STUDIES ON IN-LINE PRODUCTION OF GHEE FROM BUTTER

THESIS SUBMITTED TO THE

NATIONAL DAIRY RESEARCH INSTITUTE, KARNAL

(DEEMED UNIVERSITY)

IN PARTIAL FULFILMENT OF THE REQUIREMENT

FOR THE AWARD OF THE DEGREE OF

MASTER OF TECHNOLOGY

IN

DAIRY ENGINEERING

BY

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B. Tech. (Dairy Technology)

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KARNAL-132001 (HARYANA), INDIA

2012

Regn. No. 2041005

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CERTIFICATE

This is to certify that the thesis entitled **"Studies on in-line production of ghee from butter"** submitted by **Mr. Amit Kishor Kanhed** in partial fulfilment of the requirement for the award of the degree of **MASTER OF TECHNOLOGY in DAIRYING (DAIRY ENGINEERING) of the NATIONAL DAIRY RESEARCH INSTITUTE (DEEMED UNIVERSITY),** Karnal (Haryana), India, is a bonafide research work carried out by his under my supervision and guidance and no part of the thesis has been submitted for any other degree of diploma.

Bikram Kumar

Dated: 23th June 2012

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MAJOR ADVISOR & CHAIRMAN

(GUIDE)

Dedicated to

My Dearest Buddy

Sumit N. Agrawal

(CA, CS, B.Com, M.Com)

&

My Family

ACKNOWLEDGEMENT

The present investigation entitled, "**Studies on in-line production of ghee from butter**" has been conducted in the session 2011-1012 at National Dairy Research Institute, Karnal.

I take the privilege to express my esteem and profound sense of gratitude to my major adviser (Guide) and Chairman **Prof. Bikram Kumar** (Principal Scientist, Dairy engineering) for his insightful discussions, creative ideas, unfailing interest, valuable suggestions and encouragement all along this investigation. Moreover, his ability to look at things from new angles often gave new momentum to the work, as a result of which this thesis has taken its present shape.

I express my insufficiency to trace out appropriate words to speak highly of my advisory committee members Dr. Darshan Lal, Principal scientist, Dairy chemistry division, Dr. RRB singh, principle scientist, Dairy technology division, Dr. I.K. Sahwney, principal scientist, Dairy engineering division and Dr. R. Malhotra, principal scientist, DES & M division for their scholastic guidance, diligent help, continuous inspiration, critical appreciation and perfect patient during course of work.

I extend my sincere thanks to Dr. A.K.Shrivastava (Director), NDRI, Dr. G.R. Patil, Joint Director (Academics), NDRI Karnal for providing all necessary infrastructures to carry out the present investigation.

I thank to all teachers, whose guidance become building block and helped me to reach this stage of academics life. My sincere thanks to all the scientists of Dairy Engineering division, Er. P.S. Minz, and the technical staff Er. S.K. Chaudhary, Er.J.K.Dabas, Mr. S.S. Bhinder, Mrs. Manju, Mr. Pavan Kumar, Mr. Sunil Kumar, Mr. Saurabh, Staff of Dairy engineering and Dr .A.K.sharma, Dairy superintending, experimental dairy and all other staff of experimental dairy.

My sincere thanks to all scientists, teachers and staff members of DE division for their overwhelming help during my stay at NDRI.

I express my heart feel appreciation, thanks and sincere regards to my batchmates and friends Ranjeet Kumar Yadav, Somnath Pagire, Aswin warrier, Yogesh, Vinod Kumar, Asha Yadav, Pankaj parmar, Sunil Kumar, Rahul kumar (Mota bhai), Jiral Patel, Rakesh Sheel, Mahesh MS, Pravin, Prachi and Amrit. For their immense help, magnanimous cooperation and encouragement during my dissertation. I am also thankful to my seniors Mohit Tyagi, Santosh Chopde, Chandan solanki, Kumaresh, Savita Kinake, Akash Porohit, .I express my sincere regards to my juniors Anuj Pal, Dipak Mehta,Swapnil Dudhe sir,Bhavesh panchal, Mukesh Pratap Singh, Mohanjee Lal, Saurabh, Sharique, Kadam, Puspendra Singh, Ranvir, Pravin Dahale, Akash Arora, Rajendra, shantanu, Rashmika, Kesha, Anu, Ronak and Gunvant,

Last but not the least **my parents** n my lovely big B " **Kunal Bhaiya**" and my best friends **Sumit N.Agrawal, Sweetu, Nancy, Sanket Borad, Preity Jagtap, Padamveer singh, Upasana Yadav and MM Ali**. There are no words to express my feeling for my parents, brother and Best friends. These people really mean a lot in my life. I owe them a lot. I cannot forget to convey my special thanks to my most loving late grandma and grandfather (Abasaheb), all uncles, aunties, dear cousin brothers, sisters and Jiju.

Finally, I would like to thank to everybody who was important to the successful realization of thesis, as well as expressing my apology that I could not mention personally one by one.

