITH OPTIONAL PROCESS AUTOMATION FOR MAINTANING THE TEMP. OF FLUID.

HEMISPHERICAL TANK

USED FOR HEATING / COOLING PRODUCT IN SMALL QUANTITIES ALONG WITH REGULAR AGITATION. IT CAN ALSO BE USED FOR DIRECT HEATING OF PRODUCT USING STEAM.

STORAGE & SILO

USED TO STORING LEQUID PRODUCTS ; AVAILABLE IN MANY SHAPES : VERTICAL , HORIZONTAL & CYLINDRICAL ; OPEN TOP & CLOSED TOP ; FLAT BOTTOM ,CONE BOTTOM , SLOPE BOTTOM & DISH END BOTTOM. SUPPLY WITH MANHOLE , LIGHT & SIGHT GLASS , AIR VENT THERMOWELL , DEEP STICK CALIBRATION etc.

B-38 , SECTOR - 60 , NOIDA (U.P) - 201301 , INDIA
PHONE : +91-120-2580507 / 2584659

MOBILE : +91-9350545986 / 9971934240
E-MAIL : info@vedengineering.com
sagar@vedengineering.com

web : www.vedengineering.com

Technical Article for Oral Presentation Article Code: OP-NT-05

Antioxidant Activity of Orange Peel Powder in Ghee at Accelerated Temperature

M.Manjunatha[1], Chitranayak[2] and Mahesh Kumar G[3]
[1]Associate Professor, Agril Engg, UAS, Bengaluru; [2]Senior Scientist, ICAR-NDRI, Karnal; [3]Head, Dept of Dairy Engg, DSC, Hebbal

Abstract
Study an antioxidant potential of orange peel powder in ghee was conducted. Orange peel powder (1, 1.5 and 2%) was added in to butter and prepared ghee and stored for accelerated storage study at 60±2°C. Ghee with BHA (0.02%) and control (without any additives) were also prepared, stored and analysed for comparison during the study. Peroxide value and thiobarbuturic acid (TBA) of ghee samples stored at accelerated condition (60°C±2) were analysed at 4 day interval during 16 day storage period. Peroxide value and thiobarbuturic acid (TBA) were observed to increase in all the samples with highest in the control. Increase in peroxide value was least in the sample treated with 2% orange peel powder whereas the sample treated with BHA was observed with lowest increase in TBA value. The sensory data revealed that all the treated samples were in acceptable range and liked very much by panellist with sensory score of slightly above 8 and the score was close to control. Orange peel powder may be added to ghee as natural antioxidant for reducing oxidative deterioration of fat in ghee.

Introduction
India is the largest milk producer in the world and producing about 176 million tonnes per annum. About 35% of total milk production is converted in to ghee. Ghee is subjected to continuous and frequent heating for the purpose of cooking and frying of various food products. Shelf life of ghee is about 6 to 10 months depending up on the packaging and storage conditions. If not stored in recommended packaging under storage condition it undergoes oxidative degradation processes. Oxidative degradation processes include hydrolysis, oxidation and polymerisation followed by the formation of desirable and undesirable secondary products which affects both, ghee and finished product quality. Ghee oxidation affects major quality parameters resulting in poor consumer acceptance due to formation of undesirable end products in the oxidised ghee. There are numerous literatures which demonstrate lipids oxidisation leading to negative health implications. Lipid oxidation produces rancid odours, unpleasant flavours and discolouration decreases the nutritional quality and safety. Lipids and fat oxidation can be retarded or prevented by using antioxidants. More often synthetic antioxidants such as butylated hydroxytoluene (BHT), butylated hydroxyanisole (BHA), *tert*-butyl hydroquinone (TBHQ) and propyl gallate (PG) are used to retard oxidative deteriorations. The addition of antioxidants is a method of extending the shelf life, especially of lipids and lipid containing foods. Currently synthetic antioxidant BHA is permitted to prolong the shelf-life of ghee and in recent years there is a growing restriction in use of these synthetic AOAs in foods as these are inappropriate for chronic human consumption, suspected to be carcinogenic effects and pose toxic effects on human health and the environment. Therefore, the importance of search for natural antioxidants, especially of plant origin, has immensely increased in recent years. India is the largest producer of fruits and vegetables and huge quantity of by-products is being generated during their processing. These by-products of fruits and vegetables were proved to be potential sources of natural antioxidants. The by-products (powder or extract) of fruits containing natural antioxidants can be incorporated into fat rich dairy products like ghee for enhancing shelf-life and maintaining nutritional and sensory quality. Orange constitutes about 60 % of the total citrus world production. A large portion of this production is addressed to the industrial extraction of citrus juice which leads to huge amounts of by-products, including peel and segment membranes. Orange peel represents between 50 to 65% of total weight of the fruits and remains as the primary by product. Orange peel is underutilized though it is good natural source of bioactive compounds. Orange peel is reported to be a potential source of bioactive compounds including antioxidants. Therefore, the present work was undertaken to study the antioxidant potential of orange peel powder in ghee.

Materials and Methods
Peeled peels were separated from fruit and sliced to reduce size for faster drying. The sliced pieces were dried under oven. Dried peels were ground by mixer to obtain fine powder. The powder was immediately packed in low density polyethylene (LDPE) packaging and stored in deep freezer to preserve the antioxidant properties of powder for further use. Ghee was prepared using fresh cream (50% fat). Ripen cream was subjected to churning process using mixer. While mixing/churning of cream, ice water was added to maintain the temperature of about 15-17 °C. Churning was done in mixer for few minutes to get butter. Orange peel powder was added to butter and heated (clarification) for 15 min and butter was removed off the flame burner as soon the temperature reached 115°C. The clarified ghee filtered and stored for analysis. The ghee samples added with different levels of orange peel powder was compared control (ghee without addition of orange peel powder). Ghee samples (control without adding any antioxidants, orange peel powder and BHA) were prepared. Orange peel powder was added to butter @ 1, 1.5 and 2% by ghee weight and prepared ghee. BHA was added to butter @ 0.02% (maximum

recommended limit) by ghee weight. Ghee without any added antioxidants was considered as control. Required number of treated samples and control were prepared using conical flasks covered with stoppers and stored for analysis at 60±2°C. Stored ghee samples were analysed at different storage intervals for antioxidant properties. Peroxide value of ghee samples were determined by the method as described in IS:3508(1966). TBA values of ghee samples were determined as per the standard. Nine point hedonic scale was followed for sensory evaluation. Sensory panellists were asked to score the samples from 1 to 9 [1=dislike extremely; 2=dislike very much; 3=dislike moderately; 4=dislike slightly; 5=neither like nor dislike; 6=like slightly; 7=like moderately; 8=like very much; 9=like extremely].

Results and Discussion

Preliminary sensory evaluation of ghee added with different levels of orange peel powder

Mean values of sensory attributes of ghee samples (control, added with OPP and BHA) are tabulated in the Table 1. It is clear from the Table 1 that the ghee samples added with 1% orange peel powder (OPP) was scored highest scores for colour, aroma, taste and overall acceptability (OA) than all other treated samples except control. Sensory attributes of OPP 1% were very close to the sensory attributes of control. The OA of ghee sample with 1% OPP was highest among all the samples. Colour, aroma, taste and overall acceptability (OA) values of ghee added with 2% orange peel powder (OPP) were 8.1, 6.7, 7.3 and 7.7 and these values were more than the ghee samples added with 4 to 12 % orange peel powder (OPP) but very close to the ghee added with 1% orange peel powder (OPP). On the basis of preliminary sensory study OPP (1, 1.5 and 2%) was added in to butter and prepared ghee and stored for storage study. Ghee with BHA (0.02%) and control without any additives were also prepared and stored for comparison during the study. Antioxidant properties of OPP and BHA in ghee were analysed and compared with control during the study.

Table 1: Mean values of sensory attributes of ghee added with OPP and BHA

Treatment	Colour	Aroma	Taste	OA
Control	8.5	7.7	8.2	7.6
OPP (1%)	8.4	7.7	8.1	8.0
OPP (2%)	8.1	6.7	7.3	7.7
OPP (4%)	6.9	6.2	6.6	6.7
OPP (8%)	6.6	5.6	6.6	7.1
OPP (12%)	6.0	5.3	5.8	6.3

OPP: Orange peel powder; OA: Overall acceptability

Effect of orange peel powder and BHA on development of peroxides in ghee at accelerated storage temperature 60±2°C

The experimental data on peroxides due to lipid oxidation in ghee treated with orange peel powder and BHA in comparison with control ghee samples on the peroxides development are presented in the Table 2.

Table 2: Peroxide values (millimoles of oxygen per g of fat) of ghee samples stored at 60±2°C

Treatment	Storage period, days				
	0	4	8	12	16
Control	0.0082	0.1511	0.3282	0.4678	0.5239
OPP (1%)	0.0000	0.0286	0.0820	0.2371	0.3689
OPP (1.5%)	0.0000	0.0205	0.0574	0.2213	0.3531
OPP (2%)	0.0000	0.0123	0.0572	0.2130	0.3192
BHA (0.02%)	0.0000	0.0206	0.0739	0.2382	0.3688

OPP: Orange peel powder; OA: Overall acceptability

The peroxide value was zero in all the treated ghee samples and the control was observed with slight development of peroxides on zero day. Development of peroxide was observed after 4 days in all the samples. Highest peroxide was observed in control whereas lowest was in the sample treated with 2% OPP followed by 1.5 % OPP, BHA, and 1% OPP the. Similar trend was observed up to 12 days of storage. On 16th day storage, 2% OPP continued show less development of peroxides whereas control showed with highest increase in peroxides. Samples treated with 1.5 % OPP, 1% OPP and BHA showed increase in peroxide but more or less similar peroxide value in these samples.

Effect of orange peel powder and BHA on development of thiobarbituric acid value in ghee at accelerated storage temperature 60±2°C

The thiobarbituric acid (TBA) values (expressed as O.D. at 532 nm) of ghee samples treated with OPP and BHA tabulated in the Table 3.

TBA values in control were more as compared to the treated samples. The OPP treated samples showed more TBA values than sample treated with BHA which may be due to interference of more color from the orange peel powder during clarification rather than development of red chromophore because development of red coloure complex results from the condensation of 2 moles of TBA and 1 mole of malondialdehyde. TBA test indicates the secondary products developed on lipid oxidation. Thioabarbituric acid reacts with malondialdehyde produced by lipid hydroperoxide decomposition to form a red chromophore with peak absorbance at 532 nm. It is coloured complex phenomenon results from the condensation of 2 moles of TBA and 1 mole of malondialdehyde, under the joint effect of the medium temperature and pH, though it is the quantity of malondialdehyde (in mg) present in 1 kg of sample. The first is that malondialdehyde only forms from fatty acid chains containing at least three double bonds, like linolenic acid, to the exclusion of linoleic and oleic acid peroxide decomposition products. Secondly, TBA is not specific to malondialdehyde because it can react with other aldehydes, browning reaction products, protein and sugar degradation products, amino acids and nucleic acids.

Table 3: Thiobarbituric acid value of ghee samples stored at 60±2°C

Treatment	Storage period, days				
	0	4	8	12	16
Control	0.063	0.088	0.131	0.206	0.343
OPP (1%)	0.029	0.034	0.039	0.059	0.090
OPP (1.5%)	0.031	0.035	0.046	0.063	0.105
OPP (2%)	0.035	0.036	0.049	0.084	0.109
BHA (0.02%)	0.030	0.033	0.038	0.053	0.089

OPP: Orange peel powder; OA: Overall acceptability

Effect of orange peel powder and BHA sensory quality of ghee at accelerated storage temperature 60±2°C

The sensory score of the treated and control ghee samples is presented in the Table 4. All the samples have scored more than 8 in terms of colour, flavour, taste (except BHA) and overall acceptability (OA). Samples treated with BHA, 2% OPP and BHA have scored less for colour, flavour and taste, respectively. Sample treated with 1% OPP had scored highest sensory score overall acceptability than all other samples.

Table 4 Effect of orange peel powder and BHA sensory quality of ghee at accelerated storage temperature 60±2°C

Treatment	Colour	Flavour	Taste	OA
Control	8.38	8.38	8.33	8.17
OPP (1%)	8.38	8.38	8.17	8.33
OPP (1.5%)	8.25	8.25	8.33	8.17
OPP (2%)	8.38	8.00	8.00	8.17
BHA (0.02%)	8.13	8.13	7.83	8.17

OPP: Orange peel powder; OA: Overall acceptability

Conclusion

Development of peroxide value and thiobarbuturic acid (TBA) was less in ghee samples added with orange peel powder at accelerated condition (60°C±2) than BHA. The sensory data revealed that all the treated samples were in acceptable range and liked very much by pane list with sensory score of slightly above 8 and the score was close to control. The experimental data revealed that orange peel has got antioxidant potential and orange peel powder may be added to ghee as natural antioxidant for reducing oxidative deterioration of fat in ghee.

Technical Article for Oral Presentation Article Code: OP-NT-06

Effect of Sodium Tripolyphosphate and Sodium Hexametaphosphate on Quality Properties of Buffalo Milk Protein Concentrate 60 (MPC60) Powder

Ankush Shinde[1], Ganga Sahay Meena[2*], Sanket Borad[2], Jyoti Handge[1], Mina Nath Giri[1], Ashish Kumar Singh[3]

[1]M. Tech Scholars, [2]Scientist, [3]Principal Scientist, Dairy Technology Division, ICAR-NDRI, Karnal

Abstract

Milk protein concentrates (MPCs) powders are being used as an ingredient in several food formulations. Because of higher calcium and casein contents, MPC powders produced from buffalo milk have poor solubility that restricts its wider use in different food formulations. This investigation was aimed to produce MPC60 powder from buffalo milk with improved solubility through the addition of sodium tripolyphosphate (STPP) and sodium hexametaphosphate (SHMP) salts. Its effect on other physicochemical, reconstitution and functional properties; morphological and rheological behaviour of manufactured powder was also investigated. Ultrafiltration (UF) significantly increased ($p<0.05$) total solids (TS), protein, ash, fat and calcium contents in 2.53×UF retentate having 0.62 protein to TS ratio, but significantly decreased ($p<0.05$) its heat stability than skim milk. The applied intervention markedly improved the solubility of treated powder. Interstitial air, occluded air contents, loose, packed and particle densities; flowability, solubility, water and oil binding capacity, foam capacity and stability, heat coagulation time and, viscosity values of produced STPPSHMP-MPC60 were determined and compared with control MPC60 powder sample. Specific surface area (m^2/kg), particle size distribution (d_{50}), De Broukere (D_{43}) mean values (µm) of manufactured STPPSHMP-MPC60 were determined using Mastersizer while scanning electron microscopy was used to study the morphology of treated powder. Different rheological models were used to study the rheological behaviour of treated powder.

Keywords: Buffalo milk, Milk Protein Concentrate 60, solubility, sodium tripolyphosphate, sodium hexametaphosphate, physicochemical, functional, microstructure.

1. Introduction

The demand for Milk Protein Concentrates (MPC) as a source of high quality protein is growing rapidly owing to its nutritional and functional potential. About 900 different products were launched in market in year 2011 using MPC and milk protein isolate (MPI) as one the key ingredient. Milk Protein Isolates are another class of protein rich milk powders which have protein content much higher than in MPC. Milk protein powders with protein content lesser than 90% on dry matter basis (DM basis) are termed as 'MPC', while those with protein content ≥ 90 %, termed as MPI. These powders differ significantly from skimmed milk powder (SMP) and whole milk powder (WMP) in terms of their proximate composition, physico-chemical and functional properties. High quality caseins and whey proteins are present in MPC, in the identical ratio as naturally present in fresh milk.

Ultrafiltration process is widely used for the preparation of good quality MPC. Either skim milk or micro filtered milk is used as raw material for the manufacture of MPC. Skim milk is heat treated (e.g. 70-75°C/10-20 s) to remove the undesirable microorganisms and inactivate enzymatic action followed by concentration of milk proteins in UF plant up to desired level. During UF process, the high molecular weight components like casein, whey protein, micellar salt and residual fats are concentrated and remain at the retentate side, while the low molecular weight components like, soluble lactose, salt and non-protein nitrogen are removed into the permeate. Once the required protein to TS ratio is achieved in the UF retentate, it is subsequently subjected to the spray drying.

Definite standards for proper identification of MPCs are still not available worldwide. The present classification of MPCs is similar to the existing classification of whey protein concentrate (WPC) powders i.e. MPC56, MPC70 and MPC85; the associated number represents the protein content of that particular MPC on DM basis. Although variations in protein content of MPC are present, Sikand *et al.,* (2011) broadly categorized these powders into three main types: (a) low-protein powder (≤ 40% protein content), (b) medium protein powder (60–70% protein content) and, (c) high-protein powder (≥80% protein content). Most common MPC includes MPC 42, MPC 70, MPC 80, and MPC 85.The increase in protein content of the MPCs is indirectly proportional to the lactose and mineral content i.e. protein purity is enhanced by decreasing the content of lactose and mineral salts in MPCs during ultrafiltration and diafiltration of skimmed milk.

High protein ingredients market that was earlier dominated by casein, caseinates and other dairy products is presently being driven by MPCs owing to their high nutritional and functional properties. It is a new class of dairy based protein rich ingredient in market and rapidly gaining popularity globally. The

U.S. produced about 45,900 mt of MPC in year 2013 to meet domestic demand. USA import imported 55.0 mt of MPCs (Lagrange et al., 2015). Presently, New Zealand is the top producer and exporter of MPC followed by European Union (EU). It has been estimated that production of MPCs will grow more than 40000 mt by year 2020 and the same will expand its market volume by displacing casein in specific applications (Agarwal et al., 2015).

Most of the literature on MPC powders advocates the use of cow milk for its production. However, information pertaining to the use of buffalo milk for manufacturing MPC is scanty. In countries like India where buffalo milk represents 53% of the total milk produced, MPC manufacturing using buffalo milk offers tremendous market opportunity (Patil et al. 2018). However, utilization of buffalo milk for MPC is challenging owing to its different chemical makeup than cow milk. Recently, Patil et al., (2018) have produced and characterized buffalo milk based milk protein concentrate 60 (BM-MPC60) powder. However, its solubility was about 67% only which is markedly lower than SMP, WMP and even cow milk based MPC60. Type of milk (chemical composition) and undesirable changes occurring in milk proteins during skim milk ultrafiltration and spray drying of retentate are mainly responsible for poor solubility.

In dairy industry, various calcium binding salts such as citrate, polyphosphate or pyrophosphate have been used to influence colloidal calcium phosphate and also to improve heat stability of micelles. Sodium hexametaphosphate (SHMP) and disodium hydrogen phosphate (DSP) have been reported to improve the quality of evaporated milk, processed cheese and calcium enriched milk (Udabage, 2001). However, changes induced by addition of SHMP and sodium tri polyphosphate (STPP) in buffalo milk UF retentate on various properties of resultant MPC60 powder has not been studied so far and the same has targeted in this investigation.

2. Materials and Methods

2.1 Materials

Fresh raw buffalo milk of morning shift was collected from Cattle Yard of ICAR-National Dairy Research Institute, Karnal, India. It was subjected to cream separation. Different components i.e. total solids (TS), protein, fat, lactose, ash, total calcium and pH of skim milk were determined. It was pasteurized (72°C/ 15 s) to get pasteurized buffalo skim milk (PBSM). All chemicals used in the investigation were procured from Sigma Aldrich, St. Louis, MO, US.

2.2 Ultrafiltration of PBSM and addition of SHMP and STPP salts in UF retentate

This PBSM was concentrated to desired concentration factor (ratio of initial feed weight to weight of final retentate) or folds during UF process using a pilot UF plant (Tetra Alcross M1, Tech-Sep, France); at 50±1°C and 1.0 kg/cm^2 transmembrane pressure to achieve desired protein to TS ratio (Meena et al., 2017; Patil et al., 2018). A salts mixture consisting SHMP and STPP was then added in UF retentate. Permeate flux (L/m^2/h- LMH) was directly recorded from the flow meter equipped with the UF plant.

2.3 Production of MPC60 powder

A pilot scale spray drier (Jektron Pvt. Ltd. Pune, India; atomizer rpm–22000) was used to spray dry 2.530×UFR maintaining 200±5°C inlet air and 95±5°C outlet air temperatures. The powder thus obtained was named as STPPSHMP MPC60 powder (STPPSHMP-MPC60), packed and stored at 4±1ºC until analysed. The powder was prepared and analysed in triplicates (Fig 1).

2.4 Methods

2.4.1 Compositional analysis

Total solids, protein, fat and ash were determined using standard AOAC methods (AOAC, 1998). Calcium content of the samples were analysed in atomic absorption spectrophotometer (AAS, Model No. AA-7000, Shimadzu, Kyoto, Japan). The pH of the samples was measured according to the method given by Meena et al., (2018).

2.4.2 Determination of physical and reconstitution properties

Standard methods earlier reported by Jha et al., (2002); Meena et al., (2018) and Patil et al., (2018) were used to determine different physical properties such as interstitial air content (IAC, mL/100 g powder), occluded air contents (OAC, mL/100 g powder), particle density (PD, g/mL), loose bulk density (LBD, g/mL); packed bulk density (PBD, g/mL); flowability measured as angle of repose (ɵ°), wettability (s);; specific surface area (SSA, m^2/kg); particle size distribution (d_{50}); colour values (*L**, *a** and *b**) and water activity (a_w) of STPPSHMP-MPC60 powder.

2.4.3 Determination of functional properties

Percent solubility, foaming capacity and foaming stability; water binding capacity (WBC in g/g protein) and oil binding capacity (OBC in g/g protein) of STPPSHMP-MPC60 powder were determined according to the methods earlier reported by Patil et al., (2018). Buffer index (dB/dH) was determined as per the method reported by Slyke (1922).

HCT (min) of PBSM, 2.30×UFR and STPPSHMP-MPC60 which was reconstituted as per method of Crowley et al., (2014) was measured using an oil bath at 140°C till 90 min or till the sample went coagulated (whichever was earlier).

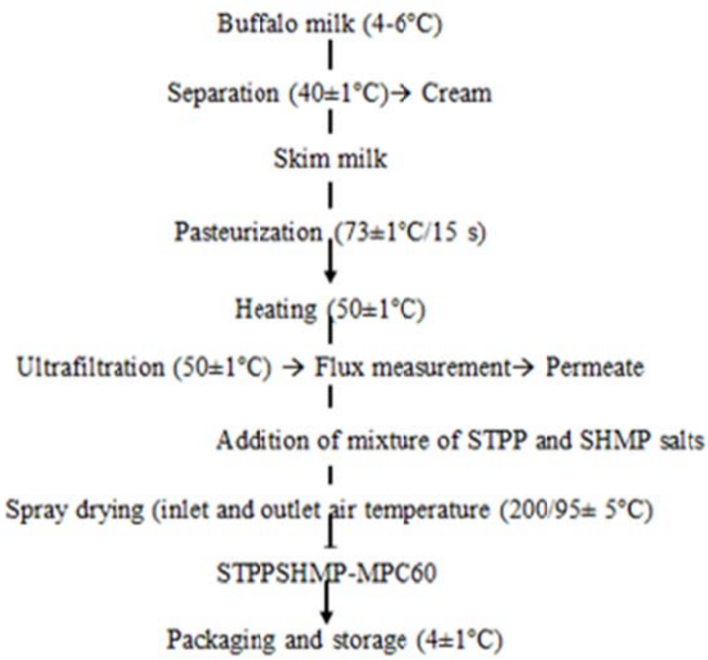


Fig. 1 Production of STPPSHMP-MPC60 from buffalo milk

2.4.4 Measurement of viscosity and rheological properties
Apparent viscosity and flow behaviour of 10% w/v solution of STPPSHMP-MPC60 were measured as per the method reported by Meena et al., (2017) and Patil et al., (2018).

2.4.5 Scanning electron microscopy
The microstructure of STPPSHMP-MPC60 powder was studied by scanning electron microscopy (SEM) (EV018, 18th special edition, Zeiss, Tokyo, Japan) by adopting the procedure reported by Shilpashree et al., (2015).

2.5 Statistical Analysis
SAS Enterprise guide (5.1, 2012) developed by SAS Institute Inc., North Carolina, USA (SAS, 2008) was used to analyzed the obtained data (n=3) for its one-way analysis of variance (ANOVA). Means were compared using Ducan's multiple range test.

3. Results and discussion

3.1 UF concentration of PBSM
During the concentration of PBSM in UF, gradual decrease was observed in permeate flux. After ~60% volume reduction or at 2.53×, flux decreased from initial 100 LMH to 60 LMH. Such decrease in flux could be attributed to concentration polarization and fouling of the membrane. Similar decrease in flux with the progression of UF had been also reported by Patil et al., (2018) and many other authors during concentration of PBSM employing UF process.

The UF concentration significantly increased ($p<0.05$) the TS, protein, ash, fat, pH and calcium content of 2.53×UFR compared to PBSM, but it also lead to decreased heat stability (Table 1).

3.2 Chemical composition of MPC60 powder
Chemical composition of the manufactured STPPSHMP-MPC60 powder has been shown in Table 1 The TS, protein, lactose and ash contents of the buffalo milk based MPC60 (BM-MPC60) have been reported as 98.12, 58.47, 27.49 and 8.24 %, respectively (Patil et al., 2018).

3.3 Physical and reconstitution properties of STPPSHMP-MPC60 powder

The quality of high protein powders are strongly governed by its physico-chemical, reconstitution and functional properties (Patil et al., 2018). Reconstitution properties of high protein powders are mainly governed by its chemical composition and physical properties and have direct impact on its other properties such as sensory property, functional property as well as nutritional attributes. Other factors which influences these properties includes TS, viscosity, and foaming of feed before spray drying of UF retentates. Amaladhas and Emerald, (2017) have reported that increase in feed viscosity results larger particle size, higher densities and moisture content as well as lesser porosity in final powder. Various physical and reconstitution properties which have been determined for STPPSHMP-MPC60 powder have been shown in Table 2.

Table 1 Chemical composition, pH and HCT values of PBSM, 2.53×UF retentate and STPPSHMP-MPC60 powder*

Samples	TS	Protein	Ash	Fat	Ca	HCT
			Percent			min
PBSM	11.37^{c}±0.42	4.70^{c}±0.15	0.80^{c}±0.06	0.10^{c}±0.00	0.22^{c}±0.00	90.00^{a}±0.00
2.53×UFR	19.37^{b}±0.59	11.89^{b}±0.58	1.62^{b}±0.13	0.24^{b}±0.02	0.64^{b}±0.01	65.00^{b}±0.00
STPPSHMP-MPC60	97.88^{a}±0.39	60.04^{a}±1.71	8.21^{a}±0.19	1.20^{a}±0.06	3.01^{a}±0.06	90.00^{a}±0.00

*Mean ± S. E. (n=3), ^{abc} are significantly different at ($p<0.05$) with each other row wise.

Table 2: Physical and reconstitution properties of STPPSHMP-MPC60 powder*

Properties		STPPSHMP-MPC60 powder
Air contents (mL/100g powder)	Interstitial air	163.98±8.09
	Occluded air	108.43±5.20
Densities (g/mL)	Loose bulk density (LBD)	0.21±0.02
	Packed bulk density (PDB)	0.29±0.03
	Particle density (PD)	0.57±0.04
Flowability	Angle of repose, ɵ°	38.08±1.68
Wettability (s)		600.00±28.87
Particle size distribution (µm)	d_{50}	78.33±0.04
Mean diameter	D_{43}	94.96±0.05
Color values	*L**	86.73±6.56
	*a**	-0.79±0.06
	*b**	14.46±1.18
Water activity (a_w)		0.26±0.01
HMF content		0.61±0.02

*Mean ± S. E. (n=3)

IAC and OAC values of BM-MPC60 powder were 173.7±2.98 mL/100 g and 98.08 ±2.23 mL/100 g, respectively (Patil et al., 2018), which are markedly higher and lower compared to these values observed for STPPSHMP-MPC60 powder. This could be due to difference in added salts, protein and TS contents of UF retentates used to produce BM-MPC60 and STPPSHMP-MPC60 powders. Apart from difference in TS of UF retentates, difference in particle size distribution of these powders can also explain the variation in IAC and OAC contents of these powders.

The LBD, PBD and PD values of BM-MPC60 was 0.18, 0.29 and 0.61 g/mL, respectively. These values for STPPSHMP-MPC60 powder were 0.21, 0.29 and 0.57 g/mL (Table 2). Thus, its LBD was higher, but PD value was lower compared to that of BM-MPC60 powder. Such observed variation in LBD and PD values of these powders could be attributed to the difference in their interstitial and occluded air contents. Apart from this, bulk density also depends upon several other factors like atomizer type, feed pressure, particle size, SSA. The flowability is one of the important powder properties from the consumer point of view. Flowability of BM-MPC60 in terms of the angle of repose (ɵ) was 37.35±1.10° which is slightly lower than that (i.e. 38.08±1.68°) observed for STPPSHMP-MPC60 powder. However, as per Carr (1965) classification, both powders have fair to passable flow (ɵ=38-45º). The flowability is directly related to the particle size and SSA as resistance to flow decreases with reduction in particle size (Schuck, 2013). The presence of very fine particles as evident from SSA values (Table 2) in STPPSHMP-MPC60 powder could explain the difference in its flowability.

The ability of milk powders to absorb water is known as wettability and it depends on various other powder properties such as density, particle size, surface activity, porosity and hydrophilic (lactose), hydrophobic (fat) and amphiphilic (protein) character of the powder constituents. Wettability of STPPSHMP-MPC60 was 600 s±28.87 (Table 2) and the same was markedly higher compared to 91.40 s ±0.87 wettability of BM-MPC60 powder. The wetting index of MPC powders, milk protein isolate (MPI), whey protein isolate (WPI) and sodium caseinate powders were reported to be higher (more than 120 s) due to the presence of higher protein load on particle surface (Bouvier et al., 2013). Moreover, wettability of granulated and non-granulated high protein powders such as micellar casein and whey protein powders were reported as 1, 3, 4 and 17 min, respectively by Schuck (2013).

The SSA; d_{10}, d_{50} and d_{90}; D_{32} and D_{43} and span of BM-MPC60 powder were 163.5±1.63 m^2/kg; 19.04±0.83 µm;, 74.34±0.71 µm;, 164.81±0.94 µm; 36.69±1.19, 84.43±0.91 µm and 1.96±0.08%, respectively. The d_{90} and D_{43} values of STPPSHMP-MPC60 powder were 78.33±0.04 µm and 94.96±0.05 µm, respectively as shown in Table 2. This noticed difference in these values of BM-MPC60 and STPPSHMP-MPC60 could be explained by the difference in TS contents of the spray drier feed used to produce these powders.

Milk powders with lower water activity is preferred to retard/ avoid problem of autoxidation, sticking, caking and to ensure better flowability. The a_w of BM-MPC60 was 0.20±0.01 which was lower than that of STPPSHMP-MPC60 (0.26) as indicated in Table 2. This could probably be due to higher TS content in retentate from which STPPSHMP-MPC60 was produced.

Colour of MPC60 powder affects its acceptability. The lightness (L^*), redness (a^*) and yellowness (b^*) values of BM-MPC60 powder were 90.45±0.01, -3.28±0.01, 13.35±0.01, respectively. The observed L^*, a^*, b^* values of STPPSHMP-MPC60 was 86.73±6.56, -0.79±0.06 and 14.46±1.18 respectively (Table 2). The noticed difference in the colour values of BM-MPC60 and other powders might be attributed to the compositional difference mainly aroused due to addition of salts in UF retentate. Generally, high protein powders have yellowish-white colour compared to greyish-white colour of SMP.

3.4 Functional properties of MPC60 powder

Protein rich powders deliver desirable attributes to the food formulations owing to their unique combination of milk proteins (Patil et al., 2018). Functional properties of STPPSHMP-MPC60 powder are shown in Table 3. The solubility of MPC powders is the key functional property which determines the expression of its other functional properties. Solubility of was 67.13±0.50% SHMP is a well-known calcium chelator and cross linking salt that is capable in shifting protein-mineral equilibrium and present in casein micelles. Because of this, casein micelles become more negatively charged that results in increased electrostatic repulsion between in casein micelles that ultimately leads to decrease in its compactness. At higher pH, it also releasing k-casein from casein micelles that also contributed in the strong increase in its zeta potential that increases the hydration of casein micelles. Such effects of added SHMP on casein micelle have been earlier also reported by several researchers. STPP is also a well-established calcium sequestering salt which had proven role as solubility enhancer in aggregated casein products such as calcium co-precipitates. The efficacy of this treatment was also advocated by the lack of severe casein-casein interactions and formation of aggregates as indicated by SEM micrograph of STPPSHMP-MPC60 as shown in Figure 2.