Date: 23 June, 2012

(Amit Kishor Kanhed)

ABSTRACT

Ghee is a pure clarified fat derived solely from milk or Desi (cooking) butter or from cream to which no colouring matter is added. Ghee production from butter mainly involves melting of butter, followed by moisture removal and finally simmering for the development of body and texture. Experiments were conducted on in-line production of ghee from butter. Each unit operation of ghee making was identified, simulated and optimized by engineering interventions in relation to quality requirement. Scraped surface heat exchanger with a high heat transfer coefficient was selected for the moisture removal from butter whereas conical processing vat (CPV) with variable heating surface was optimized for simmering for the development of flavor and texture of the ghee.

The optimized pressures of CPV and SSHE were 3 kg/cm^2 and 2.5 kg/cm^2 respectively whereas the optimized rpm of SSHE scraper was 200.The rheological characterization in terms of physico-chemical parameters was carried out to access the quality attributes in terms of acceptability of ghee. The quality of *ghee* so produced was also evaluated in terms of sensory evaluation which was carried out by the panel of ten judges. Ghee produced by using optimized parameters gave average sensory score viz., flavor, body and texture, colour, and freedom from suspended particles as 41.5, 8.5, 9.5 and 3 respectively. Moisture of ghee at optimized parameter was 0.2%. The observed sensory and quality attributes of ghee was statistically analyzed by using factorial design. Ghee prepared by in-line production system was found highly acceptable quality.

सारांश

घी एक शुद्ध स्पष्ट वसा है जो दूध या देसी मक्खन (खाना पकाने) या क्रीम से व्युत्पन्न है और इसमें कोई रंगीन सामग्री का मिश्रण नहीं जोड़ा जाता है. मक्खन से घी का उत्पादन मुख्य रूप से मक्खन के पिघलने, नमी हटाने और अंत में शरीर और बनावट के विकास के लिए धीरे धीरे खोलाया जाता है. इन- लाइन विधि द्वारा मक्खन से घी के उत्पादन पर प्रयोग आयोजित कीए जा चुके है. घी बनाने की प्रत्येक आपरेशन इकाई की इंजीनियरिंग हस्तक्षेप द्वारा पहचान अनुकरण अनुकूलन और साथ ही गुणवत्ता की आवश्यकता देखी जाती है परिमार्जन सतह गर्मी विनिमय एक उच्च गर्मी गुणांक हस्तांतरण के साथ मक्खन से नमी हटाने के लिए चुना गया था जबकि परिवर्तनशील हीटिंग सतह के साथ शंक्वाकार प्रसंस्करण वैट (सीपीवी) घी का स्वाद और बनावट के विकास के लिए अनुकूलित किया गया था.सीपीवी और एस एस एच ई के अनुकूलित दबाव 3 और 2.5kg/cm^2 क्रमशः थे जबकि एस एस एच ई खुरचनी का अनुकूलित आर पी एम 200 था. भौतिक - रासायनिक मापदंडों के मामले में रिआलाजिकल लक्षण वर्णन किया गया घी की स्वीकार्यता के मामले में गुणवत्ता विशेषताओं का उपयोग घी ताकि उत्पादित की गुणवत्ता भी जो दस न्यायाधीशों के पैनल द्वारा किया गया संवेदी मूल्यांकन के संदर्भ में मूल्यांकन किया गया था.

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LIST OF ABBREVIATIONS AND NOTATIONS

ANOVA	Analysis of variance
B & T	Body and texture
BIS	bureau of Indian Standards
CI	Cast iron
CPV	Conical processing vat
CD	Critical Difference
CPV S.P.	Steam pressure of conical processing vat
FFA	Free fatty acid
FSSR	Food Safety and Standards Regulations
g	Gram
IS	Indian standards
kg	Kilogram
kpa	kilopascal
MS	Mild steel
NDRI	national Dairy Research Institute
NS	Not significant
PFA	Prevention of food adulteration
rpm	Revolutions per minute
rps	revolutions per second
SE	Standard error
SS	stainless steel
SSHE	Scraped surface heat exchanger
% OA	Percentage of oleic acid
%	Percentage
^{o} C	Degree Celsius

cm	centimetre
Fig.	Figure
kg	Kilogram
kg/cm^2	Kilogram per square centimetre
mm	millimetre
m	meter

CHAPTER -1

INTRODUCTION

INTRODUCTION

India has emerged as a largest milk producer in world with an annual production of 121.8 million tonnes (Indian Dairyman, 2012). India is the world's fastest growing market for milk and milk products with an annual growth rate of about 4%.The mass appeal enjoyed by the indigenous sweets is underlined by the fact that about 50% of the Indian milk production is utilized for making various indigenous products like *khoa, khoa* based sweets, *ghee, rubri, basundi* etc (Indian Dairyman, 2009).Many traditional dairy products have enormous market presence and tremendous consumer base in India and overseas as well.

The total output of indigenous milk products is estimated to be $ 12 billion. This is more than the half market ($ 22 billion) of the milk and milk products in India. The market for the traditional dairy products is to the tune of more than 65,000 crores. The consumption of traditional dairy products is likely to grow at an annual growth rate of more than 20%, but for the western dairy products the growth rate is relatively much lower (5-10%). Thus the expanding business prospect provided by the Indian traditional products to the organized dairy sector triggers a through face-lift of these products.

Almost all the traditional dairy products are manufactured by the *Halwais.* The increasing demand of these sweetmeats internationally presents a great opportunity for the organized sector to mechanize and scale up the production. For this purpose mechanization and up gradation of equipment based technology for the large scale production is ultimate need of the hour. Up gradation of technology should ensure safety, wholesomeness of product with certain degree of homogeneity in the quality of the product.

Looking back in the history, there have been times when traditional Indian dairy products were hardly pure and safe to eat because their production and marketing had largely been in the hand of *Halwais* and traders. The chemical composition, taste and textural properties of the products vary to a great extent. The microbiological quality of the product also being inferior results in the poor keeping quality of the finished products. This poor shelf life may also be attributed to the post manufacturing contamination during packaging, storage and marketing.

Keeping in view the importance of indigenous dairy products and the limitations associated with its existing methods of manufacture, the National Commission on Agriculture in the year 1976 recommended that the production of various indigenous milk products and sweets derived there from should be taken up by the organized plants. The commission also suggested that efforts should be made to nationalize the technique of production of various indigenous milk products and explore the possibility of the large scale production by improving their keeping quality and packing with minimum expense. The traditional dairy products present a great opportunity for the organized dairy sector in the country to modernize and scale up their production.

Among all the traditional Indian dairy products, ghee production forms the largest segment of the milk consumption and utilization pattern in India. Rising at an annual growth rate of 5%, ghee production has been estimated in 2009 to exceed 1.9 million tones , valued at 475 billion, which has been estimated to be about 33% of the total milk production and 58.9% of the total milk used for manufacture of traditional Indian dairy products. Ghee is by far the most important product widely consumed in Indian subcontinent since time immemorial. It is prepared from the cow or buffalo milk or combination thereof. It is known in different countries with different names such as ‘maslee’ or ‘Samna’ in Egypt and Israel ‘Roghan’ in Iran and ‘Dahin hurr’ in Iraq. Butter oil, popular in western countries, is slightly different from the ghee as former has a blind flavor.

The origin of the ghee making lies far beyond the recorded history. The word ghee stems from old Sanskrit word ‘Ghrita’ which means bright or to make bright. When sprinkled on fire, butter fat enhances its brightness. Before advent of new techniques, specially refrigeration, for furthering the shelf life of the milk, the latter had either quickly consumed, or some means had to be found for its conversion into more stable product, such as ghee, which satisfies this requirement.

Ghee traditionally marketed in the *Mandis*(market) where it is brought from village collection centers. Major ghee *mandis* have been established at Hathras and Kanjura in Uttar Pradesh; Porbander in Gujrat; Guntur in Andhra Pradesh; Erode in Tamilnadu; and Jodhpur in Rajastan (Aneja *et al.*, 2002). The production of ghee is higher in winter and lower in summer corresponding to the months of higher and lower milk production. Ghee has been regularly exported from India since 1930's. Presently ghee is exported to Nepal, Bhutan, Bangladesh, the Middle East countries and the modest quantity to north-America (Aneja *et.al.* 2002).

In general ghee is manufactured by the four different methods namely *Desi* method, direct cream method, creamery butter method and pre-stratification method. Among all these methods the country or *Desi* method of ghee manufacturing contributes more than 90% of India's ghee production. But this method is having number of drawbacks such as non uniform quality, incompatible to large scale production, low fat recovery, excessive energy utilization, high acidity and low keeping quality. While in case of organized sector ghee is manufactured in steam jacketed kettles which inherently suffer from several disadvantages.

1) Low heat transfer coefficient causing equipment to be bulky.
2) Batch to batch variation in the product quality.
3) Formation of tenacious scale of ghee residue on the heating surface adding to poor performance of equipment and making cleaning and sanitation strenuous.
4) Large residence time and product inventory in the equipment presenting greater risk of bulk spoilage of the product.
5) Excessive strain and fatigue intensive operation.
6) Product spillage around equipment making the floor slippery and causing accident.

Thus need was felt to mechanize the method of ghee manufacturing by using unit operation based in-line system without compromising the product quality. The dissertation work is based on characteristic unit operations involved in the ghee manufacturing process using butter as a starting material. This method also ensures the uniform quality as the quality of the product can be monitored during each unit operation.

CPV is a multipurpose vat with variable heating surface area which could be used for the initial melting of the butter and simmering for the development of flavor and texture. SSHE is having high heat transfer coefficient which could be used for the complete moisture removal from the butter during ghee manufacturing.

Thus for present dissertation research work, it was investigated to simulate ghee manufacturing method by using CPV and SSHE which has been formulated with the following objectives.

1) To optimize the unit operations for in-line production of ghee from butter.
2) Sensory and rheological characterization of ghee made from butter.