Table 3: Functional properties of STPPSHM-MPC60 powder*

Functional properties	STPPSHMP-MPC60
Heat coagulation time (min)	More than 90±0.00
Water binding capacity (g/g protein)	3.55±0.20
Oil binding capacity (g/g protein)	4.42±0.24
Foam stability (%)	31.33±3.18

*Mean ± S. E. (n=3)

Presence of higher calcium ions decreases the electrostatic repulsive forces between the casein micelles, reduces the hydration of powder particles which might have resulted in poor solubility of BM-MPC60 powder (Patil et al., 2018). Shilpashree et al., (2015) observed typical tendency of aggregation or clustering in commercial MPC85 powder due to severe casein-casein interactions. Such aggregates were also seen in SEM micrograph by Patil et al., (2018) in BM-MPC60 powder and this can be attributed as the main cause of poor solubility and dispersibility of BM-MPC60 powder.

The HCT of BM-MPC60 powder at its natural pH (7.17) as reported by Patil et al., (2018) and STPPSHMP-MPC60 at its natural pH (7.30) were similar as reconstituted solutions of these powders did no coagulated till 90 min (Table 3). Calcium chelation or lower calcium ion activity at higher pH can easily explain the better heat stability of reconstituted STPPSHMP-MPC60 solution.

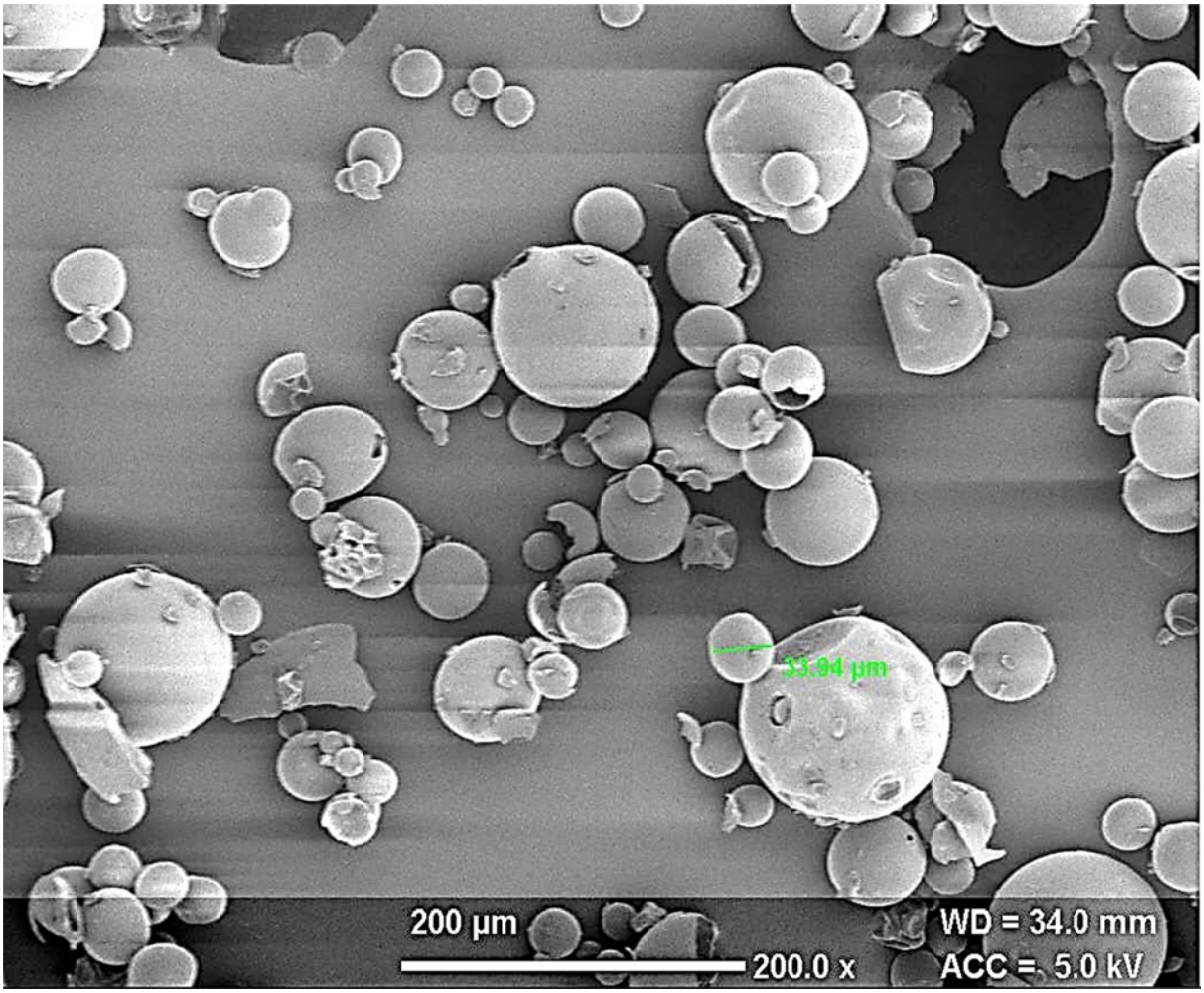


Fig. 2. Scanning electron micrographs of STPPSHMP-Milk Protein Concentrate 60 powder

The viscosity of 10% solution of BM-MPC60 was 20.3 mPa.s as reported by Patil et al., (2018). The holding of water in a 3-dimensional structure of food is referred to as water binding. This depends on several factors such as charge, physicochemical and surface properties of casein; ionic strength, pH and temperature of the surrounding medium. WBC and OBC of BM-MPC60 powder were respectively, 5.49±0.05 and 5.18 ±0.05 g/ g protein which is higher than the corresponding observed values i.e. 3.55±0.20 and 4.42±0.24g/ g protein for STPPSHMP-MPC60 powder. The alteration in native structure in casein as a result of STPP and SHMP addition could explain its lower WBC, while its higher LBD thus can explain its lower OBC values.

Foaming capacity is the ability of protein to retain and entrap air to produce foam (Patil et al., 2018). Foaming capacity and stability of BM-MPC60 were 39.81±0.22% and 19.51±1.40%, respectively Markedly higher pH and solubility of STPPSHMP-MPC60 can easily explain its better foaming stability.

3.5 Buffering capacity of STPPSHMP-MPC60 powder

The quantity of acid and base used to induce 0.5 incremental change in pH of reconstituted MPC solution and concerned change in its buffer index values are shown in Figure 3. The observed buffer index of STPPSHMP-MPC60 ranged from 0.0006–0.00343 in the pH range from 2–10. Buffer index values of BM-MPC60 varied in the range of 0.0014–0.0378 and increased with increase in solution pH from acidic side to alkaline side. The observed difference was attributed to addition of salts.

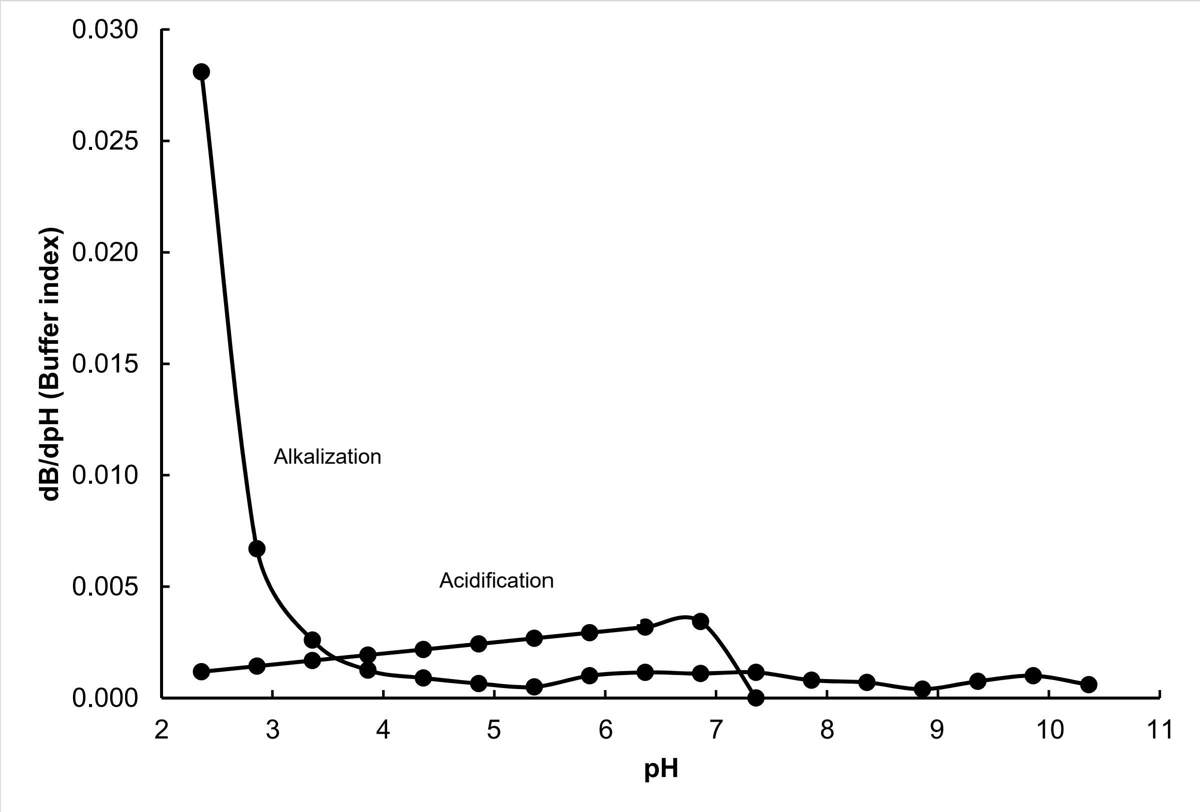


Fig. 3. Buffer index of acidification-alkalization with 0.1N HCl and 0.1N NaOH solution of STPPSHMP-Milk Protein Concentrate 60 powder (0.5% protein solution).

3.6 Rheological properties of MPC60 powder solution

The 10% solution of STPPSHMP-MPC60 powder was studied for their flow behaviour as well as temperature sweep test and the data obtained suggested that the non-Newtonian behaviour of sample as observed by the highest value for coefficient of determination (Table 4). The yield stress advocates the fitness of Ostwald model. Further, the value of flow behaviour index was less than unity suggesting the pseudoplastic behaviour. The flow behaviour could correlated well with the higher solubility and viscosity value of STPPSHMP-MPC60 sample as compared to control BM-MPC60 which was reported to exhibit the Herschel Bulkley behaviour. Further, the pH of treated sample was 7.30, significantly higher than 7.17 for control BM-MPC60. The role of pH on the solubility of protein and viscosity of its solution has already been established. Further, the temperature sweep test indicated the stability of protein solution against thermal gelation or coagulation up to 82.5°C which is supportive of higher heat coagulation time, i.e. 90 min.

Table 4: Rheological properties of STPPSHMP-MPC60 powder sample

Parameters of rheological model	Value
Ostwald	
Consistency coefficient (k)	0.086
Flow behaviour index (n)	0.787
Coefficient of determination (R^2)	0.999
Bingham	
Yield stress (τ_0, Pa)	0.077
Plastic viscosity (n, mPa.s)	22.86
Coefficient of determination (R^2)	0.920

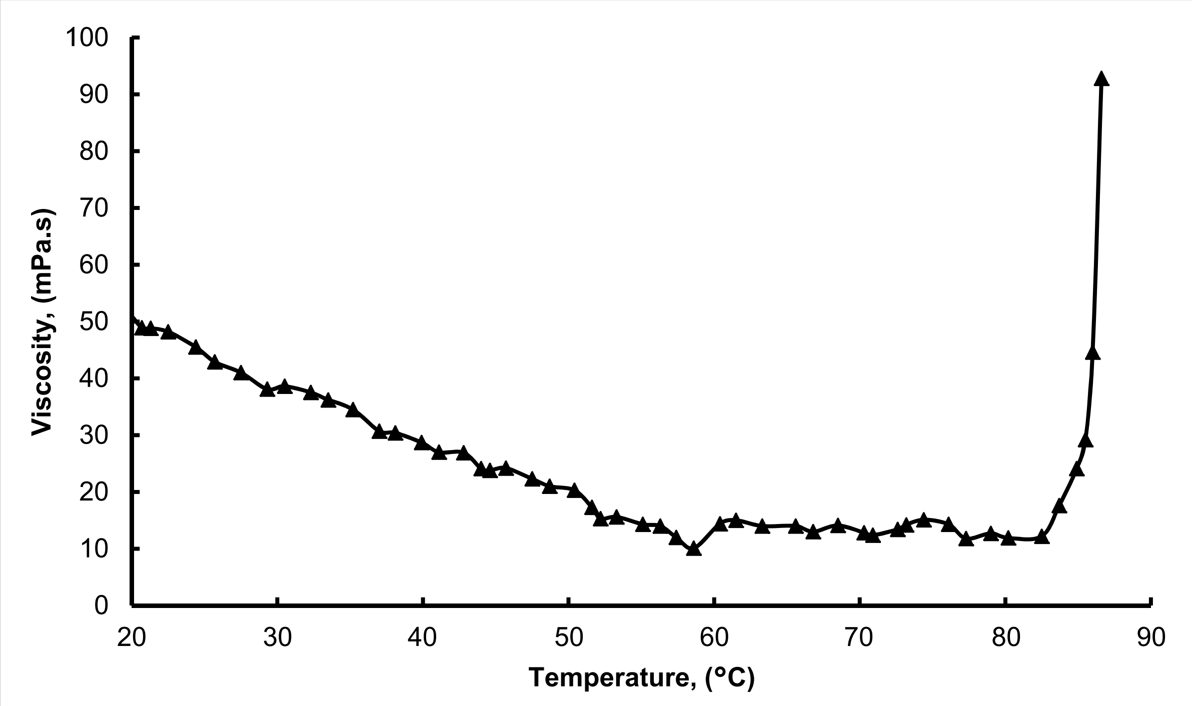


Fig. 4. Temperature Sweep Curve of STPPSHMP-MPC60

3.7 Microstructure of MPC60 powder

The morphology of BM-MPC60 powder includes smooth surfaced, different size, intact particles with a distinct tendency of aggregation or clustering due to severe protein-calcium-protein interactions acting as a main cause of its poor solubility and dispersibility. However, the manufactured powder also contained few wrinkled particles as shown in (Figure 2).

4. Conclusion

Milk protein concentrate contains casein and whey protein in the similar ratio as present in milk. Because of inherent properties of buffalo milk, MPC60 produced from it lacks desired physicochemical and functional properties. This investigation was aimed to improve such properties of buffalo milk based MPC 60 powder through the addition of STPP and SHMP salts to induce favourable changes in casein structure prior to its spray drying. The applied intervention resulted in markedly higher loose bulk density but lower particle density, almost similar flowability, but higher wettability, d_{50} and D_{43} values in STPPSHMP-MPC60 powder compared to control MPC60 powder. However, addition of these salts induced favourable changes in casein micelles and decreased casein-calcium-casein interactions during spray drying and retarded the formation of aggregates or cluster formation in STPPSHMP-MPC60 powder. Further, this intervention also resulted in better heat stability, foaming stability, but lower water and oil binding capacity than control product. This investigation has established that manufactured buffalo milk protein concentrates could be used to produce heat stable food formulations with improved nutritional properties.

5. Acknowledgement

The first author is thankful to the Director of National Dairy Research Institute, Karnal, India, for providing financial assistance in the form of Institutional Fellowship for carrying out this research work.

REFERENCES

[1] Agarwal, S., Beausire, R. L., Patel, S. & Patel, H. (2015). Innovative uses of milk protein concentrates in product development. *Journal of Food Science, 80 (S1),* A23-A29.
[2] Amaladhas, P. H., & Emerald, F. M. E. (2017). Physicochemical and Sensory Properties of Dried Dairy Products. *Handbook of Drying for Dairy Products*, 203.
[3] AOAC (1998). Official methods of analysis (16th Ed.). Washington, D.C: Association of Official Analytical Chemists.
[4] Bouvier, J. M., Collado, M., Gardiner, D., Scott, M., & Schuck, P. (2013). Physical and rehydration properties of milk protein concentrates: comparison of spray-dried and extrusion-porosified powders. *Dairy Science and Technology,* 93(4-5), 387-399.
[5] Carr, R. L. (1965). Evaluating flow properties of solids. *Chemical Engineering, 72 (2),* 163-169.

[6] Crowley, S. V., Gazi, I., Kelly, A. L., Huppertz, T., & O'Mahony, J. A. (2014). Influence of protein concentration on the physical characteristics and flow properties of milk protein concentrate powders. *Journal of Food Engineering, 135,* 31-38.
[7] Jha, A., Patel, A. A., & Singh, R. R. B. (2002). Physico-chemical properties of instant kheer mix. *Le Lait, 82(4),* 501-513.
[8] Lagrange, V., Whitsett, D., & Burris, C. (2015). Global market for dairy proteins. *Journal of Food Science, 80 (S1),* A16-A22.
[9] Meena, G. S., Singh, A. K., Arora, S., Borad, S., Sharma, R., & Gupta, V. K. (2017). Physico-chemical, functional and rheological properties of milk protein concentrate 60 as affected by disodium phosphate addition, diafiltration and homogenization. *Journal of Food Science and Technology*, 54 (6), 1678-1688.
[10] Meena, G. S., Singh, A. K., Gupta, V. K., Borad, S., & Parmar, P. T. (2018). Effect of change in pH of skim milk and ultrafiltered/diafiltered retentates on milk protein concentrate (MPC70) powder properties. *Journal of Food Science and Technology*, 55 (9), 3526-3537.
[11] Patil, A. T., Meena, G. S., Upadhyay, N., Khetra, Y., Borad, S., & Singh, A. K. (2018). Production and characterization of milk protein concentrates 60 (MPC60) from buffalo milk. *LWT-Food Science and Technology,* 91 (55), 368-374.
[12] Schuck, P. (2013). Dairy protein powders, *In: Advances in Dairy Ingredients*, Smithers GW, Augustin MA, John Wiley & Sons Inc. and the Institute of Food Technologists, pp: 1-29.
[13] Shilpashree, B. G., Arora, S., Chawla, P., & Tomar, S. K. (2015). Effect of succinylation on physicochemical and functional properties of milk protein concentrate. *Food Research International*, *72,* 223-230.
[14] Sikand, V., Tong, P. S., Roy, S., Rodriguez-Saona, L. E., & Murray, B. A. (2011). Solubility of commercial milk protein concentrates and milk protein isolates. *Journal of Dairy Science, 94 (12),* 6194-6202.
[15] Slyke, D. V. (1922). On the measurement of buffer values and on the relationship of buffer value to the dissociation constant and reaction of the buffer solution. *The Journal of Biological Chemistry, 52,* 525-570.

Technical Article for Oral Presentation Article Code: OP-NT-07

Design and Application of Artificial Lighting for increasing milk production

Bhavesh Chavhan[1]*, P. Barnwal[2], A.K. Agarwal[3], G.P. Deshmukh[4]
[1*]PhD Scholar, NDRI-Karnal, Principal Scientist, NDRI-Karnal, [3]Prof & Head, CODFT-Raipur,[4]PhD Scholar-SRS, Banglore

Introduction

Photoperiod manipulation, moreover known as long-day lighting, is the management practice of using a designed lighting system to artificially proffer the elapsing of light that a lactating cow is exposed to, with the goal of increasing milk production. Photoperiod manipulation was first pioneered in the late 1970's and gained much wide span industry interest in the late 1990's. Supplementing lactating cows with 16 to 18-hr. of continuous light at an intensity of 15 to 20 foot candles (fc) has been shown to increase milk production from 5 to 16 percent whilom cows exposed to less than 13.5 hours of light in research trials. Brightness is a measure of the value of light striking a surface. It is measured in units of foot candles. One foot candle is specified as 1 lumen of light falling on 1 square foot. The metric equivalent of a foot candle (fc) is a lux (lumen per square metre). 1 foot candle = 10.76 lux Research has moreover shown the wastefulness of the 24-hr. lighting period needs to be visionless in order to unzip a favourable response. Acceptable lighting can modernize productivity and safety on a dairy farm. On an average, lighting represents 17 percent of total dairy electrical energy use. Factors that contribute to increased milk production include the type of light, the value of light provided per watt, the temperature of work area, height of the ceilings and length of the lighting period.

Photoperiod management has received interest lately as a forfeit constructive method to increase production in lactating cows. Considering cows exposed to long days, i.e. 16 to 18 hours of light (180 lux) and 6 to 8 hr. period of darkness, daily milk production increases an stereotype of 2 litres/cow, relative to those on natural photoperiods (Dahl et al., 2000) i.e.15 to 20 foot candles (fc) has been shown to increase milk production from 5 to 16 percent for cows exposed to less than 13.5 hours of light in research trials (Peters et al., 1978). The purpose of this paper is to review the vestige for a response of lactating cows to photoperiod, describe the physiologic under structure for those responses, and discuss the energy economical lighting use in farm and thus to improved farm Productivity and increase revenue, while lowering energy costs.

Effect of Photoperiod in Lactating Cows

The impact of long days on milk production was first observed in 1978 by researchers at Michigan State University (Peters et al., 1978). Cows were placed on 16 hours of light, 8 hours of darkness (16L: 8D) or left on natural photoperiod at calving. The study was conducted in between month of September and March, when natural light was limited to less than 12 hours each day. Over the first 100 days postpartum, cows on long days produced 2.0 litre/day more milk than those on natural photoperiod. At 100 days, the treatments were switched and the cows previously on natural photoperiod increased milk production, whereas the cows previously on 16L: 8D decreased milk yield. Those results suggested that exposure to long days increased milk yield and did so across production levels. Since that first study, at least ten other experiments at 7 different laboratories across North America and Europe have confirmed the response (Dahl and Petitclerc, 2003). Based on those studies it is expected that cows on long days will produce an average of 2 litres more milk than control animals on natural photoperiod.

What is the basis of the response? Recent studies reveal a potential physiologic mechanism for the increase in yield from cows on long days. Differences in light exposure alter secretion of a number of hormones. Indeed, those hormonal shifts drive the commonly observed changes in reproductive activity in other species. The first hormone impacted by photoperiod is melatonin, which is secreted in response to darkness. Thus, in cows and other animals, a long day actually reduces the duration of elevated melatonin (Dahl et al., 2000). Animals use this pattern of melatonin to track day length, and then alter secretion of other hormones. In cows, a long day pattern is associated with higher secretion of the hormone insulin-like growth factor-I (Dahl et al., 1997). Higher IGF-I, in turn, is thought to increase milk yield. It is of interest that bovine somatotropin (bST), which also increases milk yield, stimulates IGF-I release as well (Bauman, 1999). Miller et al. (1999) treated cows with either long days or natural photoperiod, and half of each of those groups received bST as well. Relative to cows on natural photoperiod, milk yield increased 1.9 L/d in the cows on long days, and 5.7 litre/day in bST. The combination of long days and bST improved production 7.7 litre/day, clearly an additive response, which suggests that the two manipulations are not antagonistic.

Energy Efficient Light for Dairy Farm

The common theme behind the use of all these sources is the basic need for supplemental light to provide worker the visual acuity to perform required functions accurately, efficiently and safely. Well designed and maintained lighting systems become even more crucial for successful operation of the farm. This design should satisfy established criteria for light level, colour rendering, efficacy, selection of fixtures suitable for the ambient environment, controls, and proper wiring and circuit protection. An efficient lighting design and control system must be implemented to obtain the benefits of long-day lighting. The type of luminaires that can used to provide lighting includes metal halide (MH), high-pressure sodium (HPS), and fluorescent. (Dahl et al, 2001) indicated that these three light sources will create a milk yield response. There may be personal preferences with regard to MH and HPS luminaires. HPS lights deliver more lumens per Watt than MH, This is obviously an economic advantage because fewer luminaires are needed to obtain the same average light level (number of lumens measured at the work place) and lower connected load (kW). Generally HPS luminaires also have a higher average lamp life. However, MH have a higher colour rendition index (CRI), a measure of the luminaire's output light colour. MH luminaires have a more white output light colour while HPS luminaires have a yellowish/orange output colour. Lighting system designers should consult with the dairy producer and determine their preference for luminaire output light colour.

Fluorescent lights have a lamp life similar to MH. However, fluorescent lamps have a lower lamp lumen depreciation factor meaning that they stay brighter longer. In fact, mean light output for fluorescent lamps can be 95 percent of the initial light output while MH may be 65 percent. Mean light output is defined as the light output after 40 percent of average life. The rated average life for fluorescent and MH lights is determined when 50 percent of the installed lights are still operating.

Finally, LED lights can provide high energy efficiency with a reported 100,000 hour operating life. This is significantly longer than the reported 20,000 hour operating life of fluorescent and high intensity discharge (HID) fixtures. Moreover, LED lights are expected to have lower maintenance costs, contain no mercury, and provide instantaneous reliable light. However, LED fixtures are expensive compared to the other fixtures. These unique attributes can make it confusing to select fixtures best suited for dairy operations. When considering implementing LDPP, LED fixtures may provide an edge. Considering this: lighting performance is often measured based on lumens/watt. This can be misleading for dairy producers because lumens represent effective light for the human eye. Dairy cows perceive light differently than humans, meaning a light fixture can provide ample lumens/watt, but may not provide light in the appropriate spectrum to stimulate milk yield. For instance, high pressure sodium fixtures provide high lumens/watt, however, light output from these fixtures is biased towards longer wavelengths that cows cannot perceive. LED fixtures can provide light in the same spectrum as sunlight and are more reliable under cold conditions. These two considerations suggest LED fixtures may be best suited for implementing LDPP. However, this scenario needs to be investigated under barn conditions.

Lighting Design

Lighting design is important as it will determine the performance of the lighting for the life of this system. It's therefore worth getting some professional advice to get the lighting right. The preceding sections have covered the issues of lighting level, light uniformity, shadows, colour, and control - all these things must be considered in the design process.

A few additional points may need to be examined:

1. Consider the way, lighting is used on an everyday basis. Where is the most suitable area for the switches to be located? Is it possible to get different lighting levels by simply rouping and switching the lights on/off in clusters?
2. Are the lights in a, position where these can be easily cleaned and where the bulbs can be safely changed?
3. Consider reflectivity off roofs and walls. Colouring surfaces white or a light colour can increase the lighting level dramatically.
4. Fittings, in most cases will have to be water and dust proof. Make sure the ones you choose, are up to standard.

Lighting Requirement in Farm

Table No.1 gives some guidance on lighting levels and desirable light properties for different area of a dairy enterprise. There are no definitive standards in this area, so this table contains figures derived from practical experience and from similar practical references as per published.

Conclusion

Artificial lighting is one of the ways to boost the milk production than milking three times a day or using growth hormones just providing the light on longer for 16 to 18 hr a day. More and more dairy operation showed increasing milk production and profit through long day lighting especially when energy efficient lighting is used.

Table No.1- Lighting levels and desirable light properties

Application	Lux Level Required	Colour Rendering	Uniformity	Control	Comments
Cubicle and feeding area	170 to 200 lux for photo period yield effect, 50 lux for general	Low to medium	Medium	Timed, with light level sensing. Fluorescents can use light level driven dimming	High pressure sodium, metal halide lights or multiple fluorescent fittings
Milking area	500 lux for pit	Good	Very good	Timed with manual override	Fluorescent lights will punch light through the mass of pipes and fittings and give even shadow-less light.
Collection yard	50 lux	Low to medium	Medium	Timed with manual override	High pressure sodium or metal halide lights
Bulk tank area	200 lux	Good	Medium	Proximity	Fluorescent lights are most commonly used
Outside areas	20 lux	Low to medium	Low	Timed / light level	High pressure sodium or metal halide lights are the best compromise between cost and performance
Office	300 - 500 lux	Good	Good	Proximity	Fluorescent lights are most commonly used

References

[1] Bauman DE (1999) Bovine somatotropin and lactation: from basic science to commercial application. Domest. Anim. Endocrinol. 17:101-116.
[2] Dahl GE and Petitclerc D (2003) Management of photoperiod in the dairy herd for improved production and health. *J. Anim. Sci. 80 (Suppl. 2): In Press*.
[3] Dahl GE, Buchanan BA and Tucker HA (2000) Photoperiodic effects on Dairy Cattle. *A review J. Dairy sci. 83:885.*
[4] Dahl GE, Elsasser TH, Capuco AV, Erdman RA and Peters RR (1997) Effects of long day photoperiod on milk yield and circulating insulin-like growth factor-1. *J. Dairy Sci. 80:2784 2789.*
[5] Dahl GE (2001) Photoperiod control improves production of Dairy cows Feedstuffs. June 11, 2011, P.10
[6] Peters RR, Chapin LT, Leining KB, and Tucker HA (1978) Supplemental lighting stimulates growth and lactation in cattle. *J. Dairy* Science 199:911.
[7] Miller ARE, Stanisieaski EP, Erdman RA and Douglass LW (1999) Effects of long day photoperiod & Bovine somatic (Trobes) on milk yield in cows. *J. Dairy Sci. 82:1716*.

Technical Article for Oral Presentation Article Code: OP-PO-08

Design Upscaling of Ohmic Milk Heating System

Vishal Thakur[1*], P.S. Minz[2], Dhruvin Patel[3], Priyanka Rangi[4], Lanjewar Piyush[5], Subramani Nayak[6]
[1*]M-Tech Scholar, [2]Scientist, [3,5,6] M-Tech Scholar, [4]Phd Scholar, ICAR-NDRI, Karnal

Abstract
Food is a basic component required by all living beings for proper nutrition essential for their life and growth. Food quality, food safety, convenience, freshness, natural flavour and taste with extended shelf-life are the main criteria for the demand made by today's consumers. Most of the times, foods are thermally processed by conventional methods which has several disadvantages like overheating, degradation of colouring and/or flavouring compounds, loss of nutritional compounds and sensory changes, etc. To overcome these drawbacks, ohmic heating is the most suitable and innovative alternative thermal process. Ohmic heating is a process wherein an alternating current is passed through food material and heat is internally generated in the material due to electrical resistance when electric current is passed through it. Ohmic heating provide shorter heating times, avoid hot surfaces and also helping in minimization of temperature gradients. The important parameter in the design of an effective ohmic heater is an electrical conductivity. Food materials with electrical conductivities in the range of 0.01–10 S/m are considered proper for ohmic heating. It has large number of applications including thawing, cooking, sterilization and pasteurization, blanching, evaporation, distillation and in waste-water treatment but higher installation cost; lack of application in lipid foods and less awareness limit its use. Its application is still limited in milk and milk products processing because of problem of fouling and corrosion of plate. Fouling can be eliminated by provision of agitator and/or by providing rotating field type core. Localized heating of plates is another major problem in an ohmic heating apparatus. But OH also provides rapid and uniform heating, resulting in lower thermal damage than that caused by conventional heating. Thus, there is vast scope to use ohmic heating for processing in food industries.
***Keywords*:-** Ohmic heating, Electrical conductivity, Applications, Conventional heating.

1) Introduction

Food is a basic component required by all living beings for proper nutrition essential for their life and growth (Richa et al., 2017). So there is always a need to process food to prevent, reduce and to eliminate toxins as well as microorganisms that leads to various types of food deterioration. Food production processes inactivate microorganisms and provide safe and high quality finished product (Akanbi et al., 2006). Mostly conventional heating methods are used for processing of food products.

Conventional heating and cooking has many disadvantages such as low heat transfer rate which elongates cooking time such that outer layer of product absorbs more heat leading to surface hardening and thus deteriorate the quality of the product. High amount of heat losses also occurs during heat-transfer mechanisms of conduction, convection and radiation. Occurrence of heterogonous heating due internal resistance results in significant loss of product quality (Contreras et al., 2008 & Duan et al., 2011). Hence alternative technologies are introduced to overcome these disadvantages. Thus ohmic heating is such a substitute and speedy heating method that has prospective demand in food processing industry, water distillation, waste-water treatment and chemical processing etc. (Sakr and Lui, 2014).

Ohmic heating (OH) is defined as a heating method wherein electric current is passed through food materials with purpose of heating by converting electrical energy into thermal energy, resulting in fast and consistent temperature increase within the food (Cappato *et al.*, 2017). OH is a fresh technology which provides speedy and consonant heating and resulting in less thermal damage to the food product. Food materials with electrical conductivities in the range of 0.01–10 S/m are considered proper for ohmic heating (Lyng and McKenna, 2007). Ohmic heating is an innovative heating method used in the food industry for processing a wide range of food products (Cho *et al.*, 2017). It has large number of applications including thawing, cooking, sterilization and pasteurization, blanching, evaporation, distillation and in waste-water treatment. Ohmic heating is technically simple, has high efficiency (more than 90%) and have low investment costs (Kaur *et al.*, 2016). It is widely applied during meat, fruits and vegetables processing.