CHAPTER - 2

REVIEW OF LITERATURE

REVIEW OF LITERATURE

The review of literature of this investigation is here which is presented under the following sub heads:

2.1 Ghee

Ghee is one of the most important traditional Indian dairy product which holds its place in Indian culture since the Vedic time. According to FSSR (2011), ghee is a pure clarified fat derived solely from milk or from*Desi* (cooking) butter or from cream to which no colouring matter is added. Milk lipids regarded as an excellent component of diet, being a rich source of energy, essential fatty acids and fat soluble vitamins. Because of the low moisture content (0.5%), ghee has a better shelf life as compared to other traditional Indian dairy products. However it undergoes deterioration through hydrolytic and/or oxidative routes which spoils its appetising flavour, making it unacceptable and toxic (Mehta,2006) .In order to ensure the genuine product to consumer, the government of India has prescribed the compositional standards for ghee under the FSSR (2011) and Agmark rules (1981).

Desirable characteristics of ghee refer to typically pleasant, rich and cooked flavours and possessing uniform granular texture (Rajorhia, 1993). A good quality, buffalo ghee, should have a uniform whitish colour owing to the absence of carotene. Whereas the ghee made from cow should have yellowish colour. The compositions of the cow ghee and buffalo ghee and its average chemical constants are given in the table 2.1 and 2.2 respectively. Shelf life of the ghee is 6-12 months at 21^{0}C. Cold storage of the ghee should be avoided as it leads to loss of granular structure and development of the waxy consistency.

Table 2.1: Chemical compositions of ghee

Constituents	Cow	Buffalo
Milk Fat (%)	99-99.5	99-99.5
Moisture (%)	< 0.5	< 0.5
Free Fatty acid (%)	Max. 2.8	Max. 2.8

Carotene (ụg/g)	3.2-7.4	-
Vitamin A (IU/g)	19-34	17-38
Tocopherol (ụ/g)	26-48	18-37
Charred casein,salts of copper and iron etc.	Traces	Traces

Table 2.2: Average chemical constants of ghee

Constants	Cow	Buffalo
B.R. reading	43.2	42
Saponification value	227.3	230.1
RM value	26.7	32.3
P value	1.76	1.41
Kirschner value	22.1	28.5
Iodine value	33.7	29.4
Melting point (^{0}C)	28-41	32-43

(Rajorhia, 1993)

2.1.1 Methods for ghee making:

Basically there are four methods for ghee manufacturing namely *Desi* method/country method, creamery butter method, pre-stratification method and direct cream method.

a) ***Desi* Method:**

Ghee manufacturing fromdesimethod involves following unit operations

(a) Melting of butter
(b) Heating for moisture removal
(c) Simmering for the development of flavour and textural attributes.

A lot of butter, fresh or accumulated over a few days, is usually taken in a suitable open pot or metallic vessel, and heated along with stirring on a low fire to drive out the moisture. When practically all the moisture has been removed, further heating is carried out for the development of flavour and texture. This stage is judged by an experience, further heating is stopped and the vessel is removed from the fire. On cooling when the ghee residue has settled down, the clear fat is decanted into suitable containers.All these unit operations are carried out in an open kettle. Ghee made by desi method is mainly manufactured by unorganized dairy sector which inherently suffers from many drawbacks such as

(1) Non-uniform quality.

(2) Incompatible to large scale production.

(3) Low fat recovery.

(4) High acidity & low keeping quality.

(5) Excessive energy utilization.

(6) Unsanitary operation.

b) Creamery butter method:

This method is widely adopted organised dairy sector as standard, where the raw material used is unsalted creamery butter known as white butter. The butter is provided in an improved ghee boiler, which consist of stainless steel jacketed vessel provided with a manual stirrer. There may be provision for movable, hallow, stainless steel tube centrally bored through the bottom of the vessel for emptying the vessel content when required; alternatively, the vessel may be emptied by providing the simple vessel-tilting device. The steam control valve, pressure and temperature controller are generally provided in the boiler.

In the beginning, the solid mass of butter is heated over a low fire and carefully stirred so that it melts. Later the steam pressure in the jacket is raised so that the liquid mass starts boiling, with the removal of the water vapour from the vessel content at a temperature above 100^0C. This temperature remains constant as long as moisture is being driven out. The content are constantly agitated throughout the process of conversion of butter into ghee, to prevent scorching.

When practically all the moisture has been removed, the temperature of the liquid mass suddenly shoots up and the heating at this stage is carefully controlled. The endpoint is indicated by the appearance of effervescence, which is much finer than the first together with the browning of the curd particles. At this stage a characteristic ghee flavour also emanates and this is an indication that it has been heated successfully.

The final temperature of heating varies from 110 to 117 depending upon the region. After cooling and sedimentation, the ghee is filtered to separate it from the ghee residue. It goes then for granulation and packaging.

(c) Pre-stratification:

In this method, butter is left undisturbed at a temperature of 80-85^{0}C for 15 to 30 minutes in a ghee kettle, it stratifies into three distinct layers viz., a top layer of floating denatured curd particles, a middle layer of fat and a bottom layer of butter milk. This separation into three layers is known as pre-stratification. The bottom layer of butter milk contains 60-70% of SNF and 80% of moisture originally present in the butter. The butter milk is mechanically removed without disturbing the top and bottom layer. Afterwards, the temperature of the remaining two upper layers is raised to usual clarifying temperature of 110 to 120^{0}C.

(d)Direct cream method:

In this method the cream usually obtained from separation of milk is heated in the same ghee boiler described for the creamery butter method. The procedure for heating and moisture removal, final temperature of clarification, cooling and sedimentation, granulation and packaging remains the same.

The essential steps involved in the different methods of ghee manufacturing are outlined in the figure 2.1

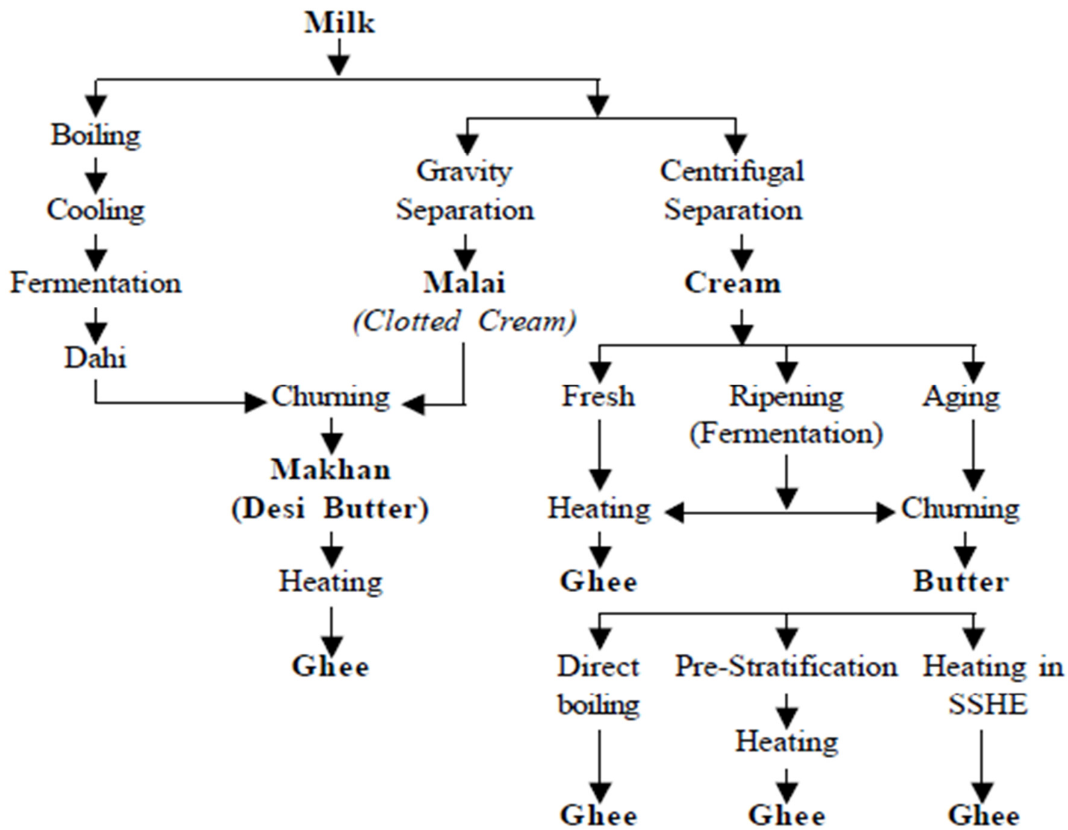


Fig., 2.1; Different methods for ghee manufacturing

2.2 Ghee characterization based on physico-chemical parameters:

Various physical and chemical constants have been derived for the characterization of ghee. Among various constants, butyrorefracrometer reading gives an overall average nature of the constituent fatty acids present.(Rangappa and Achaya,1974). Various physico-chemical constants are as follows:

2.2.1.Refractive Index and Butyrorefractometer reading:

It indicates the degree of bending of light waves passing through a liquid or a transparent solid is a characterisation for a particular solid or liquid. The refractive index of milk fat generally ranges between 1.4538 and 1.4578 (Walstra *et al.,* 1999). For animal fat at 40^{0}C, it lies in the range of 1.4570 and 1.4630. For most of the vegetables oils,it ranges from 1.4600 to 1.4750 but for some other vegetable oils like lauric fat (coconut and palm kernels oils) and palm oil, it lies in the range of 1.4480 to 1.4580 (Hamilton and Rossell,1986; Karleskinnd,1996)

Refractive index and BR readings are inter-convertible (BIS, 1981; Rangappa and Achaya,1974;Bolton,1999; Winton and Winton,1999). The values of BR reading of milk fat (40-45) and vegetables oils and fats (above 50) are so wide apart (Singhal ,1980; Gunstone*et al.*1994) that this property can be safely employed as an index for milk fat adulteration with vegetable oils and fats except coconut oil (38-39) and palm oil (39-40). Feeding of cotton seed oil rises the BR reading by 5 units in ghee.(Rangappa and Achaya,1974).Generally the BR reading or the refractive index of oils and fats increases with the increase in the unsaturation and also the chain length of the fatty acids. BR reading of animal fat is in the range of 44 to 51 (Singhal,1980).Adulteration of milk fat with animal body fat or vanaspati (Shama and Singhal,1995) at a level of 5 to 20% increases the BR reading of the milk fat.Recently some workers (Arora et al.,1996;Lal et al.,1998) have developed a simple platform test for the detection of vegetable oil (refined mustard oil) added to the milk fat at a level higher than a 10% of the original fat on the basis of increased BR reading of the milk fat.Arun Kumar (2003) reported that using general limit BR reading as 40-43, adulteration of vegetable oil up to 5% in cow ghee and 15% in buffalo ghee can be detected.