Its application is still limited in milk and milk products processing because of problem of fouling and corrosion of plates. Provision of agitator can be helpful in preventing fouling of electrodes. Fouling can also be prevented by providing rotating field type core which excluding the use of agitator. Localized heating of plates is another major problem in an ohmic heating apparatus. Presence of fat globules in food is also problematic during ohmic heating (Rahman, 1999). But OH also provides rapid and uniform heating, resulting in lower thermal damage than that caused by conventional heating (Simpson *et* al., 2014). Development of ohmic heater will be helpful for small and medium dairy processors. Heat treatment of milk is essential for manufacturing of all dairy products which can be carried out by ohmic heating system in lesser time. Thus, there is vast scope to use ohmic heating for processing in food industries.

2) Review of literature

In ohmic heating, electrical energy is directly converted into thermal heat without any loss of heat. This principle is used to generate an internal energy in the material which causes the heating of material. The rate of heat generation is directly proportional to the square of electric field strength and electrical conductivity of material (Palaniappan and Sastry, 1991). This heat is generated because of the motion and collision of ions in food. This collision causes the transfer of momentum which increases the kinetic energy hence generating heat in it. Transfer of momentum is the amount of momentum that the one particle transfers to another. The presence of electrodes contacting the food, frequency, and waveform (typically sinusoidal) made it different from other electrical heating methods. Generally 50-60 Hz alternating current is used for ohmic heating (Antonio et al., 2006).

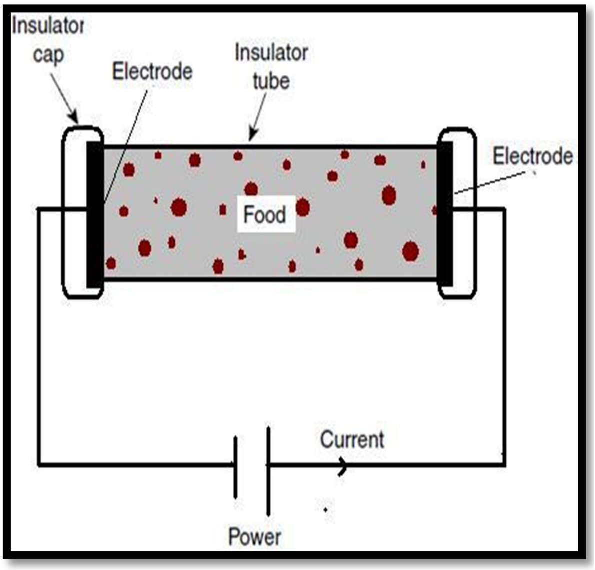


Fig 1a: working principle of ohmic heating system

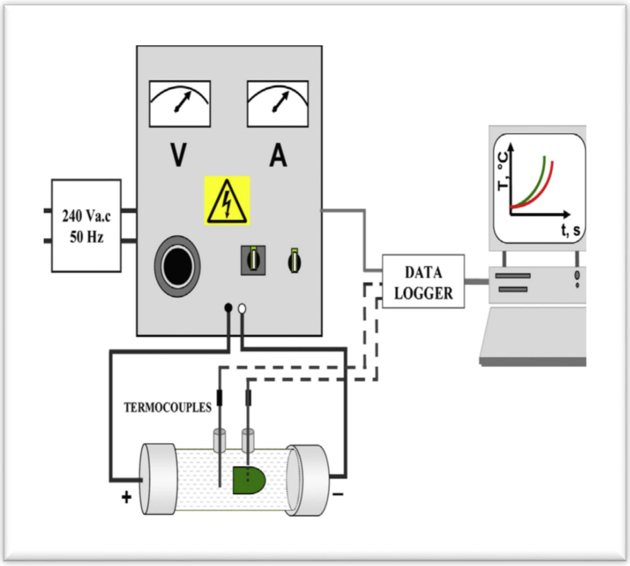


Fig 1b: Experimental setup of ohmic heating system

Ohmic heating depend on the Ohm's Law which deals with the direct relationship between voltage and current in an ideal conductor. The most important parameters affecting ohmic heating includes electrical conductivity, temperature, voltage gradient, frequency, moisture content, nature of food, particle size etc.

3) Applications of ohmic heating

Pasteurization of fermented red pepper paste is carried out by ohmic heating (Cho et al., 2016). Ohmic heating produces greater pasteurization effect than conventional conduction heating due to the uniform internal heating produced by low-frequency AC. Ohmic heating results in 99.7% reduction and effective deactivation of vegetative cells of Bacillus strains, whereas conduction heating at 100 °C for 8 mins producing a 81.9% reduction.

Blanching is also carried out by ohmic heating. Ohmic heating accelerates the enzymatic inactivation process such that ohmic blanching took 2 mins for reduction of higher than 90% peroxidase initial activity, whereas conventional blanching took 4 mins to achieve the same degree of inactivation (Gomes et al., 2018).

A study was also conducted in order to determine the application of ohmic heating system in meat thawing and its effects on quality (Balpetekty, 2015). Balpetekty (2015) concluded that use of ohmic heating system for thawing of frozen meat results in less weight loss and shorter thawing time. Thawing of the frozen beef by ohmic heating gives good results at three different voltage gradients viz. 10, 20 and 30 V/cm as compare to conventional thawing at 25°C, 95% RH. The thawing time decreased with increase in voltage gradients, while the thawing loss remained unchanged (Richa *et al.*, 2017).

Evaporation is the important operation carried out in food industry with the aim of product concentration. Ohmic heating is applied to sour cherry juice having total soluble solids (TSS) of 19.2% and was evaporated to 65% TSS under vacuum (gauge pressure of 580 mm-Hg) at three different voltage gradients (10-14 V/cm) (Sabanci & Icier, 2017). Total process times were 40, 55, 75, and 85 min for 14 V/cm, 12 V/cm, 10 V/cm and vacuum evaporation, respectively. Sabanci & Icier (2017) concluded that ohmic heating could be alternatively used as the heat source to shorten the process times of vacuum evaporation applied for concentration of fruit juices. Vacuum evaporation by ohmic heating evaporates more moisture from food product as compared to conventional method in the same time and finished product was brighter and kept more aromas (Wang & Chu, 2003). Ohmic heating is an efficient method that heats the fluid in shorter time. Thus ohmic heating can be used as an alternative for waste water treatment (Sastry 1994, Huang et al.1997).

Distillation is a important unit operation carried out in industries. It is the most time and energy consuming operation in bio-ethanol production and some food operations. Ohmic assisted hydro-distillation (OAHD) is a new method which uses the advantages of ohmic heating as well as used for essential oil separation. Gavahian et al., (2015) developed an OAHD device for ethanol distillation using titanium electrodes. Gavahian et al., (2015) concluded that the energy required for separation of ethanol in OAHD was 33% as compared to HD. This study introduce OAHD is a economical and environmental friendly method for the ethanol distillation process.

Bread dough proofing was studied at a target temperature of 35°C under ohmic heating (Gally et al., 2016). Findings of the study showed that significantly faster proofing could be obtained by using ohmic heating. OH-assisted proofing consumes less energy to reach optimum temperature of fermentation quickly, offers flexibility and accelerating the fermentation process with high efficiency. Production of pleasant aromas should be less impacted than during bulk fermentation if OH-assisted proofing is applied to last fermentation step.

4) Material and methods

4.1) Experimental setup

The batch type ohmic heating system of 40 liters capacity was fabricated. The experimental setup consists of different parts including ohmic reactor vessel, electrodes, outlet valve, insulation chamber, thermocouples, and data logger and computer system. Static ohmic heating system comprised of following components:

4.1.1) Ohmic reactor vessel

Different materials can be used for construction of ohmic reactor vessel. Mainly alloys of stainless steel are used for construction for ohmic reactor vessel due to its high strength and corrosion resistance properties. It consists of heating plates (electrodes) and stirrer to prevent fouling on electrode plates. Reactor vessel is provided with proper insulation to prevent thermal losses and thus increases heating efficiency. Reactor vessel was also provided with round corners for quick draining of the product. Round corners also improve cleaning efficiency. The capacity of reactor vessel is 40 kg.

4.1.2) Outlet valve

A two way valve (SS-304) was connected at the base of ohmic reactor vessel. These valves are specially designed to regulate varying amounts of flow. Such valves have been called by various names such as regulating, throttling, metering, or needle valves. It is a manual valve that uses a tapered plug to permit or prevent straight through flow through the body. The plug has a straight through opening. This opening is of same area as the area of the inlet and outlet ports of the valve. Both the end connections of valve were threaded. One end was connected to the vessel with the help of bend. The purpose of valve at the base of the vessel was to collect the sample after processing without any need of removing all the connections and without dismantling the whole setup.

4.1.3) Insulation chamber

Ohmic reactor vessel was surrounded by insulation chamber to prevent thermal losses and thus increases heating efficiency. Inverse of thermal conductivity (k) is a measure of insulating capability of a material that means high value thermal conductivity is equivalent to low insulating capability (Resistance value). In thermal engineering, other important properties of insulating materials are product density (ρ) and specific heat capacity (cp). Wooden cabinet of suitable dimension is used as an insulation chamber. High current flows through milk vessel which is in contact with the heating plates. Wooden cabinet was used to insulate the vessel to ensure safety of the user as the vessel is conductive to current. To avoid heat loss glass wool insulation was provided in space between the wooden cabinet and reactor vessel. Glass wool is an excellent insulating material made from glass fibres which are arranged by using a binder into a texture similar to wool.

4.1.4) Heating plates

Electrodes are placed in reactor vessel and connected with power supply. These plates make direct physical contact with the sample to be heated, in order to pass an electric current through it. Different conductive materials like stainless steel, titanium, platinized titanium; aluminium and graphite etc. are used for construction of electrodes. These are usually selected based on price, resistance to corrosion and the desired application. Mostly stainless steel is considered as a most suitable alloy for construction of heating plates. SS plates are widely used in food, dairy, chemical, paper and textile industry due to its good mechanical properties. In case of milk heating, SS plates causes slight fouling but its properties, cost availability and cleaning efficiency of stainless steel makes it the suitable material to be used as electrodes during ohmic heating. The plate gap was fixed according to formula proposed by Lanjewar and Minz (2015) for 1 kg ohmic heating system.

4.1.5) Control unit

Control unit was used for centralized power supply to all the electrical components of the ohmic reactor viz Variable transformer, current and temperature data logger. One Miniature Circuit Breaker (32 Amp) is also provided in the control unit for safety reasons so that whenever current drawn is large or in case of short circuit it will cut the supply of current.

4.1.6) Voltage regulator

A voltage regulator is a device developed for automatically maintaining a constant voltage level. Its design includes a simple feed-forward design or may include negative feedback. It works on the principle of an electromechanical mechanism. It may be used to regulate one or more AC or DC voltages on the basis of its design. It consisted of on/off switch and a variable transformer. Voltage is one of the main factors affecting ohmic heating. Variable voltage transformer (Rating 15 A) was used to vary voltage for ohmic heating. When the current reached 14 A, variac was used toreduce in steps (10 V). It was done to protect the variac from damage. But for high trial manual voltage regulation was required. A clamp-meter and current data logger was used to measure current in the circuit during ohmic heating.

4.1.7) Temperature Data logger

A temperature data logger is used for monitoring of temperature. It is a portable measurement instrument having capability of continuously recording temperature over a defined period of time. The digital data can be retrieved, viewed and evaluated after it has been recorded. Study of heating pattern during ohmic treatment is very important. Real time temperature was measured using temperature probes (PT 100) connected to data logger. Temperature gradient was determined to ensure uniform heating of milk. To determine temperatures of milk at different points in ohmic reactor, a eight channel data logger was used. Temperature data is saved directly in USB pen drive as a MS Excel compatible file. Microprocessor based data logger is linearized for J/K/R thermocouples and pt-100 sensors. It has in built auto cold junction compensation for thermocouples as well as for 3 wire pt-100 sensors. In this number of usable channels are selectable (max. 8) and having Auto/Manual mode of scanning can be selected. The rate of logging is settable by user in Mins: Secs. The digital offset user settable for individual channels and internal real time clock with battery backup for saving values along with Date and Time. The data is saved on pen drive in a file named as “TempLog.csv”.

4.1.8) Current data logger

To record the current drawn by the reactor, current data logger was used. Data is recorded directly on USB Pen Drive in an MS Excel compatible file. The data logger has separate display for current and time. Logging rate can be set by the user in minutes or seconds. The current threshold beyond which logging is enabled is also user settable. Internal real time clock with battery backup enables saving values along with date and time. Thus saving data on pen drive allows a very large amount of storage space at very low cost.

5) Results and Discussion

This system was developed to provide the small scale dairy entrepreneurs with a low cost milk processing system. Heating rate obtained on heating milk in the ohmic reactor vessel was 3.5°C/min. Figure Fig. 2 shows the temperature profile of milk during ohmic heating. Upto around 10 minutes, temperature increase followed a linear trend. After 10 minutes, as current increased to the set value and voltage was reduced to bring current in the required range. Therefore, decrease in heating rate was observed after 10 minutes.

Thermal efficiency of system was 88.8%. According to the literature, thermal efficiency of the ohmic reactor is reported to be more than 90%. Thermal efficiency was less than 90% maybe because initially no thermal insulation was used in the system. Insulation between the reactor vessel and cabinet would have resulted in higher thermal efficiency of more than 90%. Time required for heating 5 litres of milk from 15°C-90°C was 21 min in ohmic heating system without agitator. Time taken in ohmic heating was much less as compared to other conventional heating systems like induction and electrical heating.

As obtained from the data recorded in the temperature data logger for the thermocouples fitted in the vessel for monitoring the temperature. Low temperature gradient (0-1°C) was observed indicating uniform heating, which has been also reported in literature studies. Also initially the temperature gradient was more but it decreased slowly as heating progressed. Such trend may be due to circulation of bulk fluid due to natural convective heating towards the later part of trials.

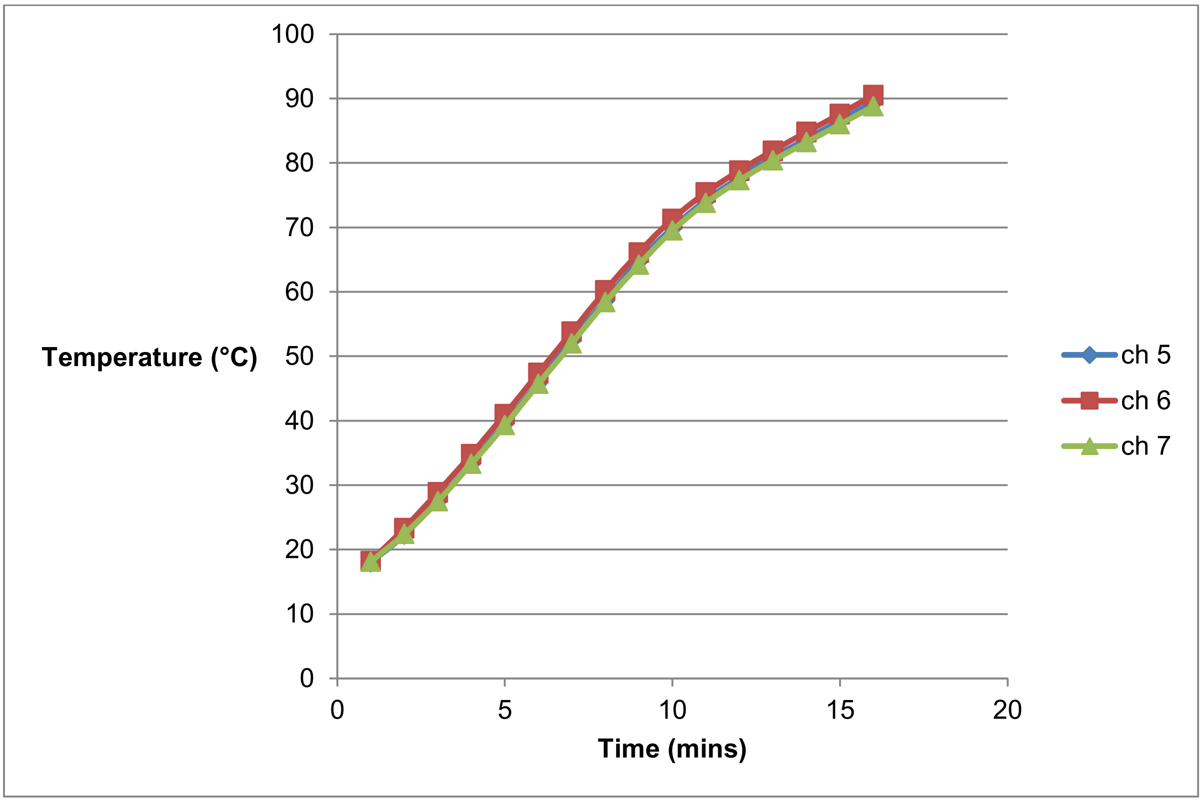


Fig 2: Temperature profile of milk heated in ohmic heating system

6) Conclusion

Development of ohmic heater will be helpful for small and medium scale processing plants. This study will help to generate basic engineering data which will be helpful for design of ohmic heater based pilot scale unit. Use of solar energy to run the ohmic heating system may also results in energy economy.Ohmic heating system was designed and fabricated based on the optimized design calculations and preliminary trials were taken to check the feasibility of the setup. Heating rate was observed to be satisfactory with rate of 3.5°C/min. Thermal efficiency of system was more than 90% but could have been improved by insulating reactor vessel. Fouling of electrode plates was reduced to minimum by provision of agitator. Problem of localized heating of plates was also reduced due to the provision of agitator which helped in proper mixing and better distribution of heat within the reactor vessel. Drilling of holes in the electrode plates led to more uniformity in mixing of milk by the agitator and temperature gradient was reduced to even more extent. By drilling, heating was more uniform not only between the plates but also behind the plates because milk was now circulated through the plates as well. It also limits foaming behind the plates. With agitator and without agitator ohmic heater took 15-17 mins and 20-22 mins for milk heating from 15°C-90°C. Sensory evaluation was also done based on the nine point hedonic scale and the results showed that there was no significant difference in the taste, flavour, colour and appearance of the milk heated by ohmic heater and conventionally heated milk. Thus, there is vast scope to use ohmic heating for processing in food industries.

7) References

[1] Cappato, L. P., Ferreira, M. V. S., Guimaraes, J. T., Portela, J. B., Costa, A. L. R., Freitas, M. Q., & Cruz, A. G. (2017). Ohmic heating in dairy processing: Relevant aspects for safety and quality. *Trends in Food Science & Technology*, *62*, 104-112.

[2] Darvishi, H., Hosainpour, A., Nargesi, F., & Fadavi, A. (2015). Exergy and energy analyses of liquid food in an Ohmic heating process: A case study of tomato production. *Innovative Food Science & Emerging Technologies*, *31*, 73-82.

[3] Joshi, C. N. (2018). Basics of Ohmic Heating-A Novel Food Preservation Technique.

[4] Kaur, N., & Singh, A. K. (2016). Ohmic heating: concept and applications—a review. *Critical reviews in food science and nutrition*, *56*(14), 2338-2351.

[5] Sakr, M., & Liu, S. (2014). A comprehensive review on applications of ohmic heating (OH). *Renewable and Sustainable Energy Reviews*, *39*, 262-269.

[6] Stancl, J., & Zitny, R. (2010). Milk fouling at direct ohmic heating. *Journal of Food Engineering*, *99*(4), 437-444.

Technical Article for Oral Presentation Article Code: OP-PO-09

Evaluation of Various Sensors for Monitoring of Quality Changes in Frying Oil

Dhruvin Patel[1]*, P.S. Minz[2], Vishal Thakur[3]
[1]*M Tech student, [2]Scientist, [3]M Tech student – NDRI, Karnal

Abstract
Frying is one of the oldest and most popular practices of cooking. But, repeated use of cooking oil had been proven hazardous due to formation of volatile and non-volatile compound which leads to undesirable changes in oil. In 1973, one of the first attempts was made to define deteriorated frying oil by German Society of Fat Research. The effects due to deterioration of frying oil range from weight loss, growth suppression, increased liver and kidney weight to cellular damage of the liver, thymus, etc. So, it is very important to test the oil quality .To determine the time when frying oils reach their maximum safe levels of deterioration is a challenging task. Conventionally, degradation is evaluated based on visual inspection, excessive foaming, odour, smoking, colour and tasting the food products, but these are not reliable methods due to their subjective nature and it may manifest only when the oil has already become unsafe. Chemical methods like free fatty acid, anisidine value, and polymerized and oxidized material are used as the oil quality indicators but are not conclusive in themselves. Presently, the rate of cooking oil degradation is indicated by the percentages of its total polar compounds (TPC). Various methods have been developed like capacitive sensor, food oil sensor, electronic nose, integrated electrode etc. However, these methods are complicated, time consuming, and expensive. In addition, improper methods to determine the time to discard the oil will result in over using it which poses a public health risk.
Keywords: Total polar Compounds, capacitive sensor, food oil sensor, electronic nose

Introduction

Frying is one of the oldest and most popular practices of cooking which make food attractive and very tasty. It is also rapid, best and simplest method of cooking because food item can be fried by dipping into the hot oil (150-190 ˚C) for a couple of minutes (Bansal et al. 2010). The fried food is endowed with attractive flavour, golden pellicle and crisp texture or mouth feel when it is fried under the appropriate conditions (Rossell, 2001; Warner, 2008). Frying oil can be different types of fatty materials i.e. hydrogenated fats and oils or hydrogenated products specially manufactured for frying. This fat is in a different state at room temperature which can be solid, semi-solid or liquid at room temperature based on types of fatty acids present. Vegetable oils are generally used due to their nutritional importance i.e. palm oil, corn oil, sunflower oil, soybean oil, safflower oil, cottonseed oil, peanut oil, rapeseed oil, and canola oil (Moreira et al., 1999). Frying involves the most complex reactions from the food science point of view (Stevenson et al., 1984). In 1973, one of the first attempts was made to define deteriorated frying oil by German Society of Fat Research (Kurzbericht 1973). During frying process, air and moisture with high temperature of oil leads to complex chemical reaction called deteriorative reaction like oxidation, isomerization and polymerization (Choe and Min, 2007; Velasco et al., 2009). These reactions results into formation of volatile and non-volatile compound. Volatile compounds evaporate with vapour and non-volatile compound remain in the oil which leads to undesirable changes in oil and quality of fried food. The kinetics of deterioration of frying fats and oils are considerably affected by food (composition, quantity of fried food), fryer (capacity, temperature, heat & mass transfer, metal), oil (repetitive use) etc.

The effects due to deterioration of frying oil range from weight loss, growth suppression, increased liver and kidney weight to cellular damage of the liver, thymus, epidydimides, and testes are happening when the highly oxidized and heated oils are fed to laboratory animals (Lizhiet al. 2010). So, it is very important to test the oil quality by determining the various chemical and physical indices (Blumenthal, 1991) that can help establish the point at which the reused oil should be discarded.

Mostly in homes, restaurants, cafeterias and food service, frying oil degradation is evaluated based on visual inspection, excessive foaming, odour, smoking and colour changes or by tasting the food products. However, these are not reliable methods due to their subjective nature and these parameters may manifest only when the oil has already become unsafe to be reused. These tests are not decisive in themselves. While the chemical indicators like Free Fatty acid (FFA), Peroxide Value (PV), Iodine Value (IV), Polymeric Glycerides, Anisidine Value (AV), Polymerized and Oxidized Material, Total Polar Compounds can be a more reliable way to assess the deterioration of frying oil (Lee et al. 2011). Innawong et al. stated that the volatile compounds produced from chemical reactions through frying process contribute to raise the peroxide value (PV) in the oil. Tsuzuki et al. argued that PV increases with time as the oil is heated at 180˚C. In addition, iodine value (IV) is used for the assessment of the suitability of the oils (Matthaus B. 2007). Garba et al. reported that oil with high IV exhibited poor performance due to the oxidation reactions of lipids and the hydroperoxide formation between the unsaturated fatty acids and oxygen. Also, free fatty acid (FFA), polymeric triglycerides, anisidine value (AV), and polymerized and oxidized material (POM) are broadly used as the pointers of the frying oil quality but are not conclusive in themselves (Gillattet al. 1990). At present, measurement of the total polar compounds (TPC) is the most commonly used method to evaluate the quality of oil because it determines overall chemical degradation taking place in the oil (Farhooshet al. 2010). Various methods have been developed like chemosensory system, fourier transforms infrared (FTIR), chromatography and image analysis. However, these methods are complicated, time consuming, and expensive. In addition, improper methods to determine the time to discard the oil will result in over using it which poses a public health risk.

For the purpose of minimizing the cost, complexity and time consumption, feasibility with automation, accuracy etc., industry required a simple sensing system to help in appraising the quality of frying oil.

Review of Literature

1. Capacitive sensor design

The capacitive sensor was designed based on the interdigitated electrodes (IDE) as shown in Fig. The sensor scheme was drawn using a CAD software before the photomask of the probe was formed. The variables of the sensor are the number of the electrodes N, width of the electrode w, electrode space s, and the length of the electrode L. Every other electrode finger is connected electrically together through a common electrode arm. These parameter have been experimented based on the maximum fabrication capability, to carry through the requirements for detecting the changes in the frying oil quality.

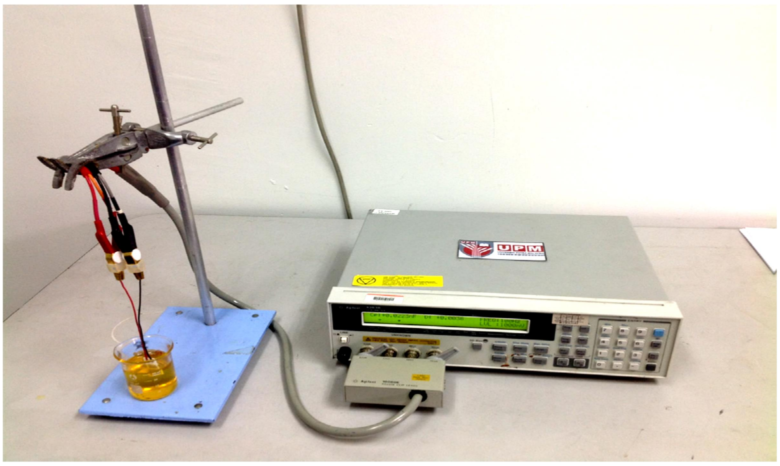


Fig.1: Capacitance sensor connected to LCR meter.

(i) Relationship between capacitance measurements and TPC measurements

The capacitance measurements data was analysed to evaluate the deterioration of frying oil quality. Overall, the capacitance of frying oil increased as the heating time increased. For example, at 100 kHz, the capacitance rise from approximately 3.48 pF to 4.24 pF with the rising of heating time from 0 to 30 h, and increment of TPC values from 6.50% to 25.50%. In this result, the trend of capacitance measured by the IDE sensor followed the same trend of TPC measured using Testo 270.

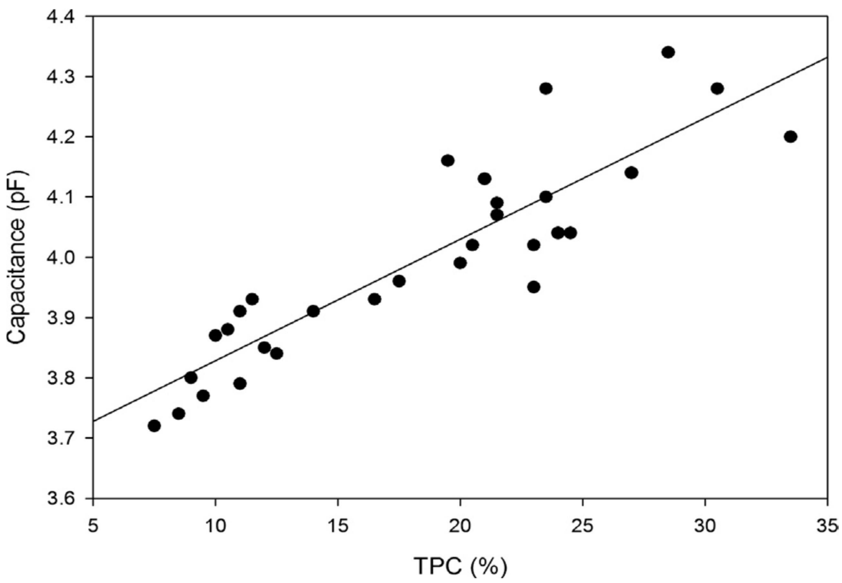


Fig. 2: Capacitance measurement at 100 kHz of heated frying oil regressed on their TPC values.

This finding is in agreement with the quantity of the polar materials in the oil increased, the dipole density and electric susceptibility also increased. For this reason, the capacitance of the frying oil samples increased. However, the fluctuation in the capacitance results might due to changes in temperature of the oven during the experiments. It is observed that the electrical capacitance measurements have significant positive correlation with TPC. The highest correlation was at 100 kHz with R^2 of 0.90. When the regression equations were validated using the validation data set, the lowest RMSE of 3.88% was found at 100 Hz.

(ii) Relationship between capacitance measurements and viscosity measurements
The viscosity values of the frying oil samples generally went up from 50.80 mPa.s to 90.60 mPa.s as the heating time increased. On the other hand, the capacitance measurements were increased from 3.48 pF to 4.24 pF as the heating time increased. Viscosity and capacitance measurements across heating time at 100 kHz where other frequencies generally had similar trend. This is where the trend of capacitance is measured by the IDE (Integrated Electrode) sensor following the same trend of viscosity measured by the Viscometer. The viscosity results can be explained by the increasing saturation of oil constituents and also the polymerization of the oil during the heating process (Santos JCO et al). The changes of capacitance value of the frying oil as a function of viscosity across heating times at 100 kHz. It was observed that the capacitance measurements have significant positive correlation with viscosity values with R^2 of 0.87. Besides that, when the regression equations were validated using the validation data set, the RMSEs found were between 3.64% and 4.99%.

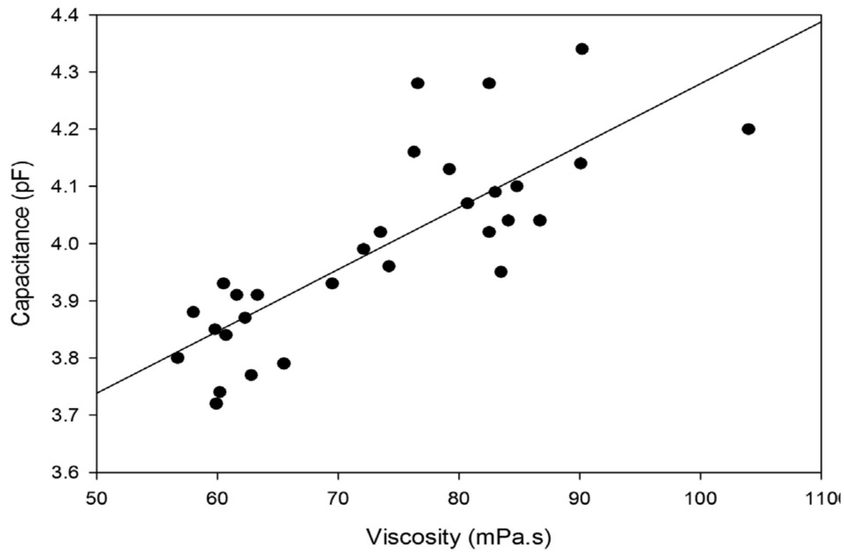


Fig.3: Capacitance measurement at 100 kHz of heated frying oil regressed on their viscosity values.

2. Electronic Nose
Changes in the headspace of frying fats during ageing are obviously a good measure for the degree of deterioration of fats. GC/FID (flame ionization detector) and GC/MS tests have shown that many fats behave similarly. That is why the influence of the kind of fat on the results of the “electronic nose” has not been examined methodically in this study.

The chance of realising the frying oil tester is good provided suitable sensors are available. The signals of sensor type 1 (special selectivity for substances responsible for the odour of used fat), compensated by signals of sensor type 2 (special electivity for pentane), correlated well with FOS values. By contrast, polar components, which are independent of the degree of degradation of a fat (for example water or odourless additional agents), are not measured. As it turned out, only a few of the tested sensors had the necessary selectivity for the substances which play a major role in recognising the degradation of fat in fat vapour. Only one of them can be used for this application, the others become clogged up, in spite of their much higher internal working temperature in relation to the frying temperature. As a consequence they are destroyed after a short working time. Strong drift or instable readings have also been observed in some cases.

A challenge is the strongly fluctuating moisture in fat vapour, caused by water from fried foods. All metal oxide sensors are more or less cross-sensitive to moisture. Therefore, precise moisture compensation is imperative for measurements taken directly after the frying procedure. This assumes stable and reproducible readings. The minimum measuring time in this tests was 1 min. As a result of the response time of the sensors at this stage the sensor signals are still not stable. This makes analysis difficult and increases the measuring uncertainity. Practical measuring times are in the range of 10-20 s, so much faster sensors are needed. However, at this stage, the results are not sufficiently suitable for setting up a practical measuring system corresponding to the set goal.