Balerao and Kummerrow (1954, 1956[a]) opined that the refractive index of whole fat cannot give reliable results about adulteration and suggested the use of alcohol fractionation (soluble and insoluble fractions) to increase the concentration of adulterants in one of these fractions ,causing enough shift in the refractive index and thus making the detection of the adulterants easier. They further improved the degree of accuracy of detection by subjecting the above alcohol insoluble fractions to acetone fractionation, and subsequent iodination of the acetone soluble fraction before determining the refractive index.

2.2.2 Free Fatty Acids:

Rangappa and Achaya (1974) reported that under optimum conditions, fresh ghee can be prepared from milk so as to have acidity as low as 0.06% expressed as oleic acid. The nature of these free acids depends on the processing stage and product involved.

2.2.3Moisture:

Thiel (1943) reported that solubility of water in butterfat increases with temperature, the solubility at 90^0C,60^0C, 80^0C and 95^0C being 0.19%,0.26%,0.36% and 0.47% respectively. The presence of 2% of free acids was stated to increase the solubility at 40 o C by 0.02%.

Paul and Anantkrishnan (1949) recorded the same moisture value of 0.2% determined by evaporation. In the usual method of heat rendering at about 115^0C, however soluble moisture content will be in the region of 0.04 to 0.19%.

2.3Ghee manufacturing and Equipment involved:

Various unit operations such as melting of butter, evaporation of moisture from butter, simmering and clarification are carried out on butter during manufacturing of ghee. Several attempts have been made to design & develop equipments for the manufacturing of the ghee but no attempt has been made to simulate each and every unit operation in mechanization process. These include batch & continuous type equipments. Each of these configurations has advantages in certain application & limitations in others. Some of these equipmentshave been discussed below:

2.3.1Batch Type Equipments:

2.3.1.1 Conical Processing Vat:

The design of conical processing vat was improvised from time to time to make it suitable for processing of various milk products such as *khoa,basundi,burfi* etc.

Agrawala*et al*. (1987) developed a mechanised vat for preparation of khoa.This is a batch type multipurpose equipment.This equipment consist of stainless steel conical vat with cone angle 60^0 and steam jacket partitioned into four segments for effective use of thermal energy and less heat loss. The mechanism is consisting of 3-equidistance arms supported at the two points at shaft and each arm having three independent spring loaded blades. A positive displacement screw pump is connected to the outlet at the bottom of the vat for recirculation and spreading of the product over a heat transfer surface.

The mixing and blending operation in the existing conical processing vat was optimised by Khojare (1999) by selecting the appropriate processing parameters.

Jayendra (2000) redesigned and installed an improvised discharge mechanism for uninterrupted discharge for viscous dairy products at higher concentration from the vat.

Gupta (2003) had designed and developed a mixing and blending mechanism for handling of viscous dairy products in conical processing vat.

Chichamalatpure(2008) studied*khoa*made from concentrated milk (20%,25% and 30% TS) along with a different steam pressure of 1.0,1.5 and2 Kg/cm^2 conical processing vat. It was concluded that the *khoa* made from 30% TS concentrated milk at 1.5 Kg/cm^2 had a desirable sensory and textural attributes. He also concluded that gumminess is sole textural parameter of *khoa* which should be used to compare the textural quality of product on the instrumental basis.

2.3.1.2.Scraped Surface Heat Exchanger:

Processing of various dairy products in the dairy and food industry is preliminary carried out in kettles, where the possibilities to control and optimize the heat treatment process are generally very limited. The demand for efficient and labour reducing in the food industry attracts the application of continuous processing in heat exchangers. For handling highly viscous products with or without particles, the productthat tends to foam and foul the heat transfer surface and heat sensitive products, the scraped surface heat exchanger is the most suitable. High heat transfer coefficient is achieved because the boundary layer is continuously replaced by fresh material. Moreover, the product is in contact with heating surface for only few seconds and high temperature gradient can be used without the danger of causing undesirable reactions. SSHEs are versatile in the use of heat transfer medium and the unit operation can be carried out simultaneously. This subhead critically reviews the current understanding and application of the thin scraped surface heat exchanger.

Bector*et al.* (1996) prepared ghee in a continuous system in horizontal TFSSHE and compared it with traditionally manufactured ghee. During storage for 180 days, a progressive decrease in retinol, vitamin E, and phospholipid content and increase in peroxide value and free fatty acid (FFA) was observed. Shelf life of continuously prepared ghee was comparable to that of ghee made of batch process.