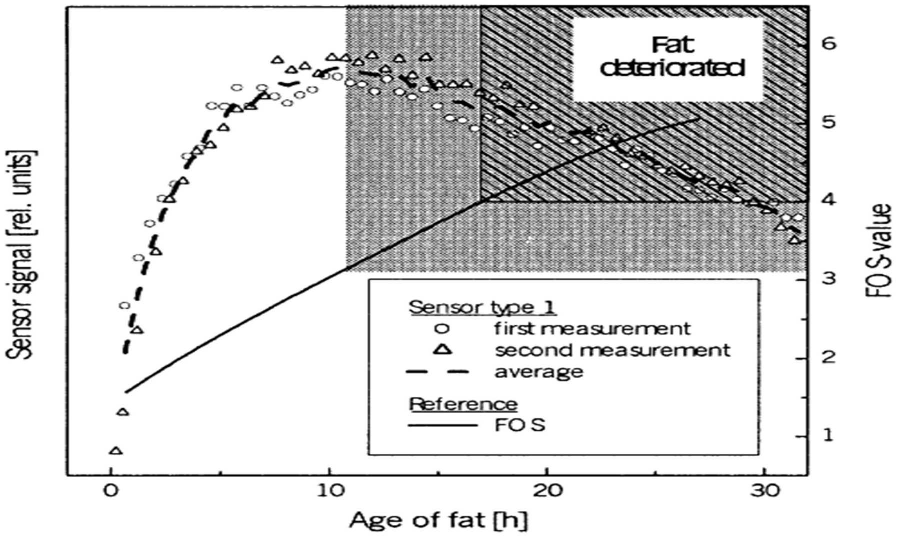


Fig.4: Comparison curve for results of Sensor type1 and Food Oil Sensor

3. Quick tests for Viscosity and Dielectricity

During the frying process the level of polar material increases continuously. With increasing level of TPM, dielectric constant of the frying oil increases too. Dielectric constant as electric measurand easily can be measured electronically. The first instrument for this purpose was the food oil sensor (FOS) from Northern Instrument Corporation. With this instrument basic studies about correlation between dielectric properties and TPM were performed. A very good correlation in the range of 0.8–0.95 between TPM determined by column chromatography and the FOS readings was found in these studies. Presently the FOS is not manufactured anymore, but some other devices based on measuring dielectric constant of frying oil are on the market, e.g., CapSens 5000 (Center for Chemical Information Technology, Switzerland), FOM 310 (Ebro Electronics, Germany), and Testo 265 (Testo AG, Germany). The Capsens instrument is a new version of the FOS, where a small sample of frying oil is put into the heated detector and the result is displayed either as FOS value or as % TPM. FOM 310 and Testo 265 also provide results as % TPM, but in these cases the sensor probe is immersed directly into the hot oil bath of the fryer. Good accordance with TPM determined by column chromatography was reported also for these instruments (Bansal, G. et al).

3.1 These tests neglected the following aspect:

In a restaurant mostly pre-fried food such as French fries are introduced into the fryer. There is a transfer of water from the fried food into the frying oil, and the migration of fat from the (often pre-) fried food into the heated oil and vice versa. More than 75% of the original fat can be exchanged with the frying fat in the fryer. Consequently, the fatty acid composition of the frying oil is constantly changing during the heating, which makes it impossible to be used as a reference for calibration. Therefore, methods such as the Food Oil Sensor or smoke point using fresh oil for calibrating must give incorrect results measuring the oil quality. The manufacturers of FOS provide a reference method for calibration of the instrument with a liquid (a mixture of myristin isopropyl ester and an alkane (Wegmüller F) delivered by the manufacturer. Using this calibration mode, unheated commercially purchased products of frying fats were measured. The results for an unheated coconut oil exceed the limit of discard. Obviously, the test results are too strongly influenced by the type of fat. Middle chain fats and oils show extremely higher results as fats with long-chain fatty acids. Another drawback is that traces of salts, water, and minerals may enhance the polarity and adversely affect measurements. Therefore, every test sample must be filtered.

4. Testo 270 cooking oil tester

The Testo 270 cooking oil tester is a handy measuring instrument for quickly testing the decomposition of cooking fats. As the power is supplied by batteries and the built-in sensor, the device is portable and there are no cables getting in the way. The ageing of the fat can thus be measured quickly and easily without long waiting times. If there are several deep fat fryers whose contents are to be checked for their TPM value, this can be done without the having to leave the sensor to cool first. Manufacturer only recommend that the sensor is wiped carefully with a kitchen towel (caution: risk of catching fire!) to avoid residues. The % TPM measured and the temperature are shown in the two-digit digital display. The temperature can therefore be determined in addition to the ageing of the fat. Due to the larger display and the optional backlighting, the values can be quickly and easily read, even in dark surroundings.

Fig.5: Testo 270 cooking oil measuring instrument

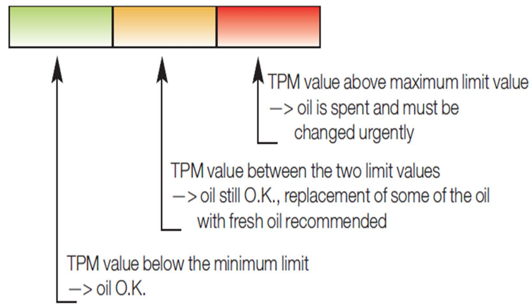


Fig.6: LED Display

The % TPM measured and the temperature are shown in the two-digit digital display. The temperature can therefore be determined in addition to the ageing of the fat.

A three-colour alarm bar additionally supports this alarm function. The bar changes colour according to the polar material content. Below the lower limit value, the bar above the display is green and the fat is still OK. In the range between the two set limit values, the bar is orange. The ageing of the fat is already advanced and the fat may require improving by replacing some of the fat with fresh fat. When the upper limit value has been exceeded, the bar is red. The fat is now so spent that it can no longer be improved by replacing it in part. The oil must now urgently be replaced.

Table 1: frying oil quality detection method and its drawback

Author	Year	Method/instrument	Drawback
Gertz, C.	2000	Food oil sensor (Fri-check®)	Calibrated with fatty acid composition and fatty acid composition constantly changes during heating constantly
Muhl, M.,	2000	Electronic Nose	destroyed after a short working time. Strong drift or instable readings have also been observed in some cases.
Weisshaar, R.	2014	NIR spectroscopy	Costly and not suitable for *halwai* shop and restaurant
Khaled, A. Y	2015	capacitance	It doesn't consider secondary products of oxidation
Khamil, K. K.	2017	Testo 270	Results can be deviate by moisture and air (a few of pF were observed as sensor response)
Merck (Germany)	-	Oxifrit-Test®	Require hazardous and flammable chemicals, therefore they are unsuitable for use in food production rooms.

Conclusion

The capacitive sensing technique has good potential in developing a simple and inexpensive way of monitoring frying oil degradation. The drawbacks of this type of technique are interferences by moisture since only a few pF were observed as sensor response. In case of electronic nose there is a problem of clogging up of sensor and corrosion of sensor also occurs. So, it leads to decrease the life span of sensor and increase cost. Food oil sensor required a calibration with special solution provided by manufacture. It is calibrated with fatty acid composition and fatty acid composition constantly changes during heating so it leads to wrong conclusion. Such other methods have been developed like chemosensory system, Fourier transform infrared (FTIR), chromatography. However, these methods are complicated, time consuming, and expensive. Available chemical methods need laboratory equipment and hazardous chemical therefore they are unsuitable for use in food production rooms. So, in actual practice the quality of frying oil is assessed based on colour, odour, excessive foaming, smoking, and by tasting the fried product. These are simple but not reliable methods because of their subjective nature In addition, improper methods to determine the time to discard the oil will result in over using it which poses a public health risk.

So, there is a more extensive research on the determination of degradation of frying fat is required. There is a need of method or instrument in the food industries which fulfil the following criteria:

- ✓ Correlate with official and recognised methods
- ✓ Provide an objective index
- ✓ Quantify the degree of degradation
- ✓ Independent from nature of frying oil
- ✓ No influence of fried food
- ✓ Easy to use
- ✓ Safe for use in food production area (no toxic chemicals, no glassware).

References

[1] Bansal, G., Zhou, W., Barlow, P. J., Joshi, P. S., Lo, H. L., & Chung, Y. K. (2010). Review of rapid tests available for measuring the quality changes in frying oils and comparison with standard methods. *Critical reviews in food science and nutrition*, *50*(6), 503-514.

[2] Gertz, C. (2000). Chemical and physical parameters as quality indicators of used frying fats. *European Journal of Lipid Science and Technology*, *102*(8-9), 566-572.

[3] Khaled, A. Y., Aziz, S. A., &Rokhani, F. Z. (2015). Capacitive sensor probe to assess frying oil degradation. Information Processing in Agriculture, 2(2), 142-148.

[4] Khamil, K. K., & Mood, M. A. U. C. (2017). Dielectric Sensing (Capacitive) On Cooking Oil's TPC Level. *Journal of Telecommunication, Electronic and Computer Engineering (JTEC)*, *9*(3), 27-32.

[5] Muhl, M., Demisch, H. U., Becker, F., & Kohl, C. D. (2000). Electronic nose for detecting the deterioration of frying fat—comparative studies for a new quick test. European journal of lipid science and technology, 102(8-9), 581-585.

[6] Paul, S., Mittal, G. S., &Chinnan, M. S. (1997). Regulating the use of degraded oil/fat in deep-fat/oil food frying. Critical reviews in food science and nutrition, 37(7), 635-662.

Technical Article for Oral Presentation Article Code: OP-PO-10

Mozzarella Cheese: Processing and Functional Properties

Lakshmana N, P. Barnwal, Ankit Deep, Anup Gadwe, Yogesh Khetra
ICAR-NDRI, Karnal

Introduction

India is the largest milk producer in the world with production of 165.4 Million Tonnes in 2016-17. The milk may be processed into various products and cheese is one of the most important products of dairy world. Converting milk to cheese is a means of conserving the major constituents, namely the fat and casein in most nutritious form by removing whey. Cheese contains high level of proteins which are rich source of essential amino acids. It is also a good source of certain vitamins and essential minerals (calcium and phosphorus). The different types of cheeses viz. hard, semi-hard and soft are classified mainly by their rheological properties governed by moisture content. The cheeses may be further classified as maturing, ripened and unripened. Mozzarella cheese is one of such variety which is gaining popularity in recent years in the country. It is a prominent member of the pasta filata, or stretched curd, cheeses that originated in Italy. It is most commonly used in pizza making due its desirable functional properties such as meltability, strechability and shredability. It is produced by using two methods such as direct acidification method and starter culture method.

Cheese: It is the most miscellaneous category of dairy products. It is possibly one of the most academically interesting and scientifically challenging among all the dairy and food products. It is cherished for the protein, fat, nutrition, long life, and minerals. It is more compact and having longer storage duration than the milk.

Cheese manufacturing is known from 6000-7000 BC. It is basically a technique of conserving the nutritive value of milk through moisture removal, fermentation, and salt-addition. There is no reliable estimate of number of cheese varieties being manufactured in the world (Banks, 1998). However, these are classified on the basis of different styles, manufacturing procedure, depending on the type of milk, species of bacteria, texture and flavours, ripening and chemical composition (Walstra *et al*., 2006).

The world production of natural cheese (excluding processed cheese) is projected at around 20 million tonnes (IDF, 2005). Cow milk contributes around 80 per cent of the natural cheese produced worldwide at the industrial level. Remaining amount is made from other type of milk (buffalo, goat, sheep etc.) at farm level. European Union (EU) and United States of America (USA) account for 70 per cent of the world cheese production in year 2012 and the production of cheese is likely to exhibit vigorous growth until year 2020 where the production will be to the extent of 16.6 million MT. The world cheese production is proposed to continue the positive slope from the last decade and the growth from 2012 to 2020 and it is expected to be 24 per cent equalizing 4.9 million MT of cheese. European Union and North America are the major cheese consuming regions in the world and the markets are largest in terms of both value and volume. In 2012, EU and North America accounted for about 70 per cent of the world cheese consumption. India is one of the fastest growing markets for cheese with compound annual growth rate (CAGR) of 18 per cent during 2014-15.

The basic technology for the production of varieties of cheese is almost similar with fairly small changes which resulting the significant differences in the final cheese. The skill of cheese manufacture consists of some main factors i.e. type and composition of milk, moisture, extent of acid production, type of rennet, curd handling and ripening conditions of cheese (Lucey *et al*., 2003). The most popular cheese varieties worldwide are Blue, Brie, Camembert, Cheddar, Gouda, Gruyere, *Mozzarella*, Parmesan, Pecorino etc.

Mozzarella Cheese

Mozzarella cheese is one of the most famous cheeses in the world. It accounts for almost one-third of total cheese consumption. It belongs to the member of *pasta-filata* group of cheese, which was originated in the Battipaglia region i.e. southern region of Italy (Citro, 1981). It is un-ripened, renneted and soft cheese variety. Traditionally, *Mozzarella* cheese is prepared from the raw buffalo milk in Italy. However, now-a-days, it is being prepared from both buffalo and cow milk worldwide.

Mozzarella cheese is salted, white, and soft, with a very sparkling surface sheen. It has a distinctive property of stretchability. The fresh cheese has slightly acidic taste, salty and pleasant aroma. The melting and textural characteristics of *Mozzarella* cheese are used for pizza application. Low moisture cheese (i.e. 45-52 % moisture) or low moisture part skim *Mozzarella* (LMPSM) cheese (45 % < moisture < 52 % and fat not less than 45 %) is considered supreme in appearance, good shredability, ability to melt, flow, stretch and possesses chewiness on cooking/baking. Usually, high moisture *Mozzarella* cheese is incompatible for pizza application because of its poor functional properties. *Mozzarella* cheese prepared from buffalo milk is better to its complement made from cow milk with respect to flavour (aromatic flavour) and stretch property.

***Processing Factors and operations for Mozzarella* cheese manufacture:**

Type of milk: Pure white colour is the basic requirement of *Mozzarella* cheese, which is lacking in cow milk cheese due to presence of carotene. Buffalo milk is stated to be more suitable than cow milk for *Mozzarella* cheese due to high yield, its characteristics aroma and its physical attributes (Bonassi *et al*., 1982; Scott, 1986). The cheese obtained from combination of cow and buffalo milk had superior organoleptic quality as well as melt ability as compared to those made from individual milks; buffalo milk cheese had higher nutritional value (Sameen *et al*., 2008).

Standardization of milk: Good quality *Mozzarella* cheese can be prepared from buffalo or cow milk standardization to 3.0-6.0% fat (Kosikowski, 1982; Patel *et al*., 1986). *Mozzarella* cheese with finest sensory attributes used as a topping on pizza, when buffalo milk was standardized to casein/fat ratio of 0.7 (Sundar and Upadhyay, 1990). *Mozzarella* cheese prepared form standardized milk with 5.0% is superior to those made from 0, 3.0 or 7.0% fat cow's milk (Ali and Abdel-Razig, 2011).

Heat treatment of milk: For *Mozzarella* cheese which is manufacture from raw milk must be pasteurized that is to be consumed fresh, because the plasticizing process does not always destroy pathogens (Caserio *et al*., 1977). Heat treatment of milk (72ºC for no hold) meant for *Mozzarella* cheese making improved protein and Total Solids (TS) recovery but decreased fat recovery, provided soft-bodied cheese, improved flavour and keeping quality (Patel *et al*., 1986).

Starter culture:

The traditional starters for Pizza cheese are the thermophiles, e.g. *Lactobacillus delbrueckii* subsp. *bulgaricus* and *Streptococcus thermophilus*. *Lactobacillus helveticus* is often used in place of *Lb. delbrueckii* subsp. *bulgaricus*, primarily to limit the browning of pizza cheese during baking. *Lb. delbrueckii* subsp. *bulgaricus* and most strains of *S. thermophilus*, are able to ferment galactose when lactose is present and are, thus, used to prevent the accumulation of galactose in the final cheese (Oberg *et al*., 1993; McCoy, 1997). In general, thermophilic starters are used much more widely throughout the world than mesophilic starters for pizza cheese.

Coagulant*:*

Various coagulants from different sources are used commercially to manufacture pizza cheese (Kindstedt, 1993). Calf rennet, consisting mainly of chymosin with a small percentage of bovine pepsin, is the traditional coagulant and is still widely used throughout the world. Microbial rennets, derived from *Rhizomucor miehei*, *Rhizomucor pusillus* and *Cryophenectria parasitica*, also continue to be used, although their use in some markets has declined considerably with the introduction of pure chymosin. As in all cheese making, the primary role of the coagulant in the manufacture of pizza cheese is to coagulate the milk and thereby initiate the process of selective concentration that ultimately establishes the chemical composition of the cheese.

Cooking and Cheddaring:

The primary functions of the cooking, draining and cheddaring steps in the making of pizza cheese are to control the moisture and calcium contents in the curd at stretching and in the final cheese. The temperature during cooking and cheddaring is one of the most useful parameters that the cheesemaker can employ to change the moisture content of the final cheese. Stretching at the low end of the suitable pH range results in lower pH values, slightly lower moisture content and calcium/protein ratio in the final cheese. Stretching at the high end of the pH range resulted in higher cheese pH, slightly higher moisture content and calcium/protein ratio and higher apparent viscosity values during ageing, indicative of a more structured, fibrous and chewy melted consistency that required longer ageing to attain optimum functionality (Yun *et al*., 1993).

Stretching and moulding:

The heating and stretching of the acidified curd is the defining operation in the manufacture of *pasta-filata* pizza cheese. Stretching has a profound impact on the microstructure and chemical composition (and yield) of the cheese, and it also represents a substantial heat treatment, all of which affect the functional characteristics of the cheese. Stretching is typically performed using continuous twin-screw mechanical mixers that contain hot water coupled with steam injection systems. Stretching involves two stages: During the first stage, curd enters the mixer and is quickly warmed by the hot water to a temperature range of at least 50–55ºC, which is necessary to transform the curd into a plastic and workable consistency. In the second stage, the plastic curd is worked by the series of augers into a unidirectional fibrous ribbon of plastic curd. The hot plastic curd then exits the mixer and is transported by augers to the moulding machine, where it is forced under pressure into a mould which gives the cheese its shape. The moulder also serves a pre-cooling function, so that the block will retain its shape when removed from the mould (Kindstedt *et al*., 2004).

Methods of Mozzarella Cheese Manufacture: The methods of manufacture of Mozzarella cheese varies considerably according to the market of the cheese.

Direct acidification method: Direct Acidification (DA) technique has gained considerable commercial interest, as it does not rely on starter performance (unpredictable, risk of phage infection, milk contaminated with antibiotics) and helps towards mechanization of production (Fox, 1978).DA method is depicted in Fig.1.The different types of acids employed in DA technique include hydrochloric acid, phosphoric acid, lactic acid**,** acetic acid, malic, citric acid and glucono-delta-lactone.

Starter culture method: Traditional procedure (Starter culture technique) for manufacture of such cheese is described by several workers. The flow chart for preparation of Mozzarella cheese by Starter culture method is depicted in Fig.2. Pasteurized milk is incubated at 33°C with rennet and a starter comprising of lactobacilli and streptococci is used. The separated curd (pH 5.2) is heated in water at 80°C, kneaded and formed into 150-250 g balls which are cooled in running water at 10-12°C for 30 min followed by immersion in chilled (5°C) brine for 30 min.

Flow Chart for Preparation of *Mozzarella Cheese*

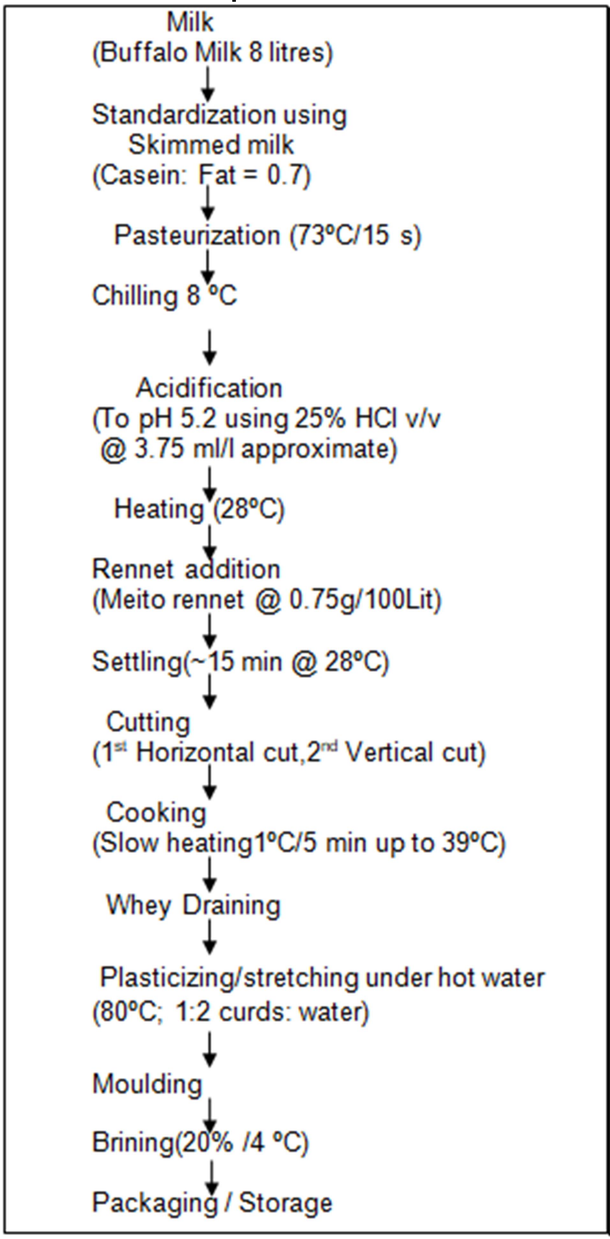


Fig.1: Direct acidification method.
(Sabikhi *et al*, 2013)

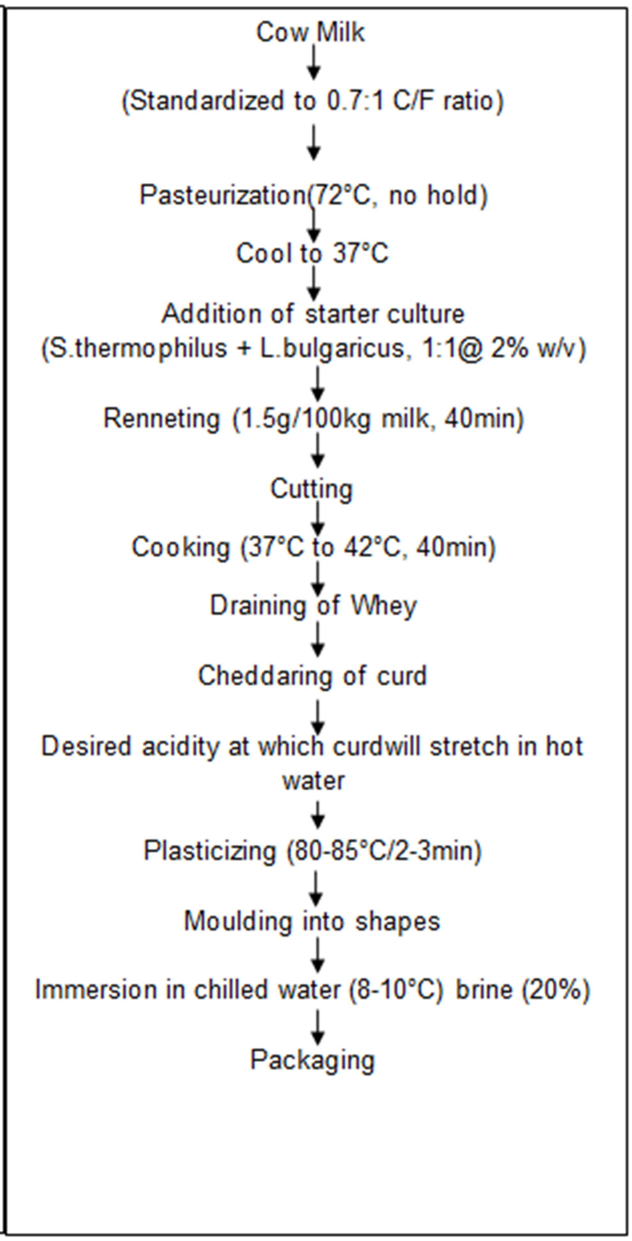


Fig.2: Starter culturemethod
(Jana and Mandal, 2011)

1. Shredability of cheese

Shredability is a broad term that includes physical attributes like as the ease of machinability, the shape and integrity of cheese shreds, the propensity of shreds to mat, and excessive production of fines during shredding (Childs et al. 2007).The shredded cheese is a value-added product. Mozzarella cheese is invariably shredded, cut or diced to enhance its handling (Gunasekaran and Ak 2002). Shredding enhances the functionalities owing to faster melting than other available forms of cheese. Conventional shredded cheese is 3.2 or 1.6 mm square cross-section, whereas fancy shreds are 0.8 or 0.4 mm. Shredded cheese should appear appetizing and eye-appealing for inclusion in salads or desserts or perhaps to be used as a garnish. Use of uniformly shredded cheese permits it to melt evenly and quickly when included in hot dishes (Dubuy 1980).

2. Meltability of cheese

Melting qualities are related to the ability of the cheese to melt to a homogenous, uniform and smooth consistency without becoming watery and releasing oil. Cooked Mozzarella cheese should melt uniformly, in order that no individual cheese shred particles are visible upon melting (Mc Mahon et al. 1993). Melted cheese has found a lot of applications, such as a pizza topping, toasted sandwiches, cheese slices on hamburgers, fillings, layers in lasagna and sauces. Cheese meltability is a functional trait reflecting closely the quality of cheese and is dictated by the consumers' requirements.

3. Fat leakage of cheese

Free-oil formation is the tendency of liquid fat to separate from melted cheese and accumulate in pockets or pools, particularly at the cheese surface. In case of Mozzarella cheese, both excessive free-oil and limited free-oil are considered to be serious defects (Jana and Mandal 2011). Abd El-Gawad (1998) and Ghosh and Singh (1996) reported that cow milk Mozzarella cheese exhibited more fat leakage than buffalo milk cheese; both made from milk of same fat content. There is a direct relation between fat content of milk and the fat leakage in Mozzarella cheese. Ageing of cheese led to marked increase in fat leakage (Richouxet al. 2008). Homogenization of milk reduces the fat leakage of cheese during baking.

4. Stretchability

Under tension, Mozzarella cheese should form fibrous strands in hot condition and should elongate without breaking. The ability of Mozzarella cheese to form such fibrous strands is quantified as stretchability (Kindstedt et al. 1989). Stretch quality is considered to be an important aspect during its end usage in baking applications. Thus, the length, tension and type of stretch (strings, feathering or fibrous) are important quality attributes of such cheese.

5. Browning and blistering

The essential quality attributes for the pizza baking performance of Mozzarella cheese are blistering and browning. Blisters are trapped pockets of heated air and steam that may be preferentially scorched during baking. Blistering and browning of cheese may occur, however a burnt appearance should be avoided (Wang and Sun 2002). Since in pizza making, retailers bake pizza at temperatures above 260°C, the tendency of the cheese to brown excessively has become a concern to the *Mozzarella* cheese industry. Colour and blister development in *Mozzarella* is due to a function of starter culture selection, sugar utilization, and manufacturing protocols that promote removal of sugars. The browning of Mozzarella cheese, resulting from Maillard reaction, is associated with its cooking (Johnson and Olson 1985; Ma et al. 2013).

Conclusion

Mozzarella cheese belongs to the member of *pasta-filata* group of cheese. *Mozzarella* cheese with finest sensory attributes used as a topping on pizza, when buffalo milk was standardized to casein/fat ratio of 0.7. It is produced by using two methods such as direct acidification method and starter culture method. It is most commonly used in pizza making due its desirable functional properties such as meltability, strechability and shredability.

Referance:

[1] Abd El-Gawad MAM (1998) Manufacture and properties of moz- zarella cheese from buffaloes milk. Ph.D. Thesis, Faculty of Agriculture, Cairo University, Egypt

[2] Ali, A.M. and K.A. Abdel-Razig, 2011. Cholesterol content of Mozzarella cheese during storage as affected by the level of milk fat. Pak.J.Nutr., 10: 65-70.

[3] Banks, J. M. (1998). Cheese. The Technology of Dairy Products. P, 81-122.

[4] Bonassi, I.A., J.B. De, C. Carvalho and J.B. Villares, 1982. Use of buffalo milk for Mozzarella cheese. Arch. Latinoam Nutr., 32: 903-912.

[5] Caserio, G., Senesi, E., Forlani, M., & Emaldi, G. (1977). Hygienic quality of Mozzarella cheese in relation to manufacturing technology. Latte, 8, 706-721.

[6] Childs JL, Daubert CR, Stefanski L, Foegeding EA (2007) Factors regulating cheese shreddability. J Dairy Sci 90:2163–2174
[7] Citro, V., (1981). A typical local product obtained from buffalo milk. Scienza-e-Tecnic-Lattiero-Casearia, 32: 263-273.
[8] Dubuy MM (1980) The French art of shredding cheese. Food Proc Ind 49:52–53
[9] Fox, P.F., 1978. Direct acidification of dairy products. Dairy Sci. Abstr., 40: 727-732.
[10] Ghosh BC, Singh S (1996) A comparison of cow and buffalo milk Mozzarella cheese. Indian J Dairy Sci 49:38–41
[11] Gunasekaran S, Ak MM (2002) In: Cheese rheology and texture. CRC Press LLC, Boca Raton, p 243
[12] IDF Bulletin (2005): The World Market for Cheese 1995-2004, 6th ed., Document No.402, International Dairy Federation, Brussels.
[13] Jana, A. H., & Mandal, P. K. (2011). Manufacturing and quality of Mozzarella cheese: A review. International Journal of Dairy Science, 6(4), 199-226.
[14] Johnson ME, Olson NF (1985) Non-enzymatic browning of Moz- zarella cheese. J Dairy Sci 68:3143–3147
[15] Kindstedt PS, Rippe JK, Duthie CM (1989) Application of helical viscometry to study commercial mozzarella cheese melting properties. J Dairy Sci 72:3123–3128
[16] Kindstedt, P., Carić, M., & Milanović, S. (2004). Pasta-filata cheeses. In Cheese: chemistry, physics and microbiology, Vol. 2. Academic Press.251-277.
[17] Kosikowski, F.V., 1982. Cheese and Fermented milk Foods. (3rd Ed.). Edwards Brothers Inc., Ann Arbor, Michigan, pp: 153-168,178.
[18] Lucey, J.A., Johnson, M.E. and Horne, D.S. (2003). Invited review. Perspectives on the basis of the rheology and texture properties of cheese. Journal of Dairy Science, 86:2725-2743
[19] Ma X, James B, Balaban MO, Zhang Lu, and Emanuelsson P (2013) Quantifying blistering and browning properties of Mozzarella cheese. Part I: Cheese made with different starter cultures. Food Res Int 54:912–916
[20] Mc Mahon DJ, Oberg CJ, Mc Manus W (1993) Functionality of Mozzarella cheese. Aust J Dairy Technol 48:99–104
[21] McCoy, D. R. (1997). Italian type cheeses. Cultures for the Manufacture of Dairy Products. Chr. Hansen, Inc., Milwaukee, WI.pp:75-83.
[22] Oberg, C.J., McManus, W.R. and McMahon, P.J. (1993). Microstructure of Mozzarella cheese during manufacturing. Food Structure. 12: 251-258.
[23] Patel, G.C., S.H. Vyas and K.G. Upadhyay, 1986. Evaluation of Mozzarella cheese made from buffalo milk using direct acidification technique. Int. J. Diary Sci. 39: 394-403.
[24] Richoux R, Aubert L, Roset G, Briard-Bion V, Kerjean JR, Lopez C (2008) Combined temperature-time parameters during the pressing of curd as a tool to modulate oiling-off in Swiss cheese. Food Res Int 41:1058–1064
[25] Sabikhi, L., Thrompkinson, D.K., NS and Khetra, Y. (2013). Cheese Technology Laboratory manual. Karnal, Haryana: National Dairy Research Institute.
[26] Sameen, A., A. Faqir Muhammad, H. Nuzhat and N. Haq, 2008. Quality evaluation of Mozzarella cheese from different milk sources. Pak. J. Nutr., 7: 7593-756.
[27] Scott, R. (1986). Cheesemaking Practice, 2nd Ed. Pp 1-36. Elsevier Applied Science, London.
[28] Sundar, R. and K.G. Upadhyay, 1990. Effects of standardization of buffalo milk for casein/fat ratio of Mozzarella cheese composition and cheese making efficiency. Int. J. Diary Sci. 43: 588-597.
[29] Walstra, P., Wouters, J.T.M., and Geurts, T.J. (2006). Dairy science and technology, 2nd Ed. Taylor and Francis Group, Boca Raton, London.
[30] Wang HH, Sun DW (2002) Assessment of cheese browning affected by baking conditions using computer vision. J Food Eng 56:339–345
[31] Yun, J.J., Kiely, L.J., Barbano, D.M. and Kindstedt, P.S. (1993). Mozzarella cheese: impact of cooking temperature on chemical composition, proteolysis, and functional Properties. Journal Dairy Science. 76: 3664-3673.

Technical Article Article Code: TP-NT-01

Hyper-filtration: Concept and Applications in Dairy Industry

Pranav Vashisht[1], Vaishali Poswal[1], Ganga Sahay Meena[2] and Nitin Kumar[3]
[1]B. Tech (DT) Students, [2]Scientist,
Dairy Technology Division, ICAR-NDRI, Karnal
[2]Assistant Professor, Food Engineering Department, NIFTEM,Sonipat

Abstract

Reverse osmosis (RO) is a dewatering process, also called Hyper-filtration and considered as a non-thermal milk processing because it concentrates milk at ambient temperature without altering its ph. Hence, this technique retains wholesomeness, nutritive value as well as typical sensory attributes in treated product. Within its working limits, this process is still most economical dewatering process from liquid dairy streams such as milk and whey. However, higher osmatic pressure of feed limits upper concentration of total solids in concentrated milk by RO process. Several dairy products have been manufactured using RO alone or in combination with other conventional processes. Hence, RO finds both classical and new applications in dairy industry on commercial scale.

Key words: Reverse osmosis, Concentration, Energy efficient, Non-thermal, Waste

Introduction

In dairy industry, membrane technology deals with the separation, concentration and purification of desired milk constituent (s) using a specific set of equipment's. Membrane processes are different from dead end filtration as the former are performed in a closed system, mainly used for micro (smaller molecules <10 μm) molecules and driven by pressure that is governed by the type of membrane process such as microfiltration (MF), ultrafiltration (UF), nanofiltration (NF) and reverse osmosis (RO). The MF is known as cold sterilization process as it can remove most of the microorganisms and spores, while UF is known for its ability to concentrate proteins in their native state. The NF process which also called "loose RO" has established application in demineralization of dairy streams and also in concentration of lactose in skim milk and whey. The RO, a dewatering process is also called 'Hyperfiltration'. Thus, membrane processing is considered as a non-thermal mean of milk processing. These membrane processes are usually performed at either 50 or <10º C without altering pH of milk. Hence, this technique retains wholesomeness, nutritive value as well as typical sensory attributes in treated product. Reverse Osmosis (RO) has found different applications in making innovative and healthy dairy products. The initial research conducted by S. Sourirajan and S. Leob has opened a wider field of application for this process. In 1998, Cheryan has reported RO as one of the most economical dewatering process from liquid food products. Till date, within working limits, RO is the most economical dewatering process for dairy streams. Although different factors influence this process, however its efficiency largely depends upon flux and life of membrane.

Operational Principle

The basic principle of RO includes the selective filtration of the feed molecules from the feed (mixture or solution) employing a selective membrane at some molecular level under the action of pressure gradient created externally with the help some pump or other flow maintenance device. The RO membrane has different retention coefficient defined as the fraction of particular component retained by the membrane for low and high molecular weight molecules. For larger molecules such as proteins, fat and sugars, smaller ions like sodium and low molecular weight compounds, its retention coefficient were 0.999, 0.90-0.98 and 0- 90, respectively.

Membrane Materials and Configurations

The membranes used for RO applications are either of first generation or of second generation, hence, apparently made of organic polymers such as polyamides, cellulose esters, polysulphone, etc. These materials are highly specific towards their resistance towards pH and cleaning or sanitation solutions and ability to withstand applied pressure and temperature as well as plastic creep (the ability of material to move slowly or deform permanently under the influence of mechanical stresses). Till date, manufacturing of RO membranes from third generation membrane materials such as alumina oxide or zirconium oxide have not become possible. Further, RO membranes are characterized to retain more than 90% sodium chloride (NaCl) and it is very difficult to modify polymers to achieve such high retention ability. This can easily explain that why RO technique in dairy industry at commercial scale is limited to the membranes like cellulose acetate. For industrial applications, now thin film composite (TFC) membrane is being preferred because of their better performance. RO membranes are very thin in nature. The separation of molecules having ≥100 molecular weight (like amino acids, sugars, chlorides, calcium and other minerals etc) are retained by active layer (5-30 nm, pore size , 5-20 Å) which is supported by a more open support material. Thus, in RO process, molecules are separated through a membrane having <0.1nm pore by sieving and diffusion mechanism under the influence of applied extra pressure of 3-5 MPa that is necessary to overcome osmatic pressure exerted by type and concentration of feed components and enabled the flow of water from higher to lower side of pressure. For example, whey protein concentrate exerts pressure of ~3.5 MPa, hence the operating pressure of RO process must be higher than this value i.e. ~4.8-5.6 MPa or more. In other words, transmembrane pressure (TMP) of even 10MPa is required for RO. The smallest entity of the membrane which can be exchanged is normally called a module or an element. In order to perform a task, required membrane area can be placed in these modules in different ways is called membrane configurations. Basically, these are of four types i.e. Tubular, Hollow Fibre, Plate and Frame and Sprial Wound, however, each of them have their own pro and cons.

Concentration Polarization and Membrane Fouling

With the advancement of RO concentration, the concentration of retained/rejected solutes increases and limits its use in further concentrating the product due mainly increased osmatic pressure. This phenomenon is typically characterized by gradual decrease in membrane flux, described as critical flux and limiting flux at different stages of the concentration process and governed by several factors such as feed composition and characteristics, viscosity, temperature, turbulence, osmatic pressure and concentration polarization. Maintenance of hygienic conditions during RO concentration is a major challenge of this technology. However, due to its technological and economic advantages over the other older and conventional methods of processing dairy industry has widely accepted this process for industrial applications globally.

Concentration polarization and membrane fouling plays a major role during RO concentration. The formation of gelatinous boundaries or formation of cake over the surface of membrane due to accumulation of rejected feed components which acts as a secondary barrier in the path of feed molecules permeating through the membrane is known as concentration polarization and characterized with reduction in membrane flux i.e. decreases process efficiency. The interaction of these rejected solutes with membrane is called membrane fouling which can be reversible or irreversible in nature. Failing in removal of such gel/cake/surface layers well in time leads to severe fouling of the RO membrane and the same has permanent damaging effects on the membrane. However, pre-treatments of feed, proper plant operation, turbulent flow during operation as well as efficient cleaning and sanitation can decrease/ slow down or may have some control on concentration polarization and membrane fouling. Membranes are critically evaluated for their separation ability and efficiency and economic feasibility prior to use. Several membranes are compared with each other for their key performance indicators such as retention coefficients, flux and membrane life to select a better membrane. Generally, life time of RO membranevaries between 6 to 15 months or one to two dairy seasons.

Applications in Dairy industry

Reverse osmosis is capable in concentrating different liquid dairy streams at milder temperature without inducing any thermal denaturation, degradation and aggregation of heat labile milk components such as whey/serum proteins and vitamins. Moreover, within its working limits of concentration, it still remains as an economic process as compared to open pan, vacuum pan and multiple effect evaporation systems and thus, feasible at industrial scale. Beaton (1978) reported that RO was employed for 2-4× concentration of whole milk, skim milk, cheese/casein whey and UF permeate and the resultant retentates were converted in to liquid milk, fermented products, and whey and lactose powders, respectively.

1. Replacement and supporter of evaporators

Bird (1996) reported that RO system cannot work better for higher concentration of sweet cheddar cheese whey. However, it worked well lower concentration of whey. RO is capable in reducing hydraulic load i.e. amount of water to be removed from a product in finite time from the evaporator and its throughput.Marshal (1985) reported that RO, 5-7 effect evaporator with MVR and freezing process requires 9-19, 37-52 and 92 KWh energy per 1000 kg of water removed, respectively.

2. Concentration of Whey

Whey is the major by-product of dairy industry and contains only about half of the (5.5-6.5 %) TS of milk. Thus, removal of 93-95% water from whey generally becomes costlier than removal of water from other dairy streams. Because of this reason, dairy owners generally prefer to either offer whey to farmers for animal feeding or dispose it instead of processing. Further, its biological oxygen demand (BOD) is very high (40,000 mg/kg or more) that creates serious environmental threats upon dumping especially to water bodies. RO lead to commercial production of whey based products such as protein and lactose as this process is capable in easy recovery of whey solids at feasible cost. In lack of drying facilities some cheese factories have used RO for pre-concentration of whey that markedly reduced bulk and thus transportation cost. Concentration of whey up to 20% TS in RO can enhance the efficiency of different methods of whey demineralization (Kelly et al. 1991; Saxena et al., 2009).RO can save upto 60% on fuel required by evaporators for the concentration of whey.

3. Ultra-filtration permeate concentration by the use of RO

Concentration and fractionation of whey, skim milk and whole milk by UF process results in huge amount of permeate containing mainly lactose and salts. To produce lactose of high purity UF permeate needs to be concentrate more than 50% TS before its crystallization. RO is a highly efficient process for the concentration of UF permeates with minimum energy and thermal degradation of its components (Pal and Cheryan 1986). RO can concentrate UF permeate it's 5-8% TS to maximum 25%, beyond this level its further concentration is not economically feasible due to higher lactose contents.

4. Skim Milk Concentration

Pal and Cheryan (1985a) reported that 3 × skim milk concentrations is possible in RO system which increases its TS 9% to27%. As per Cheryan et.al. (1986) energy required to concentrate the milk up to 45% TS through combineduse of RO membrane and evaporator is only about 33% compared that required for multi stage evaporator alone. Donnelly et al., (1974) reported that 2× concentration of skim milk in RO and its further evaporation doubled the capacity of the evaporators. Using such RO concentrated milk (25% TS), a good quality condensed and evaporated milk have been manufactured (Abbot et al. 1979) and this also prevented the major problems such as browning and development of cooked flavour. Skim milk concentrated up to 4× concentration either through RO only or by combined use of RO and evaporator havebeen used to produce skim milk powder. Both processes resulted in cost reduction, but former has less loss of vitamins as compared to latter.

5. Ice Cream Manufacturing

Ice cream consists ~36% TS of which around 21% are milk solids. Skim milk powder is one of the major ingredients use in manufacturing of ice cream. Ice cream manufactured using RO concentrate along with milk fat, sugar, stabilizer, and emulsifier was used to replace SMP by Bundgaard (1974), while Sorbensen (1980) concluded that ice cream thus produced has better flavour as well as creamier consistency. Moreover, such ice cream has smoother melt down in mouth and uniform release of water (Bundgaard 1974).

6. Yoghurt Manufacturing

Generally, low heat skim milk powder is use to increase the TS of yoghurt and hence to maintain its quality. This low heat SMP can be prepared by pre-concentrating it through RO technique. Dixon (1985) used RO concentrated skim milk for the preparation of yoghurt. Yoghurt such produced has better apparent viscosity and decreased the whey syneresis.

7. Khoa Manufacturing

RO concentrated milk has been used to manufacture traditional Indian dairy product such *khoa*. Pal and Cheryan (1986a) reported that *khoa* prepared from cow milk concentrated in RO process had higher moisture and higher fat contents but lower ash content as compare to the normal one. No significant difference was observed in flavour, body and texture, but yield increased. The energy consumed in RO and conventional *khoa* making processes were also compared. RO technique method consumed80 kcal/kg and 25 kcal/kg energies in batch and continuous RO process and, resulted in net saving of around 335 to 430 kcal/kg of milk.

8. *Dahi* and *Chakka* Preparation

Due to presence of lower protein and calcium contents in cow milk, *dahi* made from it is usually weak and fragile than buffalo milk *dahi*. Pal et al. (2002) prepared *dahi* from cow milk by concentrating it to 1.25 to 1.50× concentration by RO and this method produced *dahi* that was at par with buffalo milk *dahi* due to enhanced casein and calcium contents. Further, ~7.20 % higher yield was obtained in *chakka* produced from cow milk that was 2.5× RO concentrated.

9. In *Rabri* and *Basundi* Preparation

RO technique can be used to concentrate the milk up to ~ 24% TS followed by sugar addition and further concentration up to 50% using classical thermal processes which can induce the desired cooked flavour. Further flakes in *rabri* can be stimulated by the addition of shredded *paneer* to the final product.

10. Cheddar Cheese Manufacturing

RO concentrates obtained from skim milk and whole milk has been used in cheese production that improved the yield of the cheese due to retention of whey solids without any adverse effect on product quality.

11. Whole Milk Concentration by the use of RO

Abbot *et al.,* (1979) have been reported the concentration of whole employing RO process and changes occurred in this. The effect of RO process on bacteriological quality and free fatty acid (FFA) content has been shown in following Table.

Liberation of free fat was resulted from damaged fat globules due to shearing action of high pressure pump of RO. Further, lipase enzyme activation results in rancid flavour in concentrated milks produced from unheated milk due to its action free fat. Thermization (60-70^{0}C) treatment of milk prior to its concentration in RO checked the problem of poor bacteriological quality while use of small diameter pipe in place of pressure control valves in retentate line as well as retentate cooling below 10^{o}C reduce the free fat content markedly (Berbano*et al.,* 1983).

Table: Changes in bacterial count and FFA content of raw and heated (80^{0}C/no hold) milks during RO concentration (Source: Abbot *et al.,* 1979)

Concentration Ratio	Bacterial Count		FFA(millieq/100g fat)	
	Raw Milk	Heated Milk	Raw Milk	Heated Milk
1.0	4.1 X 10^3	1.4 X 10^2	1.7	1.7
1.5	1.8 X 10^4	2.1 X 10^2	9.0	2.3
2.0	2.6 X 10^2	4.3 X 10^2	10.2	1.7
2.5	2.8 X 10^4	5.1 X 10^2	10.9	1.8

This RO concentrated whole milk obtained has following applications and advantages:

a) **Reduction in Transportation Cost:** RO can be efficiently used to reduce the volume of the milk prior to transportation. As per Langdon et al. (1985) initial volume of milk can be reduced to 50% by RO and this result in marked decrease chilling cost and storage cost, transportation cost, respectively. As per Zadew (1985) central collection chilling depots are the most suitable place for the reduction of volume by RO technique from where milk is transported to factories. Based on certain assumptions, Gupta and Pal (1993b) reported no milk solids loss, no change sensorial as well as chemical properties of concentrated milk in 48 hours at refrigerated conditions, transported after concentration in RO to main plant from rural chilling centres. Further, energy required for concentrating the milk was 369.7 and 470.9 KJ/kg of water for 1.5 and 2 fold concentrations, respectively and it was corresponding to 3.64 and 4.64 paise. Thus, the payback period of this technique was lesser than a year.

b) **Production of Fluid Product:** Dixon (1985) reported that RO concentrated whole milk can be used to prepare certain fluid products like plain milk, high protein milk, flavoured milk etc. For the preparation two fold concentrated milk can be diluted with water upto TS of desired product and further homogenization, pasteurization, addition of flavour etc. steps can be followed. It was reported that effect of RO technique was negligible at vitamin concentration of product. Also there was no significant difference in the product prepared from the normal milk and from the milk subjected to RO concentration treatment. Further the shelf life was reported to be 9 to 12 days under refrigerated conditions.

c) **Production of UHT Products:** Kocak (1985) reported the use of RO concentrate of around 26% TS diluted to 13% TS for UHT processing. RO concentrate first stored at 2°C for 24 hours followed by its dilution with water and then subjecting it to the UHT processing i.e. heating at 140°C for 3 sec followed by two stage homogenization. The reason behind the storage was to stimulate commercial operations involving subjecting milk to RO concentration followed by its transportation to the main factory. Further it was also reported that sediment level was lower in the RO concentrated product as compare to the normal product. This difference was attributed to the lower calcium content in former. Although there was no significant difference in the gel formation ability and apparent viscosity but pH was observed to be slightly lower in case of RO concentrated UHT samples.

d) **Production of Whole Milk Powder:** It was reported that use of RO technique for the pre-concentration of whole milk prior to evaporation and spray drying abates the cost upto much extent. However, RO cannot be completely used for the replacement of conventional evaporator because spray drying requires 45-50% TS feed and that much concentration cannot be possible by the use of RO alone. Although major savings in energy can be obtained by concentrating the whole milk by RO upto 30% TS followed by its evaporation in evaporator upto 40-48%TS then subjecting it to spray drying. Abbot et al. (1979) reported that there was no significant difference in the properties such as solubility; bacterial count etc. in the RO concentrated WMP and normal milk WMP. Although free fat content was observed to be higher in case of former because of degradation of fat by the action of high pressure pump which may limits its shelf life. This limitation can be overcome by subjecting milk to proper heat treatment prior to concentration to inactivate the lipase enzyme.

Application of RO in Waste Treatment: It was reported that waste generated from rinses of cleaning in place system has high biological oxygen demand (BOD) value and if dumped, causes severe pollution of

water. Further treatment and handling of this waste requires certain effluent equipment which increase the overall cost of operations in dairy industry.RO system can be used for the removal of water from the waste and hence reduces the volume of waste which is easier to handle further.
Vourch et al., (2008) used RO to treat dairy industry waste water for its reuse. During the experiments, dairy waste water was stored at 25°C for few hours (to prevent increase of total organic carbon, TOC) followed by RO treatment until removal of 90-95% water from it. Mineral concentration in treated water was markedly low and quality wise it was at par with vapour condensate. Hence, it can be reuse for the purpose of heating, cooling and cleaning.

Conclusion

The principle and various applications of RO process have been discussed here. Within working limits, RO process still acts as an economic and efficient dewatering technique at ambient temperature. The concentration of dairy streams to very high levels of total solids alone by RO acts as a major limitation of this process. Like other processes life of membrane, poor flux and problem of concentration polarization and fouling are other limitations of this process. However, these applications have potential in bulk and transport cost reduction and have been successfully applied alone or in combination for the production of different dairy products.

References:

[1] Beaton, N. C. (1979). Ultrafiltration and reverse osmosis in the dairy industry-An introduction to sanitary considerations. *Journal of Food Protection*, *42*(7), 584-590.
[2] Bird, J. (1996). The application of membrane systems in the dairy industry. *International Journal of Dairy Technology*, *49*(1), 16-23.
[3] Heath H. and Jamie A(2011). Membranes in the Dairy Industry doi: 10.1021/bk-2011-1078.
[4] Khatkar B (2007) Daya Publishing House Delhi 110 035 Applications of RO for concentration of Milk in *Food Science and Technology*, Daya Books, Chapter 10, 120-132.
[5] Kumar, P., Sharma, N., Ranjan, R., Kumar, S., Bhat, Z. F., &Jeong, D. K. (2013). Perspective of membrane technology in dairy industry: A review. *Asian-Australasian journal of animal sciences*, *26*(9), 1347.
[6] Madaeni, S. S., &Mansourpanah, Y. (2004). Chemical cleaning of reverse osmosis membranes fouled by whey. *Desalination*, *161*(1), 13-24.
[7] Pal, D., & Cheryan, M. (1987). Membrane technology in dairy processing part 1 reverse osmosis. Indian Dairy Man 39 (6), 251-267.
[8] Vourch, M., Balannec, B., Chaufer, B., &Dorange, G. (2008). Treatment of dairy industry wastewater by reverse osmosis for water reuse. *Desalination*, *219*(1-3), 190-202.

मॉडर्न डेयरीज़®
स्वाद खुशियों का™
सेहत, स्वाद व खुशियों
का अनूठा बंधन
DAHI
CHACH
LASSI
लस्सी • लॅमी
DAHI
DAHI
CREAMY MILK
PASTEURISED FULL CREAM MILK
WHOLESOME MILK
HEALTHY MILK
SMART MILK
PROCESSED CHEESE
Pizza Cheese
BUTTER
PANEER
SHWETA
PURE DANEDAR GHEE
SLIM MILK
श्वेता
दूध·दही·मक्खन·पनीर·पीज़ा चीज़·शुद्ध देसी घी

Technical Article Article Code: TP-NT-02

Application of Membrane Technology for Dairy Processing

A. M. Rathva[1], I. A. Chauhan[1], A .D. Patel[1], Kinjal Baldha[2], S. M. Patel[3]
[1]Assistant Professor, [2]PG student, [3]Professor and Head, Dairy Engineering Department, SMC College of Dairy Science, AAU, Anand

1. Introduction

The milk is considered as the best, ideal and a complete food and has an important place in human diet especially in vegetarian diet (Shekhar and Kumar 2011; Shekhar *et al*. 2010; Kumar *et al*. 2011b; Kumar and Rai 2010).

The term "membrane technology" is used to collectively represent the separation processes by using specific semi-permeable membrane filters to concentrate or fractionate a liquid into two liquids of different compositions (Winston and Sirkar 1992) by selectively allowing some compounds to pass while encumbering the others. The liquid that is able to pass the membrane is known as "permeates" and retained liquid is known as "retentate" or "concentrate". In simple term, membranes are typically 'cross-flow', where two streams are produced - a 'permeate' and a concentrated 'retentate'. The efficiency of membranes is largely governed by the hydrostatic pressure gradients (also known as *"transmembrane pressure*") across the membrane and concentration gradient of the liquids. In few cases, electric potential has important role (Winston and Sirkar 1992; Jelen 1992; Klein *et al*. 1987; Porter 1990).
The contemporary use of membranes in dairy processing hadbeen reviewed in International Dairy Federation special issue published in 2004 and by some other authors (Daufin, et al.2001; Fox et al.2004; Moresi and Lo Presti2003; Pouliot2008; Rosenberg1995; Saxena et al.2009)

2. Classification of membrane techniques

Membrane filtrations are classified by membrane types, pore sizes, and process conditions into microfiltration (MF), nanofiltration (NF), ultrafiltration (UF), and reverse osmosis (RO). These membrane filtrations have been applied in the dairy industry for the removal of bacteria in milk, standardization of milk, concentration of milk protein, fractionation of caseins, cheese making, and whey processing for many years (Rosenberg, 1995). Membrane technologies have also been used in the dairy industry for new product development, improving product quality, and enhancing process profitability.

3. Application of Membrane Process in dairy Industry

In the modern dairy processing, membranes play a major role in clarification of the milk, increase the concentration of the selected components as well as separation of the specific valuable components from milk or dairy by- products etc. Membrane separation technology seems a logical choice for the fractionation of milk, because many milk components can be separate on size (Brans *et al*. 2004).Membranes are already well established in the processing of whey and are gaining popularity in other dairy applications (Daufin*et al*. 2001). The membrane technology improves the economics of dairy by reducing the cost of production as well generating new revenue resources (Siebert *et al*. 2001). Membrane technology proves a suitable and economical alternative to many important processing stage of milk in dairy industry such as centrifugation, bactofugation, evaporation, demineralization of whey, etc. (Pouliot, 2008).

The use of membrane filtration technology offers a wide range of advantages for the consumer as well as for the producers. The membrane technology is a novel non thermal environmental friendly greener technology with full of future possibilities that minimizes the adverse effect of temperature rise such as change in phase, denaturation of proteins and change in sensory attributes of the product. The membranes remove unwanted components viz. microorganisms, drugs or sediments that have a negative impact on product quality, making the final product more attractive in texture and increasing its shelf life. The selectivity of membranes is very high due to the unique mechanisms of action such as ion exchange, solution diffusion, etc. The membranes are suitable to different types of plant design and expansion due to their compact design and need very low maintenance. The operations of the membranes are very simple, competitive and do not required any specialized knowledge to handle or operate them. To get the desired effect, it is sometimes necessary to use a combination of membranes rather than single membrane (Balannec et al., 2005; Vourch et al., 2005) and redesigning overall industrial production by the integration of various already developed membrane operations (Saxena et al., 2009; Kumar et al., 2013).

Reverse Osmosis (RO)

RO is the most energy efficient dewatering process. RO membranes separate solutes with a molecular weight of approximately 150 Daltons and above. Hence fat, proteins, lactose and all undissociated minerals are retained and concentrated by the membrane and only water and some ionized minerals are allowed to pass through. Fluid milks and buttermilk can be partially concentrated economically using RO, particularly for the preparation of concentrated and dried products including indigenous dairy products like *Khoa*, *chakka*, *shrikhand*, *rabri*, *basundi* and kheer. The economical levels of RO concentration for whole milk is up to 30% TS and for skim milk, 22% TS.

Commonly used membrane techniques in dairy industry

Type	Pore size	Molecular weight cut off	Pressure and principle	Compounds in retentate	Application in dairy industry
Microfiltration	0.2-2 µm	>200 kDa	Low pressure (below 2 bar) driven membrane process	Low retentate, separation of protein, bacteria and other particulates	- Skim milk and cheese - Dextrose clarification - Bacteria removal
Ultrafiltration	1-500 µm	1-200 kDa	Medium pressure (1-10 bar) pressure driven process to overcome the viscosity	Large retentate with casein micelles, fat globules, colloidal minerals, bacteria and somatic cells	- Standardization of milk, reduction of calcium and lactose - Protein, whey, milk concentration
Nanofiltration	0.5-2 nm	300-1,000 Da	Medium to high pressure (5-40 bar), mass transfer phenomena by size exclusion and electrostatic interactions	Low productivity, separate monovalents salt and water	Desalting of whey, lactose free milk, volume reduction
Reverse osmosis or hyperfiltration	No pores	100 Da	High pressure, 10-100 bar	Based on the principle of solubility, low productivity	volume reduction, recovery of total solids and water

Source: Rosenberg, 1995; Childress and Elemelech, 2000; Pouliot, 2008

Production of *Khoa* by RO process

Khoa, an important indigenous Indian milk product, is presently manufactured on a small scale by continuous boiling of whole milk until a desirable solids concentration (65-70% total solids) is obtained. In recent years, several attempts have been made to develop new methods including the use of scraped surface heat kettles or heat exchangers for commercial production of *Khoa*.

The use of concentrated milk having up to 30% TS has produced *Khoa* of highly satisfactory quality. The reverse osmosis, being energy effective process for pre-concentration of milk prior to the manufacture of *Khoa*, has great potential in India. *Khoa* has been prepared from cow milk as well as buffalo milk by atmospheric boiling of RO retentates in a steam kettle (Gupta and Pal, 1994; Pal and Cheryan, 1987).

Pal and Cheryan, (1987) analysed that the process is conveniently amenable to continuous production of *Khoa* from RO milk retentate using SSHE. Such process offers attractive energy saving in the initial concentration of milk. The energy consumption in RO concentration was estimated about 80 kcal/kg of milk for batch process and 25 kcal for continuous process, which brings about a net saving of 335 to 430 kcal/kg of milk.

Application of RO in *peda* making

Dewani and Jayaprakash (2006) optimized the process of production of *peda* from RO pre-concentrated milk and vacuum evaporation because In plain *peda* making process, prolonged heating of milk leads to severe browning and loss of nutritional quality. It involved standardization (5% milk fat and 8.5% MSNF) followed by heating of milk to 90 °C/10 min, pre-concentrating milk to 30% total solids (TS) by RO and further concentrating to 40% TS at 54 - 56 °C and a vacuum of 630 mm of Hg by using a single effect vacuum evaporator. This concentrated milk was used for *peda* making. It was reported that the colour and appearance, body and texture scores of *peda* prepared from RO pre-concentrated milk improved appreciably.

Preparation of *dahi* from RO process

Pal *et al*., (2002) stated that *Dahi* is another important traditional fermented milk product where RO can play an important role. *Dahi* made from cow milk is weak and fragile in comparison with buffalo product. This problem is due to lower protein and calcium contents in cow milk, which are responsible for firmer curd. Partial concentration of cow milk to about 1.25 to 1.5 folds level by using RO system and preparing *dahi* from it adopting standard method has been found very useful in producing *dahi* similar to that buffalo *dahi*.

Preparation of *chakka* from RO process

Sachdeva *et al.* (1994) reported manufacture of *'Chakka'* from milk concentrated by reverse osmosis (RO). Cow milk, standardized to fat: SNF ratio of 1:2.2 (12.5% TS), was pasteurized and concentrated (2.5 fold) using and RO plant equipped with tubular, polyamide membranes. A temperature of 50°C and a pressure of 30 kg/m^2 were used for concentration. The concentrate was subjected to heat treatment of 90°C/5 min, cooled to 22°C, cultured at the rate of 2% with a mixed strain lactic culture and incubated for 18 hours. The coagulum then obtained was filtered and a minimal amount of whey (4.5 lit. /40 lit. of coagulum) having 18% TS was removed from it to get the *chakka*. The RO *chakka* had 32.7% TS, fat 10.3%, 8.8% protein, 11.7% Lactose and 1.9% ash against the respective values for conventional *chakka* of 28.0%, 11.5%, 12.6%, 2.6% and 1.3%. The yield of RO *Chakka* was 35.5% as compared to 28.3% in case of conventional *chakka*. Increased yield, higher solids recovery, reduced processing time, increased throughput, access to mechanization and alleviation of whey disposal problem are claimed as major advantages of this process.

Sharma and Reuter (1992) developed a process for production of *Chakka* and *Shrikhand* using ultra filtration technique. The process consisted of agitation of *Dahi* at slow speed, heating to 60-62°C for 5 min., ultrafiltration at 50°C, pressing of retentate to get *Chakka* and then mixing with sugar in planetary mixer.

Sachdeva *et al.* (1994) attempted the manufacture of *Chakka* by reverse osmosis which involved heat treatment (90°C for 5 min.) to RO concentrate, cooling to 22°C, inoculation with 20% mixed lactic culture, incubation for 18 hrs. and then removal of whey by filtration to get *Chakka.* Increased yield, higher solid recovery, reduced processing time, access to mechanization and alleviation of whey disposal problem were claimed as major advantages of the process.

Application of RO in other traditional desiccated dairy products

Rabri and *basundi* are partially concentrated and sweetened traditional milk products. Whereas *rabri* contains several layers of clotted cream (*malai*), *basundi* has either smooth consistency or small grains of coagulated milk solids. commercial method of preparing *rabri* using RO process involves pre concentration of standardized milk to about 24% total solids in a RO plant, addition of sugar to this concentrated milk and generation of characteristic cooked flavour by heating the mixture to about 95ºC followed by final desiccation to about 50% total solids in a scraped surface heat exchanger. The desired flaky texture of *rabri* is simulated by adding shredded (very thin slices) paneer to hot sweetened desiccated milk.

Preparation of Paneer by RO process

Gupta and Pal (1987) reported that Buffalo milk was concentrated, employing reverse osmosis to about 1.5 (25% TS) and 2.0 (33% TS)-folds. Reverse osmosis concentrates as such and after dilution to the composition of normal buffalo milk (6% fat and 9.5% TS) were used for the manufacture of paneer. Product from reverse osmosis processed milk retained higher moisture in comparison with control paneer and hence, the yield was about 2 to 3% higher. The recovery of milk solids in reverse osmosis paneer was always more than 68%, whereas in control paneer, it was 66.9%. texture profile of reverse osmosis paneer vis-a-vis control paneer, the sensory scores of the two types of products did not differ significantly.

Preparation of Cheddar cheese from RO process

Bynum (1984) The effect of concentration of whole milk by reverse osmosis prior to Cheddar cheese manufacture on various yield parameters was investigated whole milk was reduced in volume by 15% before cheese manufacture. Cheese total solids yield was improved by approximately 0.6% with the reverse osmosis treatment. Cheddar cheese manufacture from reverse osmosis whole milk retentates.

Nanofiltartion (NF)

World-wide an increasing amount of whey is industrially processed to whey powders and other high-quality, protein-rich products meant for nutritional use (Clark, 1987; Zadow, 1987). Whey intended for human or animal consumption will increase in value if it is demineralised (Kelly *et al*., 1991; Horton, 1987). Nanofiltration (NF) is an alternative for the concentration and demineralization of whey by Evaporation (EV) + by Electrodialysis (ED) which is now in practice (Gregory, 1987). NF-membranes have a high permeability for (monovalent) salts (NaCl, KCl) and have a very low permeability for organic compounds (lactose, proteins, urea). Nanofiltration is also sometimes referred to as ultraosmosis, 'leaky' or 'loose' reverse osmosis or tight ultrafiltration (Jelen, 1991; Rice *et al*.,2005). The use of NF instead of EV+ED has the advantage of simultaneous concentration and demineralization of whey (Horton, 1987). This will lead to a considerable reduction of the costs for energy consumption, waste water disposal and total costs (Kelly *et al*., 1991; Gregory, 1987).