Mechanization of *Basundi*making was also attempted at Gujrat Agricultural University Anand, using batch type stainless steel SSHE. The process parameters were optimised to obtain *Basundi*similar to the traditionally made product. The product was compared with the conventional method in the sensory and rheological profile, with better score and colour. The product was having uniform consistent quality in all the batches (Shah et al 2004).

Rajorhia et al. (1993) described the methods of ghee making. These methods were narrated according to the base material used (Milk, cream, butter); intermediate treatments of raw materials, & handling of the semi finished or fully formed ghee. Basically there are four methods for the manufacturing of ghee viz: *Desi* method, direct cream method, creamery butter method & pre-stratification method which are essentially based on the batch operation and these methods are suitable for the different scales of production. The*desi* method for the manufacturing of ghee involves: (1) Lactic acid fermentation of the milk or cream (3) Removal of thick clotted cream; (4) Hand driven wooden beaters are usually employed for separating the butter; (5) the butter is melted in a metal pan or earthen vessel on fire until all the moisture has been removed; (6) The clear fat is usually decanted off into ghee storage vessel.

The direct creammethod omitted the need for the production of butter because the cream is directly converted into ghee. One of the limitations of this method is that it requires long time to remove the moisture

2.3.2 Continuous operation type equipment

Punjarath*et al.* (1974) developed a process for a continuous manufacturing of ghee which is more scientific & more hygienic. The equipment is consist of receiving-cum-heating vat, gravity separator (which become optional while manufacturing ghee from cream), pressurized scraped surface heat exchangers coupled with vapour separator & positive displacement pump to move raw material through the different units. In the heat exchanger the raw material is heated with the help of steam & then superheated fluid (cream/butter) is flashed in the vapour separator. The vapour separator separates the water vapour from the liquid fat. The fluid from separator with partially removed moisture goes to the balance tank where it is pumped to the vapour separator. If butter is used as a raw material the process of complete removal of moisture & flavour development is completed in second stage. However for the cream a third stage involving balance tank, heat exchanger and vapour separator may be used to have better control over the quality of product. The product manufactured in this plant has been analysed for the chemical, organoleptic and keeping quality and found satisfactory. There was no significance difference between the ghee made in this plant and made by other processes.

Abhichandani*et al.* (1978) designed a continuous ghee making plant on the principle of flash evaporation to produce 100 kg of ghee per hour by taking creamery butter as a raw material. It consisted of one butter melting tank, pump and two stages each comprising of balance tank, horizontal scraped surface heat exchanger and a vapour separator but the equipment was neither compact nor economically viable.Lateron a new plant having capacity 100 kg/hr was designed on the falling film principle. It consisted of a butter melting tank, pump and two vertical falling film SSHEs. Trials were conducted with butter to produce 1000 kg ghee. Final ghee temperature of 118^{o}C was achieved

Abhichandani and Verma (1978) designed and developed a continuous ghee making plant based on the two stage scraped surface heat exchanger. In both the stages, scraped surface heat exchangers were used in order to have higher heat transfer coefficient and pneumatic temperature controller/recorder (RC) has been installed. The product manufactured in this plant was analysed for its chemical, organoleptic and keeping quality. On storage of ghee at 37^{0}C for 45 and 90 days showed that there was no significant change in its chemical constants. There was also no peroxide development in the ghee samples stored for 45 days, but a slight peroxide development (0.5-1.0) took place in the ghee stored for 90 days.

Abhichandani*et al.* (1982) designed and developed a falling film continuous ghee making machine. Few trials were conducted with butter. About 1200 kg of ghee was prepared. The comparison of operational feature showed that, an economy of operation is a maximum and energy consumption is minimum in the plant design on the falling film scraped surface heat exchanger principle.

Abhichandani*et al*. (1995) designed a continuous ghee making system based on thin film scraped surface heat exchanger and concluded that, the continuous ghee making machine can overcome all disadvantages and limitations of the current methods of ghee making in the industry. Capacity of the system was 400 Kg/h using plastic butter. The optimum machine parameters used were: steam pressure 4-5 kg/cm^2, number of blades was 4, and rpm was 200. Few product samples indicated very fine suspended particles of ghee residues in product.

2.4 In-line production of Indian Dairy products

2.4.1Market survey on ghee

Benerjee*et al.*(2002) have reviewed the present status of ghee in India and reported a wide variation in the moisture, fat,curd and FFA content .peroxide value of ghee samples were also collected from the different markets of India. The moisture content in the market ghee varied from 0.02 to 0.79%,fat from 93.5 to 99.9%,curd from 0.51 to 0.65%,FFA from 0.01 to 2.95% (as oleic acid) and peroxide value from 0.2 to 6.

Adulteration of ghee with vanaspati ghee was detected by various workers (Sharma and Zariwala,1978; Ghatakand Bandopadhyay,19889 and Benerjee,2002) but none of the worker found the adulteration of ghee with animal fat in the market ghee samples.