Nanofiltration (NF) membranes can reject smaller size molecule that cannot be removed by (MF) and ultrafiltration (UF) membranes. Nanofiltration (NF) membranes have molecular weight cut offs (MWCO) in the range of 200 to 1,000, Which is intermediate between conventional reverse osmosis and ultrafiltration membranes (Tsuru *et al*., 1998). Nanofiltration membranes have pore sizes from 1-10 nanometers, smaller than that used in MF and UF but just larger than that in reverse osmosis (Kwon *et al*., 2008). Operational TMP for NF 10- 30 bar.

Nanofiltration allows monovalent salts (such as sodium chloride), to pass but retains divalent salts such as sodium sulphate and multivalent ions such as calcium.Separation by NF membrane occurs primarily due to size exclusion and charge effect on electrostatic interactions (Nystrom *et al.,* 1995). The rejection of uncharged molecules is dominated by size exclusion, while that of ionic species is influenced by both size exclusion and electrostatic interactions. Electrostatic characteristics of NF membranes have been known as playing an important role in rejection anions, i.e., negative zeta potential on the membrane surface varies with different pH and concentration of an electrolyte solution (Hong *et al*., 1999).

Application of nano filtration in dairy industry mainly for,
1. Concentration
2. Partial Demineralisation
3. Lactose Reduction
4. Detergent Recovery
5. Whey protein concentration

PANEER
When paneer is prepared from normal cow milk, then it is having hard, compact and dry characteristics because of high salt content. NF of cow milk helps in overcoming these defects and produce better quality paneer. Concentration of cow milk to ~ 1.5 and 2.0 time using NF membrane system at 50°C result in reduction in **salt content of cow milk up to 74% in 1.5 time** concentration without affecting other major constituents (Khan and Pal, 2011).

CHEESE
UF in combination with NF are employed to obtain a more economical cheese production. In this process, the main target was to utilize whey. The first UF employs membrane of 6-8 kDa MWCO. The retentate of the second UF is introduced back into the cheese process, which can improve both the nutritional and economic values.

The permeate solutions of both UF processes can be fed to a NF (400 Da MWCO) to concentrate lactose for sweet industry and the nanofiltrate, containing low concentrations of organic material, can be reused in the production or for other purposes, representing a ''cleaner" production (Atra*et al.,* 2005).

Whey and Permeate
Nanofiltration of whey and permeates will reduce the mineral content especially sodium and potassium chlorides (monovalent ions) – in these products, and since both whey and permeates in most cases need to pass through a concentration step prior to further processing, nanofiltration becomes a very attractive technology. High permeability of monovalent ions (40–90%) and low permeability of multivalent ions (5–20%) typically characterise NF. Therefore, it is possible to concentrate milk with NF to obtain an improved mineral balance (Cuartas-Uribe *et al* ., 2007).

Lactose
Lactose is mainly produced from whey and permeates, and nanofiltration plays an important role in a modern lactose production facility. By applying nanofiltration, lactose can be concentrated before further processing - i.e. crystallisation. Further, nanofiltration will reduce the amount of minerals which in turn will provide a more efficient crystallisation process and will consequently result in a lactose product with a higher degree of purity (www.lenntech.com).

Thermal stress acting on the organic constituents is much lower since maximum temperatures of only 40 °C are applied. Therefore, Maillard-type decomposition reactions leading to high-molecular and colored substances can be completely prevented. The product purity is high, whereas electrolyte contamination is considerably lower. The energy requirement reduces by about 50 %, the yield of lactose increases from 70 to 93 %, and the amount of COD released with the process water reduces to nearly a third of the original values (Robert *et al*., 2000).

PARTIAL DEMINERALIZATION

Demineralised Whey

Pan et al. (2011) stated that Whey is the main byproduct obtained from cheese production, and it contains a high concentration of valuable organic matter, but demineralization is needed before it can be used. Nanofiltration (NF) membranes have high permeability for monovalent salts (e.g. NaCl, KCl) and organic compounds with low molecular weight, and very low permeability for organic compounds of molecular weight higher than 300 Da, so it is a good alternative for simultaneous concentration and demineralization of whey.

Demineralised Whey Powders

Demineralised whey powders (DWP D35, D50, D70, D90) intended e.g. for use in the production of baby food, can – depending on the degree of demineralisation - be manufactured by means of nanofiltration and combinations of ultrafiltration and nanofiltration as well as nanofiltration combined with electrodialysis (ED) before evaporation and spray drying.

LACTOSE REDUCTION

Lactose-free Milk

Nanofiltration is a commonly applied technology for the production of high quality lactose-free milk products. As the membrane layer in the nanofiltration technology rejects lactose but allows passage of various minerals, the milk will maintain most of its original composition and the consumer will get a sensory experience which is almost **similar** to that of fresh milk.

MILK PROTEIN CONCENTRATE

The demand of milk protein concentrate (MPC) as a functional food ingredient is increasing in recent years. One of the most important characteristics of MPC is the ratio of casein and whey protein which is similar to raw milk (Fang et al. 2011). Solubility is also one of the prerequisites of other functional properties, such as gelling, emulsifying, and foaming properties (Moughal et al. 2000; Baldwin and Truong 2007).It has been reported that the solubility of MPC decreases with time and temperature of storage (Anema et al. 2006; Udabage et al. 2012; Haque et al. 2010). The insoluble material of MPC formed during storage, mainly consists of casein micelles (McKenna 2000; Anema et al. 2006; Havea 2006). The release of micelles from powder particles was found to be the rate-limiting step of MPC rehydration process and was inhibited upon storage (Mimouni et al. 2010b). Thus, nanofiltration can help to improve the solubility of MPC products. Since nanofiltration allows lower temperatures, the milk proteins would be exposed to lower heat treatment, leading to less denaturation and enhanced solubility.
Cao et al. (2016) analysed that the MPCs produced by evaporation and nanofilteration were stored at different temperatures (25, 35, and 45 °C) for a period of 24 weeks to observe any changes in the storage stability. The results showed that at a given storage temperature, the rehydration properties, such as solubility, viscosity, turbidity, and particle size of the nanofiltered milk protein concentrate (NF-MPC) were better compared to the same properties of the evaporated milk protein concentrate (EP-MPC).

ULTRAFILTARTION

Ultra filtration

Ultrafiltration is a pressure-driven, permeability-based membrane separation technique, mainly used for processing macro-molecules such as proteins, nucleic acids, and polysaccharides Ultrafiltration membranes have pore size in the 1- to 100-nm range .The main separation mechanism is size-based sieving, but other factors such as electrostatic solute-membrane and solute-solute interactions can significantly affect separation (Nystrom *et al*., 1998; Ghosh and Cui, 1998).

Liquid Milk Processing

On-farm concentration of milk

The concept of milk concentration on the farm, near the point of milking, dates back to the early 1970s. From that time many benefits for concentrating milk on the farm rather than at a separate processing plant have been claimed. The milk retentate can be separated on-site from the permeate, enabling each product to be shipped to the most profitable location. However, the most economical way to dispose of the permeate is to feed it to cows on the farm. Thus, dairy farmers can reduce their milk transportation costs because of reduction of milk volume; they are no longer paying to ship unwanted water. Concentrated milk reduces refrigeration costs because of smaller volume required for storage facilities and, once such milk reaches its destination, the heating cost is reduced due to less fluid being processed. In addition, if the concentrated milk is used for cheesemaking, the yield is increased.). In 1977, Alfa-Laval (a Swedish company and currently known as Tetra Pak) developed an on-farm UF processing unit, known as Ultratherm (Kosikowski, 1985). UF was used in French farms to concentrate milk two-fold. The retentate, after thermisation and cooling, was delivered to a cheese plant for the manufacture of Emmental and Saint Paulin cheeses without any adverse effects on the yield of the products. The permeate produced at the farms was fed to cows, resulting in savings in feed (Anonymous, 1984). In another study, milk was collected from 22 farms located on a French island, it was then concentrated two-fold by UF and heat treated (72◦C for 15 s). After cooling to 2◦C, the concentrates were shipped to a local factory twice a week (Kosikowski, 1985). The use and economic impact of the transportation of RO milk was also evaluated in Australia (Cox & Langdon 1985). In a long study in California, a 400 cow herd was used to study the feasibility of both UF and RO on-farm (Zall, 1987).

Protein standardisation by ultrafiltration

For nearly 40 years, UF offered the possibility of standardising the protein content of milk. This operation makes it possible to concentrate all the milk proteins (serum proteins and caseins) and fat contents, and simultaneously allow the lactose and minerals to pass through the membrane. The change in the protein composition of milk from that which is received from the producer is called protein standardisation. The main objective of the standardisation of the proteins, one of the two most valuable components of milk, is to overcome the inherent day to day variations in milk composition, resulting in significant nutritional and technological and economical benefits. It has been reported that the average protein content of milk (3.3–3.4 g 100 g−1) collected by dairy plants may show relatively wide natural variations (2.8–4.2 g 100 g−1) by international comparisons (Rattray &Jelen, 1996) due to various factors, such as stage of lactation, feeding, breed, seasons of the year, weather, etc. Depending on the objective of the standardisation, the UF process can be performed either for the concentration of protein so as to reach the prescribed protein content of milk, or for the reduction of protein content of milk by addition of ultrafiltered permeate Nowadays, the standardisation of proteins using the UF process is well established for the increase of the protein content of milk during the manufacture of cheese.In cheese manufacture, one can note that MF using a 0.1 μm pore membrane is used more and more for the specific enrichment of milk in native casein micelles (Maubois, 1991; G´esan-Guiziou et al., 1999; Saboya&Maubois, 2000).

Fermented Milks

In the mid-1980s, UF technology had been recommended during the manufacture of cultured buttermilk to increase the calcium content and improve the viscosity of the product (Mann, 1986), but no industrial application has been reported. However, in recent years, membrane technology has been applied during the manufacture of whey-based fermented beverages and cultured buttermilk, especially in the fermentation of liquid UF whey protein retentates where it seemed to be a feasible process during the manufacture of whey-based drinking fermented products (Ozer &Kırmacı, 2010).

UF is a suitable alternative standardisation method of the SNF compared with SMP addition in the manufacture of cultured buttermilk as long as the UF processing conditions are selected carefully. Rao et al. (1995) and Rao (2002) demonstrated that the flux pattern of buttermilk was strongly affected by pH. Increasing the pH of buttermilk from 6.6 to 8.0 tended to reduce the initial flux rate and increase the fouling rate on the membrane surface.

Several reports on the use of ultrafiltered treated milk for the manufacture of high-quality yoghurt have been published (Lankes et al., 1998; Tamime et al., 1984; Biliaderis et al.,1992).

Whey processing

Whey is a dairy by-product which is obtained during the preparation of milk products viz. cheese, paneer and casein. Paneer is an Indian dairy product similar to soft cheese prepared by coagulating casein with citric acid, lactic acid or tartaric acid (Kumar et al., 2011a; Kumar et al., 2008). Whey is simply drained in most of the cases in developing countries. This causes huge loss of valuable nutrients as well as creating environmental hazards. The separation or concentration of whey nutrients by traditional method is cumbersome and time consuming. By application of different membrane filtration technology, the nutrients in whey are concentrated, fractionalized or purified into valuable products such as whey protein concentrate/ isolates, α-lactalbumin, β-lactoglobulin, lactose and salts. Up to 60% more saving on fuel has been reported in whey concentration by applying RO over the traditional evaporation methods. By application of UF and DF, the protein content of the whey protein concentrate can be increased by 35 to 85% of the total solids whereas by removing bacteria and fat by passing whey through MF, the protein content of whey protein isolates can be increased to 90% of the total solid content (Lipnizki, 2010)

Shrikhand and chakka

Shrikhand and chakka (traditional Indian fermented dairy products) produced by the UF method had similar physical properties to ultrafiltered concentrated yoghurt (Ozer, 2006). However, a manufacturing protocol for ultrafiltered shrikhand has been proposed by the Indian National Dairy Research Centre and, according to this protocol, skimmed milk is heated to 85–90◦C for 10–20 min, cooled to 21–22◦C and inoculated with a selected blend of mesophilic starter culture until the pH reaches 4.5–4.6, which takes about 15–16 h. The fermentate (i.e. cow's or buffalo's skimmed milk) is heated to 60◦C for 5 min with continuous agitation, cooled to 50◦C and ultrafiltered up to about 16 g 100 g−1 TS. Whey is then removed from this concentrated coagulum by hanging it in a muslin cloth (eight layered) overnight at room temperature followed by mild pressing to get chakka. This UF/traditional skimmed milk chakka is pressed through a sieve for the kneading action to give smooth chakka without any visible grain (Sharma, 1998).

Concentrated Milk and Powders

Dulce de Leche (milk jam, milk caramel) is a form of sweetened condensed milk that is very popular in some South American countries, such as Argentina, Uruguay, Brazil and Mexico. The industrial manufacturing stages of these products are similar to that of sweetened condensed milk, where the milk solids are concentrated by heating and evaporation. In the particular case of Dulce de Leche, sucrose is added to the milk prior to the concentration until 70% total solids are reached. The most technological problem in Dulce de Leche production is the sandy texture of the product, which, as a consequence, has a negative impact in reducing product acceptability. This phenomenon is mainly attributed to the high concentration of lactose in the product leading to crystallization; the lactose crystals can be up to 1500 µm in size. Much effort has been made to resolve this problem by breaking down lactose using bacteria or enzymes, by seeding with lactose micro-crystals or by using UF in order to reduce the processing time and lowering the final lactose content of the milk (Oliveira et al., 2009).

Manufacture of milk protein concentrates

MPCs, which are usually processed and marketed in spray-dried form, are produced from skimmed milk by using UF and/or diafiltration, evaporation and drying technology. The manufacture of MPCs typically includes UF of skimmed milk with or without the use of diafiltration. The diafiltration makes it possible to reduce the level of lactose in the retentate, and then to achieve higher protein content than 65 g 100 g^{-1} in the final powder. The resulting retentate, depending on the desired protein level, is then subjected to pre-heat treatment. Since the viscosity of the retentate increases as proteins are selectively enriched, the capacity of UF plants to maximise solids concentration is affected by a rapid decline in permeate flux across the UF membranes. Additional thermal evaporation is then necessary in order to increase retentate solids further so that the resulting spray-dried powder has the desired physical characteristics, such as bulk density. High concentration is carried out by evaporation in a one- or two-stage falling-film tubular evaporator, and spray drying, preferably in a tall-form spray dryer, followed by 'after-drying' and cooling in an external fluid bed drier (Kelly, 2011).

Microfiltration

In terms of applications, MF has been developed at industrial scale for two main applications: removal of bacteria from milk and selective separation of casein micelles from soluble proteins. The MF area can be estimated to reach 15,000m^2. This is far-removed from ultra – filtration, which is widely used mainly for milk and whey protein concentration.

The major application of MF in the dairy industry concerns the removal of microorganisms from skim milk in order to produce a debacterized raw material which is afterwards transformed into fluid milks, cheeses or long storage dairy products such as powder or protein derivatives. Moreover these two main industrial developments, numerous other applications have been proposed which will be briefly reviewed here2010; Kumar et al., 2011b; Shekhar and Kumar) The CO2-aided cold MF process has the potential to become economically attractive to the dairy industry, with direct benefits for the quality and shelf life of dairy products (Fristch and Moraru, 2008). Initial reports have indicated that MF will reject fat and microbes while allowing other milk constituents to pass through the membrane, resulting in (theoretically) fat-free, bacteria-free milk (Piot et al., 1987). MF is developing due to its capability to retain, partly or totally, particles (microorganisms, casein micelles, fat globules),

Bacteria Reduction

• ESL (Extended Shelf Life) Milk

Extended shelf life (ESL) milk products are products that have been treated in a manner to reduce the microbial count beyond normal pasteurization, packaged under extreme hygienic conditions, and have a prolonged shelf life under refrigerated conditions (Rysstad and Kolstad, 2006). Microfiltration constitutes an alternative to heat treatment to reduce the presence of bacteria and improve the microbiological safety of dairy products while preserving the taste (Pafylias et al., 1996). It is a non thermal method of removing bacteria and spores from milk, whey and cheese brine and extending shelf life without damaging sensory attributes (Meersohn, 1989). The significant reduction of mesophilic, *Salmonellae* and *Listeria* count have been reported upon using MF with 1.4 µm pore size (Madec et al., 1992). Cold MF could also minimize microbial fouling of the membrane and prevent the germination of thermophilic spores (Fristch and Moraru, 2008). MF of skim milk reduced bacteria by about 99.5%, extended shelf life, and retained the milk properties intact (Papachristou and Lafazanis, 1997).A maximum extended shelf life of 74 days was found for milk after the combination of microfiltration and direct heat treatment at 125–130 °C and storage at room temperature. An extended shelf life of 33 days was obtained after microfiltration followed by pasteurization at 90 °C and storage at 4–6 °C.

ESL milk has been prepared by removing bacteria from milk by MF without causing any compositional change or negligible decrease in the total protein by 0.02 to 0.03% (Hoffmann et al., 2006). It extends the shelf life of milk by 12 to 45 day at 4°C (Olesen and Jensen, 1989; Puhan, 1992; Saboya and Maubois, 2000; Goff and Griffiths, 2006). The major hitch is that it does not remove all pathogenic bacteria from milk, thus still necessitate the heat treatment (Rosenberg, 1995).

Damerow (1989) reported the extension of shelf life of refrigerated milk from 12 d to 18 d at 8°C by the combined application of MF and HHT without compromising sensory attributes by reducing the number of psychrotrops.

The somatic cell counts (SCC) increase in the milk of lactating cows suffering from mastitis and thus severely affecting the composition and quality of milk (Sharma and Maiti, 2010; Sharma et al., 2011; Sharma et al., 2012a; Sharma et al., 2012b). This somatic cell count can be reduced up to 100% by the application of combined processes of MF (microfiltration) followed by HHT (high heat treatment) (Pedersen, 1992). Damerow (1989) reported the extension of shelf life of refrigerated milk from 12 d to 18 d at 8°C by the combined application of MF and HHT without compromising sensory attributes by reducing the number of psychrotrops. The MF process is more efficient in removing bacteria and spores than the bactofugation (Stack and Sillen, 1998).

- **Cheese Milk**

Improvement of cheese milk can be achieved using microfiltration. Cheese made from the 1.4µm MF skim milk added with pasteurized cream are at least safe from hygienic point of view as cheese made from pasteurized milk(Saboya and Maubois.2000).

Milk is enriched in micellar casein by 0.1µm MF done at normal pH(6.6-6.8),mineral phosphocalcic salt bound to the casein micelles are concentrated in the same proportion as casein .The result in an increase in the buffering capacity MF retentates(Hannon et al .,2006).
The use of cheese milk in which casein is concentrated by MF 0.1 µm leads to saving in rennet .When the protein content of milk is increased ,there is an increase of the enzymatic reaction velocity, and the required degree of proteolysis at gelation also decrease.(Garnot,1988).

- **Milk & Whey Powders**

Microfiltration can improve the quality of milk and whey powder considerably through a reduction of bacteria and spores. As a consequence, heat treatment can be kept at an absolute minimum which - among other things - contributes to a preservation of the functional properties of the whey proteins in the powder.

- **Cheese brine purification**

Efficient sanitation of cheese brine is required in the dairy industry in order to prevent post contamination of cheeses during salting. It is effectively well demonstrated that brine may contain unwanted microorganisms such as gas-producing lactobacilli, pathogenic bacteria (*Staphylococci,Listeria*and others) yeast and molds. As well as its bacterial load, the overall quality of brine and consequently the quality of the cheese salting, results from a relatively delicate balance equilibrium between NaCl content (18 to 26%), soluble and precipitated Ca salts, lactose and lactic acid soluble and denaturated whey proteins.

MF in a UTP equipment with a pore size of 1.4 µm or 0.8 µm membrane completely rejects yeasts and moulds, retains 99.9% of the contamination bacteria and only 6.7% of the calcium salts and 2–3% of the nitrogen matter. The flux at 20 °C was 600 L.h–1.m–2 during 8 h and the concentration factor higher than 1:100. From these very satisfactory results, it is likely that MF of cheese brine will expand rapidly if the investment cost of UTP ceramic membranes decreases as it can be expected.

4.2 Casein Standardisation of Cheese Milk

When it comes to obtaining process control and quality, a uniform and stable production process is of the highest importance to any cheese manufacturer. By using microfiltration, it is possible to fractionate casein and whey proteins and thereby to standardize the concentration of casein in the cheese milk to obtain the correct ratio between casein and fat.

- **Casein Production**

Microfiltration can fractionate milk proteins into casein and whey proteins. The fractionated casein can be used in the production of high-quality casein and caseinate or in the production of special casein-rich milk products. The by-product of this fractionation (permeate) contains whey proteins in their natural form which are unaffected by heat treatment, enzymes (rennet) or bacteria (starter cultures). This by-product is especially suited for the production of high-quality liquid stabiliser, Whey Protein Concentrate (WPC) and Whey Protein Isolate (WPI).

4.3 Milk Fat Removal

1) Protein Isolate

In the production of protein isolate - e.g. Milk Protein Isolate (MPI) or Whey Protein Isolate (WPI) - where a protein level of more than 90% in the total solids is required, the fat content constitutes a limiting factor. The milk fat is concentrated to a very high level, and in order to achieve the final protein concentration, removal of the milk fat is required. Microfiltration is the obvious solution for performing this fat removal.

2) Selective separation of micellar casein

When whole or skim milk is circulated along a MF membrane with a pore size diameter of 0.1–0.2 μm, a microfiltrate with a composition close to that of sweet whey is obtained. This microfiltrate is crystal clear and it can be sterile and claimed without any viral particle if the downstream equipment prevents recontamination. The MF retentate is an enriched milk solution of native micellar casein. Excepting the pore size of the MF membrane, engineering characteristics of the technology are the same as those used for bacteria removal of milk i.e. use of a device leading to a uniform transmembrane pressure, a retentate velocity of at least 7 m.s–1 and a running temperature of 50–55 °C. As proposed by Pierre et al. and by Schuck et al. purified micellar casein can be prepared according to this application of MF by following the process . (a) concentration of the MF retentate up to a VRF of 3–4; (b) diafiltration of this MF retentate with 4 diavolumes of R.O. treated water; (c) concentration of the diafiltered MF retentate up to a VRF of 6–7; (d) spray-drying of the 6:1 MF retentate. Many variants of this process can be envisaged such as use of UF instead of MF at step (c), diafiltration at lower or higher VRF or uses of saline or acid solutions for diafiltration instead of pure water.

References

[1] Anema SG, Pinder DN, Hunter RJ, Hemar Y (2006) Effects of storage temperature on the solubility of milk protein concentrate (MPC85). *Food Hydrocolloids* 20(2–3):386–393

[2] Ansari, M.,Raip,I.A., Sahoo, P.K. and Datta, A.K.(2006) Manufacture of Shrikhand from ultra filtered skim milk retentates. *Journal of .Food Science Technology* 43(2):49-52.

[3] Atra, R, Vatai, G, Molnar, E.B. and Balint, A. (2005) Investigation of ultra- And nanofiltration for utilization of whey protein and lactose, *Journal of Food Engineering*, 67(3) :325-332.

[4] Balannec B, Vourch M, Rabiller-Baudry M and Chaufer B (2005) Comparative study of different nanofiltration and reverse osmosis membranes for dairy effluent treatment by dead-end filtration. *Separation and Purification Technology* 42:195–200.

[5] Baldwin A, Pearce D. 2005. Chapter 15 - Milk Powder. In: C. Onwulata, editor. Encapsulated and Powdered Foods. 1st ed. New York: Taylor & Francis. p 387-433.

[6] Baldwin AJ, Truong GNT (2007) Development of insolubility in dehydration of dairy milk powders. *Food Bioproduction Process,* 85(C3):202–208

[7] Barros, C.M.V., Ribeiro, A.C.O. and Viotto W.H. (2006) Impact of low concentration factor ultrafiltration on the composition and yield of reduced fat Prato cheese. Desalination, 200: 555-556.

[8] Biliaderis, C. G., Khan, M. M.,and Blank, G. (1992) Rheological and sensory properties of yogurt from skim milk and ultrafiltered retentates. *International Dairy Journal*, 2, 311-323.

[9] Brans G, Schroen C G P H, Van der Sman R G M and Boom R M (2004) Membrane fractionation of milk: state of the art and challenges. *Journal of MembraneScience* **243** 263-272.

[10] Cao, J., Wang, G., Wu, S., Zhang, W., Liu, C., Li, H., Li, Y. and Zhang L.(2016) Comparison of nanofiltration and evaporation technologies on the storage stability of milk protein concentrates, *Dairy Science and Technology* 96: 107.

[11] Caron A, Saint Gelais D, Pouliot Y. (1997) Coagulation of milk enriched with ultrafiltered or diafilteredmicrofiltered milk retentate powders. International Dairy Journal;7:445-451.

[12] Childress A E and Elimelech M (2000) Relating Nanofiltration Membrane Performance to Membrane Charge (Electrokinetic) Characteristics. *Environmental Science and Technology* 34,3710-3716.

[13] Clark, Jr. W.S., 1987. Status of whey and whey products in the USA today. Trends whey utilization. Bull. IDF, 212: 6-11.

[14] Gregory, A.G., 1987. Desalination of sweet-type whey salt drippings for whey solids recovery. Trends in whey utilization. Bull. IDF, 212: 38-46.
Horton, B.S., 1987. Anaerobic fermentation and ultra-osmosis. Trends in whey utilization. Bull. IDF, 212: 77-83.
Kelly, P.M., B.S. Horton and H. Burling, 1991. Partial demineralization of whey by nanofiltration. *International Dairy Fedration. Annual. Sessions* Tokyo, 213: 87-87.

[15] Cox, G.C. and Langdan, I.A.(1985) Economic Evaluation of reverse osmosis for reduction in milk transport costs. Australian Journal of Dairy technology, 40 : 113-117.

[16] Cuartas-Uribe B, Alcaina-Miranda MI, Soriano-Costa E, Bes-Pia A (2007) Comparison of the behavior of two nanofil-tration membranes for sweet whey demineralization., *Jornal of Dairy Science* 90:1094–1101

[17] Damerow G. Die anwendung der mikrofiltration fur die konsummilch, kessel-milch, Molke. DtschMolkereiZeitung. 1989;110:1602–1608.

[18] Daufin, G., Escudier, J. P., Carrère, H., Bérot, S., Fillaudeau, L., &Decloux, M. (2001). Recent and emerging applications of mem- brane processes in the food and dairy industry. Food and Bio-products Processing, 79(2), 89–102.

[19] Dewani, P. and Jayaprakasha, H. (2006) Effect of addition of whey protein concentrate on the physico-chemical and sensory characteristics of Khoa and Khoa based sweets. *Journal. Food Science Technology* 39(5): 502-506

[20] Dhineshkumar V, Ramasamy D. (2017).Review on membrane technology applications in food and dairy processing. *Journal of Application of Biotechnology and Bioenergy*

[21] 3(5):399–407.

[22] Fang, Y., C. Selomulya, S. Ainsworth, M. Palmer, and X. D. Chen. (2011). On quantifying the dissolution behaviour of milk protein concentrate. Food Hydrocoll. 25:503–510.

[23] Ferreira, D.N., Moura, D.B., Cunha, C.R. and Viotto, W.H. (2006). Rheological properties of reduced fat mozzarella cheese made by direct acidification using low concentration factor ultrafiltration retentates. Desalination, 200: 552-554.

[24] Fox, P. F., McSweeney, P., Cogan, T. M., & Guinee, T. P. (2004). Application of membrane technology to cheese production. Cheese: major cheese groups (3rd ed., 2:261–286).

[25] Fritsch J, Moraru CI. (2008) Development and optimization of a carbon dioxide-aided cold microfiltration process for the physical removal of microorganisms and somatic cells from skim milk. *Journal of Dairy Science* .;91:3744–3760.

[26] Fritsch J, Moraru CI. (2008) Development and optimization of a carbon dioxide-aided cold microfiltration process for the physical removal of microorganisms and somatic cells from skim milk. *Journal of Dairy Science*. ;91:3744–3760.

[27] G´esan-Guiziou, G., Boyaval, E. and Daufin, G.(1999) Critical stability Conditions in cross flow microfiltration in skimmed milk: transition to irreversible deposition. *Journal of membrane science*, 158: 211-222.

[28] Garnot, P. (1988). Influence od milk concentration by UF on enzymatic Coagulation. Bulletin 225.*International dairy federation, Brusseles*.11-15.

[29] GermanoMucchetti, Giorgio Zardi, FiorenzoOrlandini, Carlo Gostoli. The pre-concentration of milk by nanofiltration in the production of Quarg-type fresh cheeses. Le Lait, INRA Editions, 2000, 80 (1):43-50.

[30] Ghosh R, Cui ZF. (1998). Fractionation of BSA and lysozyme using Ultrafiltration Effect of pH and membrane surface pre treatment. *Journal of Membrane Science*. 139:17-28.

[31] Ghosh R. 2002. Study of membrane fouling by BSA using pulsed injection technique. *Journal of Membrane Science* 195:117–126.

[32] Goff HD, Griffiths MW. (2006), Major advances in fresh milk and milk products: Fluid milk products and dairy desserts. *Journal of Dairy Science*, 89:1163–1173.

[33] Govindasamy-Lucey S, Jaeggi JJ, Bostley AL, Johnson ME and Lucey JA (2004). Standardization of milk using cold ultrafiltration retentates for the manufacture of parmesan cheese. *Journal of Dairy Science*, 87: 2789-2799.

[34] Govindasamy-Lucey, S., Jaeggi, J.J., Johnson, M.E., Wang, T., and Lucey, J.A. (2007). Use of cold microfiltration retentates produced with polymeric membranes for standardization of milks for manufacture of pizza cheese. *Journal of Dairy Science*, 90, 4552-4568.

[35] Guinee TP, Kennedy BT, Kelly PM. (2006), Effect of milk protein standardization using different methods on the composition and yields of cheddar cheese. *Journal of Dairy Science*, 89:468–482.

[36] Guinee TP, Pudja PD, Reville WJ, Harrington D, Mulholland OE, Cotter M, Cogan TM. (1995), Composition, microstructure and maturation of semi-hard cheese from high protein ultrafiltered milk retentates with different levels of denatured whey protein. InternationalDairy Journal.5:543–568.

[37] Gupta S. K and Pal, D. (1994). Production of Khoa from buffalo milk concentrated by Reverse Osmosis. *Indian Journal of Dairy Science* 47 (3): 211-214.

[38] Gupta SK, Pal D. (1995)Suitability of reverse osmosis concentrated milk for the manufacture of paneer. *Jouranl of Food Science Technology*. 32(2):166–168.

[39] Hannon, J., Deutsch, S.-M., Madec, M.-N., Gassi, J.-Y., Chapot-Chartier, M.-P., Lortal, S. (2006). Lysis of starters in UF cheeses: behaviour of mesophilic lactococci and thermophilic lactobacilli. *International Dairy Journal*, 16, 324–334.

[40] Haque E, Bhandari BR, Gidley MJ, Deeth HC, Moller SM, Whittaker AK (2010) Protein conformational modifications and kinetics of water-protein interactions in milk protein concentrate powder upon aging: effect on solubility. *Journal of Agricultural Food Chemistry* 58(13):7748–7755.

[41] Havea P (2006) Protein interactions in milk protein concentrate powders. Int Dairy J 16(5):415–422

[42] Hoffmann, W. Klobes, H. Kiesner, C. Suhren, G., Krusch, U., Clawin-Rädecker, I. and Larsen PH (1996). Use of Microfiltrationfor the Production of Pasteurised Milk with Extended Shelf Life. IDF Bulletin No 311. Pg. no: 45–46.
[43] Ivanna Kyrychuk1 ,Valerii Myronchuk1 , YuriiZmiievskii 1 , SerhiiHoliachuk,(2015) Two-stage whey treatment by nanofiltration and reverse osmosis..Ukrainian Food Journal, 4(4): 638-647.
[44] Jelen P (1992) New applications of membrane processes. In IDF SplIss 9201Brussels Belgium 7-14.
[45] Jelen P, Renz-Schauen A. (1989), Quarg manufacturing innovations and their effects on quality, nutritive value, and consumer acceptance. Food Technol.43:74–81.
[46] Jelen, P. (1991). Pressuredriven membrane processes: principles and definitions. *International Dairy Federation [Special Issue] S.I., 9201, 7-14.*
[47] Johnson ME, Lucey JA.(2006) Major technological advances and trends in cheese *Journal of Dairy Science* . 89:1174–1178.
[48] Kanawjia SK, Singh S.(2002),Technological advances in paneer making. Indian Dairyman. 52(10):45–50.
[49] Kanawjia, S.K, Rizvi, S.S.(2003) Development of paneer from microfiltered retentate. Indian *Journal of Dairy Science*,56(4):203–207.
[50] Kanawjia, S.K. and Rizvi, S.S.(2000) Development of paneer from microfiltered milk. Indian *Journal of Dairy Bioscence*,.11(1):67–70.
[51] Kanawjia, S.K. and Singh, S. (2000) Technological advances in paneer making. *Indian Dairyman.*52(10):45–50.
[52] Kelly P. (2011). MILK PROTEIN PRODUCTS | Milk Protein Concentrate. In: Editor-inChief: John W. Fuquay, editor. *Encyclopedia of Dairy Sciences (Second Edition*). 2nd ed. San Diego: Academic Press. 848-54.
[53] Kemal Erdem Y (2005). Effect of ultrafiltration, fat reduction and salting on textural properties of white brined cheese. *Journal of Food Engineering*, 71: 366-372.
[54] Khan, S.U. and Pal, M.A. (2011) Paneer Production : A review, *Journal of Food Science and Technology,* 48(6): 645–660
[55] Klein E, Ward R A and Lacey R E (1987) Handbook of Separationn Process Technology. J Wiley and Sons publishing,Canada.
[56] Kosikowski, F.V.(1985) Ultrafiltration of milk on French farms and in the making of a new speciality cheese industry. *Journal of Dairy Science*,68, 2403:2401.
[57] Kumar P, Shrama N, Kumar S, Rajan R and Bhat Z (2013) Perspective of Membrane Technology in Dairy Industry : A review. *Asian Australasian Journal of Animal Sciences* 26(9):1347-1358
[58] Kumar S and Rai D C (2010) Effect of antioxidants and paraffin wax on the physico chemical properties of aerobically packaged buffalo milk paneer at refrigeration temperature. Milchwissens chaft,65;388:393.
[59] Kumar S, Bhat Z F and Kumar P (2011) Effect of apple pulp and Celosia argentia on the quality of characteristics. *American Journal of Food Technology*,817:826.
[60] Kumar S, Rai DC, Verma DN. (2008). Effect of different levels of lactic acid on the physico-chemical and sensory attributes of buffalo milk paneer. Indian Journal of Animal Research 42:205–208.
[61] Lawrence, N.D., Kentish, S.E., O`Connor, A.J., Barber, A.R. and Stevens, G.W. (2008). Microfiltration of skim milk using polymeric membranes for casein concentrate manufacture. Separation and Purification Technology, 60, 237-244.
[62] Li, Y.; Corredig,(2014) M. Calcium release from milk concentrated by ultrafiltration and diafiltration. *Journal of Dairy Science* 97, 5294–5302
[63] Madec MN, Mejean S, Maubois JL. Retention of Listeria and Salmonella cells contaminating skim milk by tangential membrane microfiltration (Bactocatch process) Lait. 1992;72:327–332.
[64] Maubois JL, Mocquot G, Vassal L. (1969). A method for processing milk and dairy products. French Patent FR 2 052121.
[65] Maubois JL.(2002) Membrane microfiltration: a tool for a new approach in dairy technology. Australian *Jouranl Dairy Technology*.57:92–96.

[66] Maubois, J.L.(1991) New applications of membrane technology in the dairy industry,Australian *Journal of Dairy technology*,46,91-95.
[67] Maubois, J.L., Pierre, A., Fauquant, J., and Piot, M. (1987). Industrial fractionation of the main whey proteins. Bulletin of the *International Dairy Federation*, 212, 154-159.
[68] McKenna AB (2000) Effect of processing and storage on reconstitution properties of whole milk and ultrafiltered skim milk powders. Massey University, Palmerston North
[69] Mehaia MA (2006). Manufacture of fresh soft cheese (Domiati-type) from camel milk using ultrafiltration process. *Journal of Food Technology*, 4: 206-212.

[70] Mimouni A, Deeth HC, Whittaker AK, Gidley MJ, Bhandari BR (2010) Rehydration of high-protein-containing dairy powder: slow- and fast-dissolving components and storage effects. *Journal of Dairy Science* 90(2–3):335–344

[71] Mistry VV, Maubois JL. (1993), Application of membrane separation technology to cheese production. In: Fox PF, editor. Cheese: Chemistry, Physics and Microbiology. Chapman & Hall; London: 493:522.

[72] Moresi, M., & Lo Presti, S. (2003). Present and potential applications of membrane processing in the food industry. *Italian Journal of Food Science,* 15, 3–34.

[73] Moughal KI, Munro PA, Singh H (2000) Suspension stability and size distribution of particles in reconstituted, commercial calcium caseinates. *International journal of dairy science* 10(10):683–690

[74] Neocleous M, Barbano DM, Rudan MA. Impact of low concentration factor microfiltration on the composition and aging of Cheddar cheese. *Journal of Dairy Science* 2002;85:2425–2437.

[75] Nystrom M, Aimar P, Luque S, Kulovaara M, Metsamuuronen S. 1998. Fractionation of model proteins using their physiochemical properties. Colloid Surface 138:185:205.

[76] Olesen N, Jensen F.(1998), Microfiltration. The influence of operating parameters on the process. Milchwissenschaft.44:476–479.

[77] Oliveira, R.P.S., Perego, P., Converti, A., Oliveira, M.N., 2009. The effect of inulin as a prebiotic on the production of probiotic fibre-enriched fermented milk. *International Journal of Dairy Technology* 62 (2), 195–203.

[78] Ordonez, G.A., Jeon, I.J. and Roberts, H.A. (2000) Manufacture of frozen yoghurt with ultrafiltered milk and probiotic acid bacteria. *Journal of Food Processing and Preservation*, 24(2): 163-176

[79] Ozer, B. (2006) Yoghurt Science and Technology. SidasMedya LTD.STI.

[80] Ozer, B.H. and Kirmaci H.(2010) Functional milks and dairy beverages, *International journal of dairy technology,* 63(1) : 1-15.

[81] Pafylias, I., Cheryan, M., Mehaiab, M.A, andSaglam, N. (1996)Microfiltration of milk with ceramic membranes. *Food Research International*,29:141–146.

[82] Pal, D. and Cheryan, M. (1987) Membrane technology in dairy processing. Part I. Reverse osmosis. *Indian Dairyman.* 39, 251

[83] Pal, M.A., Kapoor,C.M.(2000) Effect of emulsifying salts on the chemical constitution of processed paneer. *Indian Journalof Dairy Bioscience*11(1):42–46.

[84] Pan, K., Song, Q., Wang, L. and Cao, B. (2010) A study of demineralization of whey by nanofiltration membrane, *Desalination,*267 : 217–221.

[85] Papadatos, A.,Neocleous, M., Berger, A.M. and Barbano, D. M.(2003) Economic feasibility evaluation of microfiltration of milk prior to cheesemaking. *Journal of Dairy Science* ,86:1564–1577.

[86] Pedersen, P.J., andOttosen,N.(1992) New Applications of Membrane Processes. Brussels, Belgium:. pp. 67–76. IDF SpIlss 9201.

[87] Piot, M., Vachot, J.C., Veaux, M.,Maubois, J.L. and Brinkman,G,E.(1987)Encremage et epurationbacteri-enne du laitentier cru par microfiltration sur membrane en flux tangentiel. Tech Laitiere Marketing.1016:42–46.

[88] Porter, M. C. (1990) Handbook of Industrial Membrane Technology. Noyes Publishers. Park Ridge, N J, USA.

[89] Pouliot, Y.(2008). Membrane processes in dairy technology—from a simple idea to worldwide panacea. *International Dairy Journal*, 18(7), 735–740.

[90] Puhan, Z. (1992) New applications of membrane processes. Brussels, Belgium:pp. 23–32. IDF SpIlss 9201.

[91] Qvist,K.B.(1987) Objective and sensory assessment of texture of danbo cheese made from milk concentrated 2-fold using ultrafiltration. 272, Beretning/StatensMejeriforsøg, Hillerød, Denmark.

[92] Ramanna, B.R., Bhat, K.K., Mahadevaiah, B., Dwarkanath, C.T., Dhanraj, S., Potty, V.H and Sen, D.P.(1983) Investigation on large scale preparation and preservation of milk Burfi. *Journal of Food Science and Technology*,**20**(27): 67-71.

[93] Rao KVSS, Mathur BN (1990) Process upgradation in the manufacture of a traditional Indian dairy product, paneer. In: Brief communications of the XXIII International Dairy Congress, Vol II, Montreal, 8–12 October, p 459

[94] Rao, H.G.R., Lewis, M.J. and Grandison, A.S.(1995) Effect of pH on Flux During ultrafiltration of sweet whey and buttermilk, Journal of Dairy Research 62(03):441 - 449

[95] Rao, K.V.S.S. and Mathur, B.N. (1990) Process upgradation in the manufacture of a traditional Indian dairy product, paneer. In: Brief communications of the *XXIII International Dairy Congress*, Vol II, Montreal, 8–12 October, p 459

[96] Rautenbach, R. and A. Groschl, 1990. Separation potential of nanofiltration membranes. Desalination, 77: 73-84.

[97] Rice, G., Kentish, S., Vivekananda, V., Barber, A., O'Connor, A. and Stevens, G. (2005). Membrane-Based Dairy Separation: Comparison of Nanofiltration andElectrodialysis, Developments in Chemical, *Engineering* and *Mineral Processing*, 13 (1/2) : 43-54.

[98] Rosenberg, M. (1995). Current and future applications for membrane processes in the dairy industry. *Trends in Food Science and Technology*, 6(1), 12–19.
[99] Rysstad, R. andKolstad, J. (2006) Extended shelf life milk-advances in technology. *International journal of Dairy Technology*,59:85–96.
[100] Saboya, L.V., Maubois, J.L. (2000) Current developments of microfiltration technology in the dairy industry. Lait. 80:541–553.
[101] Saboya, L.V. and Maubois, J.L. (2000) Currents developments of microfiltration technology in the dairy industry.*Lait*80, 541-553.
[102] Sachdeva, S., andBuchheim, W.(1997) Separation of native and whey proteins during crossflow microfiltration of skim milk. *Australian Journal of Dairy Technology*, 52, 92-97.
[103] Saxena, A., Tripathi, B. P., Kumar, M., & Shahi, V. K. (2009). Membrane-based techniques for the separation and purification of proteins: an overview. *Advances in Colloid and Interface Science*, 145(1–2), 1–22.
[104] Schafroth, K., Fragnière, C., Bachmann, HP. Herstellung von Käseausmicrofiltrierter. konzentrierterMilch. Deutsche Milchwirtschaft. 2005;56:861–863.

[105] Sharma, N.Maiti, S.K. (2010)Incidence, etiology and antibiogram of sub clinical mastitis in cows in durg, Chhattisgarh. *Indial Journal of Veterinary Research*,19:45–54.
[106] Sharma, N. Rho, G. Hong, Y.H. Kang, T.Y. Lee, H.K.Hur, T.Y, (2012)Jeong DK. Bovine mastitis: An Asian Perspective. *Asian Journal of Animal and Veterinary Advances*,7:454–476.
[107] Sharma N, Singh NK, Bhadwal MS. Relationship of Somatic Cell Count and Mastitis: An Overview. *Asian-Australian Journal of Animal Science*. 2011;24:429–438.
[108] Sharma N, Srivastava AK, Bacic G, Jeong DK, Sharma RK. Bovine mastitis. 1st edn. Satish serial publishing house; Delhi, India: 2012b. Epidemiology; pp. 231–312.
[109] Sharma, D. K. and Reuter, H.(1992) *Indian Journal of dairy Science*,45:209.
[110] Shekhar C and Kumar S (2011) Quality of buffalo milk procured from milk vendors a case study. *Indian Journal of Animal Research* 45, 223 - 225.
[111] Shekhar C, Motina E and Kumar S (2010) Microbiological quality of raw milk and its public health significance. *Journal of Dairying Foods and Home Science*, 29,15 18.
[112] Siebert John W, Alejandro, L. and Sung-Yong K. (2001) The Commercial Potential of New Dairy Products from Membrane Technology. *Journal of FoodDistribution Research* **3:**24-33.
[113] Sivakumar S, Ramasamy D, Ayyadurai K. A.(2005) study on the preparation of paneer from ultrafiltered skim milk. In: Kumar A, editor. Concepts of biophysics. Dumka: APH Publishing Corporation,. pp. 209–213.
[114] Sivakumar, S.,Ramasamy, D. and Ayyadurai,K.(2005) A study on the preparation of paneer from ultrafiltered skim milk. In: Kumar A, editor. Concepts of biophysics. Dumka: APH Publishing Corporation; pp. 209–213.
[115] Stack A, Sillen G. Bactofugation of liquid milks. *Nutrtion and Food Science*. 1998;98:280–282.
[116] Tamime, A.Y., Kalab, M., and Davies, G. (1984). Microstructure of set-style yogurt manufacture from cow's milk fortified by various methods. Food Microstructure, 3, 83-92.
[117] Timmer, J.M.K. and H.C. Van der Horst, 1998. Whey processing and separation technology: State of the art and new developments. Proceeding of the 2nd International Conference, Oct. 27-29, Chicago, pp: 40-65.
Udabage, P., Puvanenthiran, A., Yoo, J.A, Versteeg,. C, Augustin MA (2012) Modified water solubility of milk protein concentrate powders through the application of static high pressure treatment. J Dairy Res 79(1):76–83
[118] Vourch, M., Balannec, B., Chaufer, B. and Dorange, G. (2005) Nanofiltration and reverse osmosis of model process waters from the dairy industry to produce water for reuse. *Desalination,*172 245–256.
[119] Winston H, W.S. and Sirkar, K. K. (1992) In: Membrane Handbook.Pp :3-16, Winston Ho W S and Sirkar K K, eds. Van Nostrand Reinhold.
[120] Zadow, J.G., 1987. Whey production and utilization in oceania in trends in whey utilization. Bull. IDF, 212: 12-16.
[121] Zall, R.R. (1987) Accumulation and quantification of on farm ultrafiltered milk: The California experience.Milchwissenschaft, 42,98-100.

Abstract for Poster Presentation   Article Code: PP-PO-01

Assessment of Residence Time Distribution in Scraped Surface Heat Exchanger using Image Analysis

Ravi Prajapati[1*], Prashant Minz[2], Ish Sawhney[3], Piyush Lanjewar[4], Arpita Rathva[5]
[1]Assistant Professor, GN Patel College of Dairy Technology, SDAU-Dantiwada
[2]Scientist, ICAR-NDRI, Karnal, [3]Emiritus Scientist, ICAR-NDRI, Karnal
[4]Proposal Engineer, SPX Flow Technology, India
[5]Assistant Professor, SMC College of Dairy Science, AAU-Anand

SSHEs are most often used for products that are highly viscous in nature. For evaporation, thin film SSHEs are used where process liquid moves along the heat transfer surface as a thin film. The major factors which are important for heat transfer in heat exchangers are type and pattern of flow, residence time distribution, rotational speed of scraper, space in annulus and nature and properties of product to be process. In present study, an attempt was made for measurement residence time distribution using image analysis. The pulse input injection method was used to insert the tracer dye and colourimetric analysis (L*, a*, b*) of milk at SSHE outlet done by program developed in Scilab software. The scraper speed, percentage of milk total solids, flow rate of milk and steam pressure is kept as fixed parameter. It was investigated that mean residence time distribution was 41.46 s at 120 rpm scraper speed, 294 kPa steam pressure and 450 l/h milk feed rate. The assessment of RTD in SSHE gives records of time spent by fluid particles in the equipment. To determine hold up volume of SSHE, RTD was assessed and further obtained data were used for thermal performance evaluation of SSHE. The rapid and simple image analysis method for RTD analysis was established. The method was found novel, accurate and distinct then other method used for RTD analysis.

Keywords: Scraped surface heat exchanger, residence time distribution, image analysis.

Abstract for Poster Presentation   Article Code: PP-PO-02

Application of Hyper Spectral Imaging (HSI)-a next generation finger printing technology for food and dairy industry

Tanmay Hazra*, Manishkumar Parmar, C.V.K. Sudheendra, Subhash Prasad
College of Dairy Science, Amreli, Gujarat

Hyper spectral imaging (HSI) is an evolving technology that participates conventional imaging and spectroscopy to attain both spatial and spectral information from food or dairy products. Hyperspectral images are made up of hundreds of contiguous wavebands for each spatial position of a target molecule. Thus, each pixel in a hyperspectral image contains the spectrum of that specific locus. The resulting spectrum acts like a fingerprint that can be used to characterize the feature of that particular pixel. This is an emerging tool for food and dairy products quality and safety analysis; the spectral feature helps to identify of a wide range of multi-constituent products. However due to high cost of HIS systems, most food and dairy products related HSI research mainly concentrated for identification of important wavelength for the development of low cost multispectral imaging systems. Although , continuous improvement on process analytical technologies to provide accurate, rapid, analysis of food and dairy products, it is likely that hyperspectral imaging will be increasingly adopted for safety and quality control in the food and dairy industry, as well as pharmaceutical industry. Future developments in HSI equipment manufacture, such as lower purchase costs and improvements in processing speed, helps to increase it's rapid utilizations in food, dairy and pharmacy industry rapidly.

Key Words- Hyper spectral imaging, spectroscopy, spectrum of specific locus, quality control

---

Abstract for Poster Presentation   Article Code: PP-PO-03

Applications of Radiofrequency (RF) in Food Industry

Tanmay Hazra, Subhash Prasad, Manishkumar Parmar, Akash Kumar Solanki
College of Dairy Science, Amreli, Gujarat

Thermal and non-thermal technologies are mainly apply for the processing and preservation of foods and dairy products. The awareness about upright nutrition along with the increasing demand for fresher appearance have shifted the way for new food processing technologies including microwave (MW), radiofrequency (RF), infrared (IR) heating etc. Radio frequency (RF) heating is an advanced and emerging technology for food application because of its higher penetration depth, heat distribution and low energy consumption. RF heating of foods are complicated physical processes that depend on the propagation of electromagnetic waves governed by Maxwell's equations, interactions between electromagnetic waves and foods determined by their dielectric properties, and heat dissipation governed by basic heat and mass transfer theories. Two common kinds of radio frequency (RF) systems (free running oscillator and 50 Ω) are widely applied in industry and research purpose. RF has been introduced in food and dairy industry to sterilize, pasteurize, disinfect food and agricultural commodity like fruits and dry nuts, milk, dairy products and in many more. It is one of the most promising physical disinfestation methods in agricultural products due to rapid heating, deep penetration depth, and leaving no chemical residues. The demand for safe, hygienic, tastier, no fat and preservative free food has widened up RF application in the modern industries.

Key Words- Preservation, Radio frequency (RF), Dielectric properties, Maxwell's equations

---

Abstract for Poster Presentation — Article Code: PP-PO-04

Membrane Technology: Review on Applications in Dairy Industry

Arpita Rathva, Ashish Patel, I. A. Chauhan, Y. V. Vekariya, Kinjal Baldha, S. M. Patel
SMC College of Dairy Science, Anand, Gujarat

The membrane technology is a novel non thermal environmental friendly greener technology with full of future possibilities. This technology minimizes the adverse effect of temperature rise, change in sensory attributes of the product and also helps to preserve the nutritional quality. Mainly four types of membrane processing use in the industry such as Reverse osmosis, Nano-filtration, Ultra filtration and microfiltration each have their unique usage. In the modern dairy processing, membranes play a major role in clarification, demineralization, increase the concentration of the selected components as well as separation of the specific valuable components from milk or dairy by-products etc. The membranes are suitable to different types of plant design and expansion due to their compact design. Membranes are already well established in the processing of whey, cheese making, traditional products etc. In the present paper, developments related to membrane separation in the dairy industry are presented along with the research conducted by the authors.

Key words: Membrane technology, Whey, Cheese, Traditional Indian Dairy Products

---

Abstract for Poster Presentation — Article Code: PP-PO-05

Role of Extrusion Technology in Dairy industry

Subhash Prasad[1], Ankit Deep[2]
[1]College of Dairy Science, Kamdhenu University, Amreli, Gujarat
[2]Dairy Engineering Division, ICAR-NDRI, Karnal

Extrusion process is a high temperature and short time process in which moist, soft food material is fed to the extruder for desired temperature, pressure, and residence time. Today their processing functions may include, conveying, mixing, shearing, separation, heating, cooling, shaping, venting, flavour generation, encapsulation and sterilization. Dairy products enriched with the health attributes of functional ingredients such as breakfast cereals would be safe and viewed as potential novel foods for health promotion. Milk protein possesses health benefits and desirable functional properties. When milk protein is subjected for mechanical shear, considerable changes in the molecular structures of the protein are seen. Texturization stretches and shears the protein to form a new fibre-bundle like structure which withstands - hydration, cooking and other procedures. In the dairy industry extrusion technology is hardly known but some research work has been done, for example on casein/ caseinate conversion, production of processed cheese, mozzarella cheese, *sandesh*, kneading of *chhana* for formation *chhana* balls to make *rasogolla* etc. Recent research works of extrusion technology in dairy industries like, characterization of extruded and toasted milk proteins concentrates, pre-biotic fibre incorporated whey proteins crisp processed by supercritical fluid extrusion, functionalization of whey protein by reactive super critical fluid extrusion and physic- chemical evaluation and optimization of enriched expended pallets with milk protein concentrate.

Abstract for Poster Presentation Article Code: PP-PO-06

X-Ray Applications in Dairy and Food Industries

Subhash Prasad, Tanmay Hazra, Manishkumar Parmar
College of Dairy Science, Kamdhenu University, Amreli, Gujarat

Among machine vision techniques, x-rays have distinct advantages in non-destructive inspection because they can penetrate through the most objects. Therefore, x-rays are used to identify internal defects non-destructively, where other imaging techniques, such as visible light, fail. Dairy and Food applications mainly use soft X-rays. Soft X-rays are easily absorbed in air; the attenuation length of 600 eV (~2 nm) X-rays in water is less than 1 micrometre. X-ray imaging has been extensively researched for dairy and food inspections. Poor image contrast, due to similarity in the attenuation properties of an object and its background, pose a challenge in image segmentation. Development of local adaptive approaches has improved image segmentation and classification accuracies. Hardware developments have resulted in commercial-grade X-ray inspection systems. Future developments in x-ray generation and detection technologies, advances in image processing algorithms, and worldwide food safety concerns indicate increased opportunities for X-ray inspection in the dairy and food sector.

Key words: Image processing, Machine vision, Plant, X-ray.

Abstract for Poster Presentation Article Code: PP-PO-07

Solar Pasteurization of Milk

S.K. Singh
Agricultural and Food Engineering Department, IIT Kharagpur

Due to usage of fossil fuels for human activities, significant undesirable effects on the environment as well as on people's health are encountered. In recent years national and international concerns about energy production has been outstanding. This has given a fresh impetus to the researchers for resorting to non-conventional energy sources like solar, wind, biomass, hydrothermal etc., because these are renewable, inexhaustible and clean. Pasteurization is a process of heating milk for killing of pathogens and to prolong the shelf life by destroying undesirable enzymes as well as reducing the number of viable spoilage microorganisms. Pasteurization requires a large amount of fossil fuel. So, keeping in view of above problems a prototype of parabolic trough collector type solar pasteurizer has been developed. Milk (initially preheated to 60 °C) was passed through absorber tube at flow rate 28 L/h. Considerable temperature rise up to 75.2 °C was obtained. Sufficient holding of milk at requisite temperature was done in a holding tube. Efficacy of the pasteurization process was determined using ALP test. Aim of current study is to enhance the performance of the developed prototype by incorporating a micro-controller based single axis Sun tracking mechanism. This study also focuses on a finite element modelling of the pasteurizer using COMSOL multiphysics for better understanding of how solar energy is distributed over the pipe and to find out the parameters which will give us maximum utilization of energy.

Keywords: Pasteurization, Parabolic Trough collector, Solar Energy, Milk, Sun Tracking, ALP.

Abstract for Poster Presentation Article Code: PP-PO-08

Energy-Exergy Analysis on Baking of *Chhana Podo* in a Hybrid Oven

F. Magdaline Eljeeva Emerald, Heartwin A. Pushpadass, M. Manjunatha, B. Surendra Nath
ICAR-NDRI, Southern Regional Station, Bengaluru

The principal step in the preparation of *chhana podo* is baking, which is an energy-intensive process. Analysing the heat and mass transfer and enhancing the energy efficiency of baking are thus important. In this study, *chhana podo* was prepared by kneading *chhana*, sugar and *tikhur* starch in the ratio of 19:6:2 and the dough was baked in a hybrid oven (combination of convection and infrared). The performance of baking process was evaluated by energy and exergy analyses. Baking of *chhana podo* was carried out at different temperatures. The energy consumption, energy savings and time savings in the hybrid baking mode were calculated. It was observed that the exergy efficiency at 110, 120, 130, 140 and 150°C with IR level at 800W was 18.86, 21.56, 26.17, 27.99 and 29.09%, respectively. The exergy efficiency increased with increase in temperature from 110°C, but appeared to reach a plateau beyond 150°C or might fall thereafter. Increase in drying air temperature enhanced the exergy efficiency due to the high rate of heat and mass transfer and increase in the corresponding exergy utilization for the quantity of moisture evaporated from the product. The energy consumed in convective mode ranged from

1591.33 to 2820 W for baking at different temperatures. The energy consumption under convective baking decreased with increasing temperature because the time required for baking decreased and the rate of heat and mass transfer increased. Energy savings of nearly 10% and baking time reduction of approximately 25% were achieved for baking of *chhana podo* in the hybrid oven depending on the selection of temperature and infrared power level.

Keywords: Baking, *chhana podo*, energy, exergy

Abstract for Poster Presentation Article Code: PP-PO-09

Sorption isotherms and isosteric heat of Dairy Whitener

Bhavesh Chavhan[1]*, C. Sahu[2], A.K. Agarwal[2], G.P. Deshmukh[3], R.S. Kavitkar[3]
[1*]PhD Scholar, NDRI-Karnal, [2]Prof, CODFT-Raipur, PhD Scholar, NDRI-Karnal[3]

In present communication, sorption isotherms and isosteric heat of dairy whitener have been investigated for three temperatures viz 30, 40 and 50°C. The sorption isotherms describe the equilibrium relationship between water activity (a_w) and moisture content of the food, at constant temperatures and pressures. Dairy whitener is generally used in making tea and coffee and has different variations of fat. The fraction of adsorption and desorption isotherms of dairy whitener were drawn at three temperatures viz 30, 40 and 50°C. A gravimetric static method was used approximately between 11– 92% relative humidity for sorption isotherms that were found to be typical type II sigmoid shape. Equilibrium moisture content (EMC) at 30°C was higher when compared at 40 and 50°C. Experimental data were fitted to five mathematical models viz. Modified Mizarhi, Caurie, Oswin, Hasley and Guggenheim–Anderson–de Boer (GAB). It was found that GAB models were acceptable in describing equilibrium moisture content–equilibrium relative humidity (EMC–ERH) relationships for dairy whitener over the entire range of temperatures (30-50°C). Monolayer moisture content of dairy whitener decrease with increasing temperature from 3.355 at 30^0C to 2.199 g/100g solids at 50°C. Thermodynamic property of the product i.e the isosteric heat of sorption were determined as a function of the product moisture content. The isosteric heat of adsorption for dairy whitener ranged from 15.79 kJ/mol at 5% moisture (d.b.) to 1.404 kJ/mol at 30 % (d.b.) moisture content.

Keywords: Dairy whitener, moisture sorption isotherms, equilibrium moisture content, water activity, relative humidity and Isosteric heat.

Abstract for Poster Presentation Article Code: PP-PO-10

Concentration of Liquid Foods by Vacuum Microwave Evaporator

Devaraju R.[1], Heartwin A. Pushpadas[1], F. Magdaline Eljeeva Emerald[1], Spoorthy G. S.[2]
[1] ICAR, SRS-NDRI, Bangaluru, [2] College of Dairy Technology, SVVU, Tirupati

Liquid foods like milk, fruit and vegetable juices have high nutritional value due to their minerals, vitamins, phenolic compounds and antioxidant substances. Multistage thermal evaporators are generally used to concentrate and increase the soluble solids of fruit juices and milk from 5-20% to 60-75% so that the costs of storage, packaging and transport are minimized, and shelf life is improved. Concentration affects the quality of liquid foods such as colour, aroma, flavour, appearance and taste. The traditional techniques of concentration destroy the nutritional and bioactive components, including sensory attributes such as the colour and flavour, etc. In recent years, novel concentration techniques have gained importance in light of the drawbacks of traditional processes. Some of these novel techniques include freeze concentration, sublimation concentration, and vacuum microwave concentration. In vacuum microwave concentration, as the food is heated by microwave energy, the electromagnetic energy is absorbed and heat is generated within the food by the reorientation of the dipoles of water. Combination of microwave heating and a vacuum system may allow still faster rates of mass and energy transfer at low temperature. More water vapour could be separated from the product using a VME system, besides efficient use of energy and maintenance of product quality. Thus, recent research works are focused on application of such VME system for concentration of pineapple juice, raspberry juice, black mulberry juice, and pomegranate juice. The applied microwave energy and vacuum decreased the process time to 115, 95 and 60 min for black mulberry juice and to 118, 95 and 75 min for pomegranate juice as compared to conventional rotary heating method. Similarly, concentration of apple juice in VME showed that the evaporation rate was three times higher than that of rotary evaporator and two times higher than that of rising film evaporator. VME also produced minimal colour changes in apple juice as compared to

the other two methods. Thus, it could be stated that it is a promising and emerging technique for concentration of liquid foods.

Abstract for Poster Presentation Article Code: PP-PO-11

Cold Plasma and its applications in Dairy Industry

Lakshmana N.[1*], P. Barnwal[2], Bhavesh Chavhan[3]
[1*]M. Tech. Student, [2]Principal Scientist, [3]Ph. D. Scholar - ICAR-NDRI, Karnal

Cold plasma (CP) processing is an emerging non-thermal technology for mild surface decontamination of dairy and food products and packaging materials. Plasma is generated when an inert gas gets in contact with electricity; reactive substance composed of charged particles, free radicals, photons and various radiations are formed. This whole formulation is known as plasma. Plasma produced at an ambient temperature is referred to as cold plasma having a temperature of 30-60°C, which is mostly preferably used in the food processing industries. The cold plasma processing has been reported for microbial inactivation while maintaining quality of fresh produce. In recent years, its applications were extended into the dairy and food industry as a powerful tool for non-thermal processing, with diverse forms for utilization. Non thermal preservation technique CP treatments will be useful in pasteurization and sterilization for preservation of milk and milk products in dairy industry, which will minimize the undesirable changes like protein denaturation, cooked flavour, browning and loss of nutrients to the products. The CP kills the microbial cells at moderate temperature and short times. The plasma technology is also offering high potential in food packaging as it enhances the adhesion properties. Conjointly it is use in the treatment of sliced Cheddar cheese. Cold plasma technology is gaining fame for its unique characteristics like treatment in low or ambient temperature for a short period of time which helps in retaining the integrity and quality of food and dairy products.

Abstract for Poster Presentation Article Code: PP-PO-12

Cheese processing developments and manufacturing equipments: An Overview

Lakshmana N.[1*], P. Barnwal[2], Ankit Deep[3], Bhavesh Chavhan[4]
[1]M tech student, [2]Principal scientist, [3]Scientist, [4]PhD Scholar - ICAR-NDRI, Karnal

In general, cheese is a fermented food derived from milk of various mammals. In some cheeses, direct acidification is also practiced in place of fermentation method e.g. mozzarella cheese. Cheese is a milk concentrate, the basic solids of which consist mainly of protein (actually casein) and fat. Cheese has been made by most starter cultures since ancient times. Different types of cheeses have been made in different parts of the world. Depending on type of cheese, unit operations vary to some extent. The generalized method of cheese making involves pre-treatment of milk, possibly pre-ripened after addition of a bacteria culture appropriate to the type of cheese, and mixed with rennet. The enzyme activity of the rennet causes the milk to coagulate into a solid gel known as coagulum. This is cut with special cutting tools into small cubes of the desired size – primarily to facilitate expulsion of whey. During the remaining curd making process, the bacteria grow and multiply and form lactic acid from the lactose. The curd grains are subjected to mechanical treatment with stirring tool. The finished curd is placed in cheese moulds, mostly made of plastic, which determine the shape and size of the finished cheese. The various equipments are involved in different unit operations of cheese manufacturing such as cutting of coagulum, mechanical stirring of curd during cooking, straining the whey, cutting the curd, pressing and moulding of the curd. The cheese equipment consists of cheese vats, cheese knives, agitator, curd strainers, cheese mould.

Abstract for Poster Presentation Article Code: PP-PO-13

A Comparative Study on the Effect of Ohmic Heating and Conventional Thermal Treatments on Sugarcane Juice and Potential Applications in Milk Processing

Abhilasha P., Pal, U. S.
Department of Agricultural Processing and Food Engineering, College of Agricultural Engineering and Technology, Orissa University of Agriculture and Technology, Bhubaneswar, Odisha

The effect of ohmic heat (OH) treatment was measured in sugarcane juice under different electric field strengths (16, 32 ,48 and 64 V/cm) and the samples were held at 70, 80 and 90^{o}C for 1, 2 and 3 min as holding time and for optimised conventional thermal (CT) treatment for same temperature for 5, 10 and

15 min respectively. The processing condition of 48 V/cm and 1 min holding time at 70 °c was found optimum and was analysed for Polyphenol oxidase (PPO), titrable acidity (TA), reducing sugars (RS), sensory tests, colour and microbial load for 5 and 20 days at room and refrigeration temperatures respectively. During refrigerated storage, TA and RS remained significantly ($p < 0.01$) unchanged and also it was observed that PPO activity also decreased significantly ($p < 0.05$)and even in sensory test also. Both treatments resulted in significant microbial reductions but growth resurfaced after 5th and 15th day of room and refrigeration storage respectively. No yeast and mould growth was witnessed after OH-treatment but colour change was noticed more in OH as compared to CT treatment. Overall, the OH-treatment was found to inhibit PPO enzyme activity in a shorter processing time than CT, while maintaining the potential quality attributes of the sugarcane juice. Ohmic heating is now receiving increasing attention from the dairy & food industry as an alternative for the indirect heating methods of food processing. Potential areas of application of OH-treatment in processing of milk and milk products include the pasteurization of milk, heat treatment of ice cream mixes and whey. The effect of OH-treatment of milk has been reported as the inactivation of milk enzymes, microorganisms, alkaline phosphate and reduced protein denaturation. It helps in avoiding fouling of surfaces and heat damage to milk products and is specially suited to shear sensitive milk products.

Abstract for Poster Presentation Article Code: PP-PO-14

Whey Draining Mechanism for *Chhana*

V. K. Ammu*, P. S. Minz, A.K. Singh, Amita D. Vairat, Chitranayak, Khushbu Kumari, Dharin Jayswal
ICAR-NDRI, Karnal

A whey removal phenomenon during chhana production was studied using mathematical modelling and conventional whey draining characteristics of *chhana* was determined. As traditional process is time consuming, equipment for rapid draining of whey was developed. Process of whey removal using lab centrifugal separator was studied considering three variable parameters spin speed (50 to 150 rpm), time (5 to 15 min) and quantity of cow milk (3-5 l). It was observed that by controlling the speed and spin time, *chhana* of desired quality was obtained. The optimized solution upto 5 kg milk in centrifugal based whey removal system was 65.57 rpm for 5 min. A prototype of whey removal system was designed and developed for handling 20 l milk. The range of speed and time considered in the experimental design were in the limits 80 to 200 rpm and 7 to 20 min respectively. The performance evaluation of developed system for whey removal showed a high desirability at 80 rpm, 9.5 min for 20 kg milk. The developed equipment for rapid whey removal for *chhana* reduces the production time and yields *chhana* with optimum moisture content and soft body.

Keywords: *Chhana*, Experimental design, Optimized solution

Abstract for Poster Presentation Article Code: PP-NT-01

Merits of MOSFET Based Pulsed Electric Field Applicator

Preeti Birwal, Menon Rekha Ravindra, Gajanan Deshmukh
Dairy Engineering Division, SRS of ICAR-NDRI, Bangalore

Pulsed electric field (PEF) equipment is generally designed to handle and process very high voltages around 20-60 kV. Equipment for the PEF treatment usually consists of a pulse generator, a treatment chamber and a system for control and data acquisition. Conventionally, thyratron switches is reported as the preferred choice to handle high voltages and fast turn-on. However, in thyratron switches only turn-on is controllable, whereas the turning off is often dependent on a Resistor-Capacitor (RC) circuit with a constant load of resistance. Metal Oxide Semiconductor Field Effect Transistors (MOSFETs) and Insulated Gate Bipolar Transistors (IGBTs) have been projected as the future of high power switching. A MOSFET based system is amongst recommended systems to generate a square wave pulse in range of micro. N-channel MOSFETs are used for switching the pulses of set width at desired frequency for high speed, fast rise and fall times, and short propagation delay. MOSFETs are said to be capable of faster switching system, low voltage and current rating compared to IGBT and have wide application in industry. MOSFET based circuits are less complex compared to other. However, to increase the switch capacity, several units are often connected in series and parallel; this results in a significant increase in costs. MOSFET based systems have flexibility for the designing precisely controllable systems.

Keywords: Pulsed electric field, MOSFET, Voltage Generator

Abstract for Poster Presentation Article Code: PP-NT-02

Modernization of Processes for Manufacturing of Traditional Indian Dairy Products

Gajanan Deshmukh[1], Preeti Birwal[1], Rekha Menon[2], Naveen Jose[3], Priyanka[1]
[1]Ph.D. Research Scholar, [2]Sr. Principal Scientist, [3]M.Tech. Research Scholar, ICAR-NDRI, SRS, Bangalore

India has emerged as the leading milk producing country in the world. It is estimated that majority of milk produced in India (50-55 %) is converted by the traditional sector (*halwais*) into variety of Indian milk products. During last two decade lots effort has been put by organized sector as well as research institutes towards modernization of traditional dairy products through mechanized production and organized marketing of several popular dairy products. The research stations like National Dairy Research Institute, SMC College of Dairy Science, Anand and others research institute in India contributed significantly in development of small as well as large scale mechanical unit for mechanized production of traditional Indian dairy product. In current date for almost all traditional Indian dairy products mechanical units for their production are available in market. Manufacturing of *khoa* and *khoa* based sweets like (*peda, burfi, kalakand, kheer*) in batch type conical process vat (CPV), multipurpose SSHE, thin film SSHE as well as inclined and three stage SSHE are the some achievement in mechanical manufacturing of traditional Indian dairy product. A mechanized semi-continuos system for the manufacture of *gulabjamun* at Sugam Dairy, Baroda, mechanized system for Continuous Basundi Machine (CBM) and Batch type Halwasan making Machine (BHM) at SMC Anand, mechanized unit for kneading of *chhana* and *chhana* ball-forming at IIT Bombay, subaric thermal processor for deep fat frying of traditional Indian dairy product NDRI-SRS Bangalore, continues ball forming and ball making machine for *peda gulabjamun* and *rosogolla*, concentration of *khoa* through RO, production of *chakka* and *shrikhand* trough UF unit, mechanized manufacturing of *Kulfi*, inline manufacturing of ghee are some recent advances in mechanization of traditional Indian dairy products.

Keywords: Traditional Indian dairy product, Mechanization, SSHE

Abstract for Poster Presentation Article Code: PP-NT-03

Application of High Pressure Processing for Milk and Milk Products

Rajasekhar Tellabati, Priyanka, Gajanan Deshmukh
ICAR-NDRI, Adugodi, Bengaluru

Thermal pasteurization technology may affect the appearance, flavours, and nutritional value of foods. High pressure processing (HPP) also called high hydrostatic pressure processing, ultra high pressure processing, pascalization or cold pasteurization is a non-thermal processing method for high value products. It involves application of a very high pressure of the order of 400-600 MPa for a time period varying from few seconds to up to 20 min. HPP offers opportunities for food manufacturers to develop new foodstuff with extended shelf life maintains the organoleptic properties and nutritional values. Milk is a highly valued product. High pressure processing has been applied in milk for studying the various quality aspects. Pressure up to 400 MPa is used for high pressure processing of milk for various purposes. Lower pressure up to 250 MPa with mild temperatures of (40°C) is suggested for destruction of microorganisms while pasteurization is reported at 448 MPa at 41°C for 11 min. Studies have also indicated selective influence of high pressure processing on digestion on milk proteins and increase of total serum calcium and phosphorus levels. HPP of milk has also been used for cheese and yoghurt production and is reported to increase the wet curd yield. Few studies have also suggested the use of high pressure processing for preservation of probiotics, starter cultures and dairy based infant foods. However, process line needs to be fine-tuned in terms of output and tools need to be developed to guarantee safe and constant temperature-pressure combination. HPP is an emerging technology that meets the consumer demand for safe, wholesome, new foods containing fewer additives.

Abstract for Poster Presentation | Article Code: PP-NT-04

High Pressure Shift Freezing- A Novel Technique for Food Freezing

Naveen Jose [1*], Abhinash. P[1], Seethu. B. G[1], Gajanan P. Deshmukh[2], Menon Rekha Ravindra[3]
[1]M Tech Scholar, [2]Ph D Scholar, [3]Principal Scientist, ICAR-NDRI, SRS, Bengaluru

Freezing is one of the most successful methods for long-term preservation of the natural quality attributes of perishable foods as it delays or prevents microbial, chemical and physical alterations by reducing water activity (solidification to ice), microbial growth and reaction velocities in enzymatic systems. High-pressure freezing has been envisaged as a promising freezing method by the food industry, mainly due to its potentiality for improving the kinetics of the process and the characteristics of the ice crystals thus formed. Three different types of high-pressure freezing processes can be distinguished in terms of the way in which the phase transition occurs: High-pressure assisted freezing (HPAF), High-pressure shift freezing (HPSF) and High-pressure induced freezing (HPIF). In High-pressure shift freezing, the sample is cooled under pressure at less than 0°C and kept in a non-frozen state. When the desired temperature is reached in the product, pressure is released inducing uniform super cooling throughout the sample due to the isostatic nature of pressure. This super cooling induces uniform formation of nuclei throughout the sample (regardless of its shape and size), so that latent heat is released, raising the sample temperature to the corresponding freezing point. Freezing is then completed at constant pressure, usually at atmospheric conditions and the ice crystals thus formed are granular in shape with no specific orientation and are dispersed throughout the sample, demonstrating that in expansion, ice nucleation occurs throughout the product and not only on the surface. HPSF finds its applications in inactivation of enzymes, microorganisms, and preservation of sea foods, gels and vegetables. Major advantages of this process are granting small average crystal size, reduced microbial load, inactivation of enzymes, less mechanical damage to the product due to quasi-static cooling, enhancement of product safety due to synergistic effect of high pressure and sub-zero temperatures. Complete modelling of HPSF systems is required to achieve real control and optimization of both freezing processes and equipment.

Keywords: High Pressure Shift freezing, isostatic, quasi-static cooling

---

Abstract for Poster Presentation | Article Code: PP-NT-05

Role of Infrared Heating in Food and Agricultural Processing

Priyanka, Seethu B.G., F. Magdaline Eljeeva Emerald, Heartwin A. Pushpadass
Southern Regional Station, ICAR-NDRI, Adugodi, Bengaluru

Heating is the most important unit operation in food and agricultural processing. For the success and profitability of any unit operation, energy conservation is one of the major factors to be considered. Infrared (IR) heating is a novel heat processing technique being adopted in the food industry. In infrared heating, heat generated can be directly absorbed by the food material by exposing the object to infrared radiation in the wavelength 0.78-1000 µm. IR heating is gaining popularity because of its high thermal efficiency and fast heating rate/response time along with high efficiency, wavelength and reflectivity. These advantages have led to the successful application of this technology in a number of thermal processing operations such as dehydration, frying and pasteurization for fruits, vegetables and meat products. Infrared technology is classed into 3 categories, namely near-infrared (NIR), mid-infrared (MIR) and far-infrared (FIR). Infrared radiative properties of the food materials depend on the size and form of particles, on their microstructure and optical properties, and on the wavelength of the radiation. For food processing, FIR is widely used as most food components absorb radiative energy in the FIR region. IR heating finds major application in the food industry for inactivation of enzymes and pathogenic microorganisms and is primarily attractive for surface heating applications. At ICAR-NDRI, infrared energy was used for baking of *chhana podo*, wherein energy savings of about 10 % and baking time reduction of about 25% were achieved. However, the product quality was maintained as in the case of convective baking. Despite being unique, IR technology is still in the stage of infancy in the food processing sector. For optimum energy efficiency and practicability, combination of IR heating with microwave and other common conductive and convective modes of heating holds great potential in the dairy sector.

Abstract for Poster Presentation Article Code: PP-NT-06

Application of Carbon Nano Tubes (CNTs) for removal of Chemical Oxygen Demand (COD) from Dairy Wastewater

Spoorthy G. S.[1], Devaraju R.[2], Adarsh M. Kalla[2], Rajunaik B.[2]
[1]Assistant Professor, Dairy Engineering Department, College of Dairy Technology, SVVU, Tirupati,
[2]Dairy Engineering Section, SRS-NDRI, Adugodi, Bangalore

The importance of the treatment of water and wastewater is gradually increasing because of the increasing demands to reduce environmental pollution. The dairy industry, like most other agro-industries, generates strong wastewaters characterized by high biological oxygen demand (BOD) and chemical oxygen demand (COD) concentrations reflecting their high organic content. Dairy waste effluents are concentrated in nature, and the main contributors of organic load to these effluents are carbohydrates, proteins and fats originating from the milk. Furthermore, dairy-processing effluent also has high concentrations of dissolved salts (total dissolved solids [TDS]). A number of biological treatment systems have been used for wastewater treatment such as activated sludge system, anaerobic pond, oxidation pond, trickling filter and combined trickling filter/activated sludge system. However, each system has its own disadvantages. Carbon nanotubes (CNTs) as new adsorbents have gained increasing attention of many researchers, due to their large specific surface area, small size and hollow and layered structures, CNTs have been proven to possess great potential as superior adsorbents for removing many kinds of organic and inorganic contaminants. Thus, current research works are focused on application of CNTs. The dairy wastewaters were treated by CNTs, for the removal of COD. Studies were carried out with CNTs by varying parameters such as initial pH, adsorbent dose, contact time, initial COD concentration, etc., The amount of COD adsorbed per unit CNTs mass increased with increase in initial COD concentration, CNT dosage and temperature and decreased with an increase in pH. Thermodynamic studies of adsorption of COD revealed that the negative values of Gibbs free energy were denoted to the spontaneous process, and the positive value of enthalpy for adsorption of COD on CNTs showed that the adsorptions process is endothermic. The kinetics of COD adsorption onto CNTs followed the pseudo-second-order model. Thus, it could be identified that it is a favourable and emergent technique for dairy waste water treatment.

Abstract for Poster Presentation Article Code: PP-NT-07

Spray Freeze Drying: Applications in Dairy Industry

Seethu. B.G., Priyanka, Abhinash. P., Heartwin A. Pushpadass, F. Magdaline Eljeeva Emerald
Southern Regional Station, ICAR-NDRI, Adugodi, Bengaluru

For decades, different technologies were employed for extending the shelf life of dry products. By combining conventional techniques such as spray drying and freeze drying, a new technology was developed called 'spray freeze drying' (SFD). This technique is used for producing powder products with long shelf life and better quality than that from conventional drying methods. The main steps involved in this technique are atomisation, freezing and drying. The liquid solution is first atomised into a cryogenic medium (commonly used is liquid nitrogen) and it is followed by removal of frozen solvent by lyophilisation. Spray freeze drying can be classified as spray-freezing into vapour, spray freezing into vapour over liquid and spray-freezing into liquid, depending upon the spray freezing and freeze drying conditions. The main advantage of this process is that it helps to maintain inherent attributes of highly heat-sensitive and bioactive compounds. It has been used in the production of skim milk and whole milk powders, and the obtained powders were reported to have porous and fine-textured surface. Therefore, the SFD skim milk powder was reported to have more wettability compared to conventional spray-dried powder. This technique has also been used for microencapsulation of probiotic microorganisms like *Lactobacillus paracasei, Lactobacillus plantarum,* etc. The viability of the probiotics was improved by SFD. In recent times, ultrasonic and four fluid nozzle atomizers are employed for atomization of the feed. By varying the frequency of ultrasonic atomizer, a high degree of control could be achieved in particle size. SFD can be carried out under vacuum, atmospheric pressure and sub atmospheric pressure conditions. The major limitation, however, is the high operating cost compared to conventional methods. It has been widely used in nutraceutical industry, and it has the potential to be applied to dairy and food industries for the production of high value products.

Abstract for Poster Presentation Article Code: PP-NT-08

Biosensors and their application in Food and Dairy Industry

Vishal Thakur[1*], P.S. Minz[2], Amita D. Vairat[3], Khusbhu Kumari[3], Dhruvin Patel[1]
[1*]M.Tech. Scholar, [2]Scientist (Sr. Scale), [3]Scientist, ICAR-NDRI, Karnal

Food producers are increasingly asking for efficient quality control methods to satisfy the consumer and regulatory requirements to improve the production feasibility, quality sorting, automation and reduction in production cost and time. Generally in the food and agricultural industries, chemical and microbiological analyses are done periodically by trained operators, which are expensive and increasing the time of analysis. Biosensors can overcome all these disadvantages by offering rapid analysis, non-destructive and affordable methods for quality control by using optical, mass, electrochemical and thermal biosensor. The most important characteristics of biosensors are their specificity, high sensitivity, short response time, act as an integrated system, facility to automate them, versatility and low production cost. Biosensors are classified according to the transduction mechanisms and bio-reception mechanism. The principle of detection of a biosensor is based on the specific interaction between the analyte of interest and the biological components. Biosensors have number of applications in food and dairy industry like online determination of lactose in milk, determination of tea quality, and determination of glucose concentration in meat, detection of pathogens etc. Ascorbate oxidase biosensor is also used for rapid analysis of vitamin C in food and pharmaceutical samples. By taking all these aspects related to food and dairy industry into consideration, the development and use of biosensor has really became a boon. Biosensors have the potential to produce an analytical revolution to resolve the challenges in the food and dairy industries.

Keywords: Biosensors, transduction, non-destructive, bio-reception.

Abstract for Poster Presentation Article Code: PP-NT-09

Role of Robotics in Dairy and Food Industry

Dhruvin Patel[1], P.S. Minz[2], Vishal Thakur[1]
[1*]M Tech scholar, [2]Scientist, ICAR-NDRI, Karnal

In present competitive age the demand of meeting the requirements of large quantities with high quality simultaneously is posing greater challenges before food processors and researchers. Automation is one of the proven key tools to cope up with these challenges. The dairy and food industry is now highly automated, from the raw material production to the processing and manufacture of products. The implementation of automation in the dairy and food sector offers great potential for improved safety, quality and profitability by optimizing process monitoring and control. Robotics may be feasible to automate many of the complex and repetitive tasks that are carried out in the dairy and food industry. However, there is a broad range of potential applications for robotics in dairy and food industries are grading of food products, pick and place operations, packaging and palletizing, meat processing, milk and milk product production and processing that can be accomplished by types of robot like portal robot, articulated robot, SCARAs, delta robot etc. Even though robots bring with them so many advantages like safety, consistency and efficiency but they have some disadvantage like the high costs, requirement of skilled engineers and sophisticated system for its training/programming. There is immense potential of application research on robotics for specialized food processing operations and as components of the advanced automation systems.

Abstract for Poster Presentation Article Code: PP-NT-10

Potential of Ultrasonication in Dairy and Food Processing Industry

V.K. Ammu, P.S. Minz, A.K. Singh, Amita D. Vairat, Chitranayak, Khushbu Kumari
ICAR-NDRI, Karnal

Global dairy industry is on a good pace of progress expected to witness revolutionary changes in industry towards attaining a high efficiency in all aspects of its run. A wide variety of innovative and efficient technologies are now available to enhance processing efficiency, shelf life, safety and functional properties of dairy products. Among those emerging technology ultrasonication as well as thermosonication are regarded as promising technology of significant potential in many aspects of dairy processing. The main cause of efficiency enhancements or functional property modification observed in dairy systems is attributed to the physical effects generated under cavitational and non-cavitational conditions. Application of ultrasound includes ultrasonic cutting devices for hard and soft cheeses minimizing wastage, ultrasonic welding for sealing milk containers and grated cheese packages, ultrasonic imaging to study structure development, rheological properties and cutting time in cheese, ultrasonic degassing, homogenization and emulsions, membrane flux enhancement and cleaning efficiencies. Thermosonication and manothermosonication has been found useful for inactivation of microbes and enzymes associated with spoilage, safety and quality deterioration in a range of liquid food systems. Other applications are spray drying using ultrasonic atomizers, ultrasonic crystallization and freezing (sonocrystallization) and modification of functional properties of dairy ingredients. Ultrasonics, technology can be adopted to improve efficiency of existing process line or can be taken as a way to improve the functionality of dairy ingredients.

Keywords: Efficiency, Innovative, Manothermosonication. Thermosonication, Ultrasonication,

---

Abstract for Poster Presentation Article Code: PP-NT-11

Potential of Renewable Energy Applications in Dairy Industry

Abhinash. P., Seethu, B.G., F. Magdaline Eljeeva Emerald, P. Heartwin Amaladhas
Southern Regional Station, ICAR-NDRI, Bengaluru

India is blessed with vast resources of renewable and sustainable energy. The estimated power generation from renewable sources is 15.9% of the total installed capacity in India by 2022. Dairy industries consume huge amounts of energy daily due to thermal processing and refrigeration of various milk products. The renewable energy options that are available to the dairy industries are solar and wind. The vast solar potential of the country could be utilised for hot water generation, cooling, pumping, lighting, electric fencing, etc. Photovoltaic cells and solar thermal systems use radiative energy from the Sun to produce electricity and heat, respectively. With the advent of more efficient photovoltaic cells in the recent years, the solar panel could generate as high as 250-300 W/m^2 of energy. The energy conversion efficiency of photovoltaic cells has increased from nearly 6% in the 1950s to 18-23% today. Simultaneously, the cost of solar energy panels has crest-fallen by 90% due to the advances in manufacturing and electronics. Another promising source of alternative energy for dairies is the cleaner wind energy. Wind turbines convert about 45% of the kinetic energy of the wind passing through the blades into electricity. They can be installed in places where the productive wind speed ranges from 6-35m/s. The power density of energy generation is about 200 W/m^2 of utilized area. It is the cheapest source of renewable energy available to the industry. For reasons above, solar and wind energies are more adaptable to dairy industries, and can be used as an alternative for the existing energy sources that are polluting the environment. Adoption of these two energy generation could also help the industry to tide over power cuts during peak seasons. It is recommended that the dairy industry should take advantage of the incentives and promotions offered by the Government to shift from utilization of depleting conventional energy sources and harness these two promising green energy sources of the future.

Abstract for Poster Presentation Article Code: PP-NT-12

Microwave Assisted Vacuum Drying

Sharanabasava, Shivanand, Nagaratna M. D.
Department of Dairy Engineering, Dairy Science College, Mahagaon cross, Kalaburagi

Dehydration is one of the most effective techniques in preserving foods. Dried foods are more resistance to microbial spoilage and objectionable enzymatic reactions due to its lower moisture content. Drying for foods can be achieved using various techniques which cause a significant loss of characteristic flavour in dried products because of high temperature and long drying time also degrades the product's original colour. Hence, it is clear that the nature of conventional drying methods does not result in best quality and least cost. Vacuum drying can be successfully used for the faster removal of moisture but heat transfer to the solid phase is slowed down significantly due to the absence of convection and the low water vapor pressure at the reduced evaporation temperature. When vacuum drying in combination with dielectric heating is used, the rate of heat transfer can be increased approximately 10-fold. The food absorbs the microwave energy due to the existence of substances containing dipoles or dipolic regions. Due to this interaction heat is produced in the product and directly transferred by means of conduction mechanisms throughout the entire mass of the radiated material. This phenomenon greatly reduces the required drying time for complete drying by more than 30% when compared to conventional methods and

leads to a significant improvement of the final product quality. The microwave-vacuum drying technique has been successfully applied to numerous food materials such as apples, grapes, peanuts, rice, asparagus, mushrooms and soybeans.

Key words: microwave, vacuum, drying, dipole

Abstract for Poster Presentation Article Code: PP-NT-13

E-beam Technology and its Application in Food Industry

Adarsh M. Kalla[1], Rajunaik. B.[1], Abhinash. P.[2] Manjunatha B.M.[1], Saurabh Patel[1]
[1]Ph. D. scholar, [2]M.Tech scholar, Department of Dairy Engineering, ICAR-NDRI, SRS, Bengaluru

E-beam technology is a non-thermal, chemical free, food processing technology that can be used to maintain quality and safety of foods. It is an example of ionizing radiation technology, however it is not similar to conventional cobalt 60 based food irradiation which is less economical due to its limited availability, cost, shipping, storing and replenishing. The e-beam technology is easier and less expensive and faster than cobalt 60. The e-beams are generated from commercial electricity and therefore are truly on–off technologies. The equipment that generates e-beams and are generally called linear accelerators. It accelerates electrons to very high velocity and high energies (upto 10MeV) which are then allowed to penetrate the case ready packages. The energetic electrons can directly attack DNA of microorganism and inactivate them. They can also split the water molecule generating free radicals which in turn inactivate pathogens. The e-beam technology has a broad application in various fields like polymers, where it is used for cross linking of polymers to improve their physical properties. It is a better solution in waste management can help break down food and agricultural wastes to help recover some of these high value products. It can reduce microbial population in drinking water. For food industry, e-beam application can be broadly categorized into high energy (5-10MeV), medium energy (1-5MeV) and low energy (0.1-1 MeV). Many studies have reported to achieve significant reductions of microbial pathogens on a variety of foods like lettuce, spinach, oysters, strawberries etc. E-beam technology is an emerging technology which can reduce public health risks and can reduce enteric virus contamination at in packaging houses.

Abstract for Poster Presentation Article Code: PP-NT-14

Applications of 3D Printing in Dairy and Food industry

Shubham Thakare[1], Chitranayak[2], P.S. Minz[3], Amita D. Vairat[3], Khushbu Kumari[3]
[1]M. Tech. Scholar, [2]Senior Scientist, [3]Scientist, Dairy Engineering Division, ICAR-NDRI, Karnal

3D Printing is also known as additive manufacturing technology has been dubbed the next big thing and be as equally wide spread as cellular telephone industry.3D printers print objects from a digital template to a physical 3D physical object. The printing is done layer by layer manufacturing(Additive manufacturing) using plastic ,metal, nylon, and over the hundreds of other materials.3D Printing has been found to be more useful in sectors such as manufacturing, industrial design , footwear, jewellery, architecture, engineering and construction, aerospace, dental and medical industries, education, geographic information system, civil engineering and many applications. It has been found to be fast and cost effective solution of in whichever field it is use. The applications of food printing is ever increasing and its proving to be very exciting technology to look out for. There are different methods used for the 3D printing such as Stereolithography (SLA), Laminated object manufacturing(LOM), Selective laser sintering(SLS) Selective laser melting(SLM), Electron beam technology(EBM), Fused deposition modelling(FDM), Granular material binding etc. Now this technology is also being used in Dairy and Food industry for different types of food and dairy product fabrication such as cheese, pasta, noodles, cookies, cakes, chocolates and for the decorative purposes. Hence due to different benefits such as lower cost, time saving quality, flexibility, quality product, less wastage this technology is expanding rapidly in the different sectors in the world.

Keywords: 3D Printing, Additive manufacturing, Steriolithography, Fused Deposition modelling

---

Abstract for Poster Presentation — Article Code: PP-NT-15

Amperometric Biosensors for Food Processing Industries

A .D. Patel[1], I. A. Chauhan[1], A. M. Rathva[1], Y. V. Vekariya[1], S. M. Patel[2]
[1]Assistant Professor, [2]Professor and Head, Dairy Engineering Department, SMC College of Dairy Science, AAU, Anand

In the food industry, quality, freshness, as well as safety of the products, are major concerns. Food quality control is an important and inherent stage in any food processing industry. Quality of raw material, contamination of food during processing, quality of final product, and the changes in the food during shelf life are important factors for the food producer and consumer. Biosensors offers several advantages in the food industry such as high specificity, selectivity, short response times, lower costs, diversity, potential miniaturization, simplicity of operation, and potential adaptation to automation. In addition, biosensors may be used as portable devices and give the opportunity to work with real samples, thus eliminating the sample pre-treatment steps. Various types of transducers may be combined with different types of bio-recognition elements used to build a certain type of a biosensor; amperometric biosensors have a distinct advantage over other types of bio sensors. Amperometric biosensors are one of the good choices for monitoring markers associated to the properties of the food. In amperometry, the electrode is held at a constant potential to detect the relevant electroactive species by oxidation or reduction. The optimum potential for detection in amperometry is chosen after obtaining the current response of the analyte as a function of electrode potential. Amperometric transducer allows the electrochemical reaction (oxidation or reduction) to proceed at the electrode surface, giving rise to a current. This current is directly related to the bulk substrate concentration. The application potential for some of the target molecules, measured by amperometric enzyme electrodes, are glucose, dextrose, sucrose, lactose, alcohol, some organic acids, and others. It is also possible to determine some of the contaminants such as microorganisms, pesticides, and toxins using an amperometric enzyme electrode. Besides determination of food components and contamination, enzyme electrodes are used for the measurement of the food additives.

Abstract for Poster Presentation — Article Code: PP-NT-16

Shelf life Enhancement of Buffalo Milk *Kheer Mohan* through Hurdle Technology

Ganga Sahay Meena[1], Gaurav Kumar[3], Raghu H.V.[2], Mina Nath Giri[4], Yogesh Khetra[1]
[1]Scientist, [4]M. Tech (D.T.) Research Scholar,
By Product Lab, Dairy Technology Division, ICAR-NDRI, Karnal
[2]Scientist, Dairy Microbiology Division, ICAR-NDRI, Karnal
[4]M. Tech (FT) Research Scholar, BFIT, Dehradun

Kheer Mohan, a regional product, is preferred for its palatability and taste. It had moderate to light brown colour, cooked and moderate caramelized flavour, and pleasant taste with heated note. It had fairly tough, close knit, dense and chewy, non-elastic, granular body and texture with moderate sweetness and juiciness. However, traditionally it is being sold in paper cardboards and had a shelf life of 7days in summer and 12-14 days in winter season. Therefore, present investigation was aimed to improve the shelf life of buffalo milk *Kheer Mohan.* The product was subjected to cooking, packaging in tin cans containing sugar syrup and permitted preservative followed by further heat treatment at relatively higher temperature (hurdle technology) and storage at 30±1ºC. During storage changes in sensory attributes, physical properties (pH, free fatty acids), textural attributes and microbiological counts (total plate counts, yeast and molds counts, and coliform and staphylococcus aureus counts) were determined. The *Kheer Mohan* was very much liked by the sensory panel after 6 month storage. During storage, microbial counts were absent while, marked changes were observed in pH, free fatty acids, water activity and hardness of the *Kheer Mohan.*

Key words: Buffalo milk, *Kheer Mohan*, Shelf life enhancement, Sensory and textural attributes Microbiological counts


Vita
स्वाद, सेहत और शुद्धता अपनाएं
वीटा ही घर लाएं
हमारे उत्पाद: फुल क्रीम, स्टैण्डर्ड और डबल टोंड पाश्चुरीकृत दूध, A२ देसी गाय का दूध , दही, शुद्ध देसी घी, पनीर, मक्खन, मीठी और नमकीन लस्सी,
खीर, पिन्नी, काजू पिन्नी, आइस क्रीम, मिल्क केक, फ्लेवर्ड इलायची और बटर स्कोच मिल्क

Food & Biotech Engineers (I) Pvt. Ltd.

(An ISO 9001 : 2008, 18001: 2007, 14001 : 2004 Certified Organization)

JAS-ANZ

M441021011

IAF

Designers, Engineers, Consultants, Manufacturers & Exporters of Plant & Plant & Machineries for Dairy, Food Processing, Herbal, Chemical, Distillery

List of Equipments

Evaporators

- Falling Film Evaporators
- Forced Recirculation Evaporator
- Batch Type
- Scrapped Surface Evaporator
- Wiped film Evaporator

Dryers

- Spray Dryer
- Fluid Bed Dryer
- Vacuum Band Dryer
- Vacuum Tray Dryer
- Ring Dryer
- Rotary Dryer
- Drum/Roller dryer

MISCELLANEOUS EQUIPMENTS

- Milk Silo
- Butter Churn
- Butter melting system
- Road Milk Tanker
- Khoa Pan
- Screw Conveyor
- Bottle Sterilizer
- Rotary Valve
- Blow through Valve
- Steam radiator
- Disc Atomizer
- 10-25 kg Butter packing machine
- Twin shaft mixer
- Turbo Blender
- Paddle mixer
- Cone mixer
- Sigma Mixer
- High solids (75% TS) mixing equipments
- Ribbon Blender
- Finger Stirrer with baffles
- Mixer with turbine agitator at bottom and paddle stirrer at top
- Auto hot water washing station
- SS pump
- Lobe pump
- Cheese kettle
- SS valve
- CIP spray nozzle (Rotary type, turbine type)
- Triple concentric tubular heater
- Sifter
- Mist type Jet condenser
- Compactor
- Online sieving system
- Milling Machine
- Rotary Extractor
- Vertical Extractor
- Reactor

Off. & Works: Chaprola Road, Prithla, Tehsil & Distt. -Palwal, Pin: 121102 Haryana
Contact No. : 9312069945, 01275-262157, 01275-262158 Fax: 01275-262259

Email: info@foodbiotech.co.in Website: www.foodbiotech.co.in, www.dairyfoodtech.com