Physico-chemical constants of market ghee have been studied by many workers and they have found wide variation in the BR reading. The BR reading varied from 40.1 to 49.10 (Beneerjee*et al.*,2002).

2.5Integrated system of SSHE and CPV:

Manufacture of *Basundi*was tried at NDRI using conical processing vat and two stage TFSSHE with standardized buffalo milk.(Ranjeet,2003).

Patel (2009) carried out a study on feasibility of integration of SSHE with conical process vatfor continuous production of *khoa.* He concluded thatsuch integrated system leads to the production of better sensory textural quality of*khoa* in continuous manner. He concluded that the*khoa* made from the integrated system is comparable to the*khoa* made from traditional method.

Mahesh Kumawat (2010) optimised the process parameters of SSHE and CPV for in-line production of *khoa* and recommended that the best quality of *khoa* can be prepared by keeping SSHE steam pressure 4.90 kg/cm^2, SSHE scraper speed 200 rpm, concentration of milk in SSHE to 44.5% TS and CPV steam pressure1.50 kg/cm^2.

Santoshchopde (2011) optimised the process parameters of SSHE and CPV for in-line production of *Rabri.* The optimised parameters for unit operation based in-line production of Rabri were,

(a) Initial concentration in SSHE: 29.90% TS
(b) Final concentration (Before sugar addition) in CPV: 39.41% TS
(c) CCL/SCM ratio: 0.16
(d) The steam pressure of CPV during removal of clotted cream layer: 0.75 kg/cm^2.

2.6INFERENCES DRAWN FROM REVIEW OF LITERATURE:

The literature revealed that scraped surface heat exchanger are commonly used in food, chemical, and pharmaceutical industries for heat transfer, crystallization and other continuous processes to handle highly viscous, sticky and heat sensitive products. The thermal performance of the equipment has shown that it can handle wide viscosity range products without appreciable falling in the heat transfer coefficient. The equipment has been found very successful for the manufacturing of *khoa, Burfi* and *basundi*. Thus SSHE could be used for the rapid moisture removal from the butter during ghee manufacturing, in a cost effective way. While conical processing vat is a multipurpose vat with provision of variable heating surface which could be used for the butter melting and simmering for the development of desirable textural attributes. Thus it can be inferred from review of literature that the traditional method of ghee manufacturing can be simulated by using scraped surface heat exchanger and conical processing vat.

CHAPTER- 3

MATERIALS & METHODS

MATERIALS AND METHODS

This chapter deals with materials and methods employed to carry out research work as per technical.

3.1 Experimental Set-up and Accessories:

3.1.1 Experimental setup:

The experimental setup for the proposed study consisted of scraped surface heat exchanger, multipurpose conical processing vat, balance tank and reservoir tank. The equipment was installed in the equipment testing and display hall-I of the dairy engineering division under the supervisions for separate steam connection, condensate outlet and air vent.

3.1.1.1 Feed Tank:

Five hundred liter capacity rectangular tank is used as a feed tank. The feed tank is having 0.58m length, 0.50 m width and 0.50 m height.

3.1.1.2 Feed Pump:

The sanitary type centrifugal pump having 2000 liter/hr capacity is used to feed the molten butter in SSHE. This pump is fitted with a flow control valve to control the flow rate of melted butter during operation.

3.1.1.3 Scraped Surface Heat Exchanger:

Scraped surface heat exchanger with four SS blades (two for scraping and two for conveying) was used for the complete moisture removal from the butter during the manufacturing of ghee. Scraper was driven with a 3 HP, 1400 rpm. Dynodrive was used to regulate the scraper speed. SSHE was coupled with vapour vent, vapour vent cock, steam trap, pressure gauge, air vent, and safety valve.

3.1.1.4 Reservoir Tank:

To maintain a constant flow rate of butter to the conical processing vat to have a better control over the final quality of the product. Two way valve was used to control the flow rate of butter from reservoir tank which had a 90 liter capacity having 0.56 m diameter and 0.38 m length.

3.1.1.5 Recirculation System:

Recirculation system is attached with the experimental unit for recirculating the product till complete removal of moisture from butter. A three way valve is attached in between balance tank and conical vat recirculation pump. Pipe connected to the three way valve forward the flow of butter from SSHE to conical processing vat when all the moisture from the butter has been removed.

3.1.1.6 Circulation Pump:

A positive displacement single screw pump having capacity of 300 liter/hr has been hooked to the discharge line of reservoir tank for transferring the product after complete moisture removal to the conical processing vat for simmering and development of desired flavor and textural attributes.

3.1.1.7 Conical Processing Vat:

The equipment consists of a stainless steel conical vat with a cone angle 60^0 and steam jacket is partitioned into four segments for efficient use of thermal energy and less heat loss. The mechanism is consisting of three equidistant arms supported at two points at shaft and each arm is having three independent spring loaded blades. A positive displacement roto-screw pump is connected to the outlet at the bottom of the vat for recirculation and spreading of the product over the heat transfer surface. The design of conical processing vat was improvised from time to time to make it suitable for processing of various milk products such as *khoa, basundi, burfi* etc. The equipment as shown in the figure 3.1 has the following features:

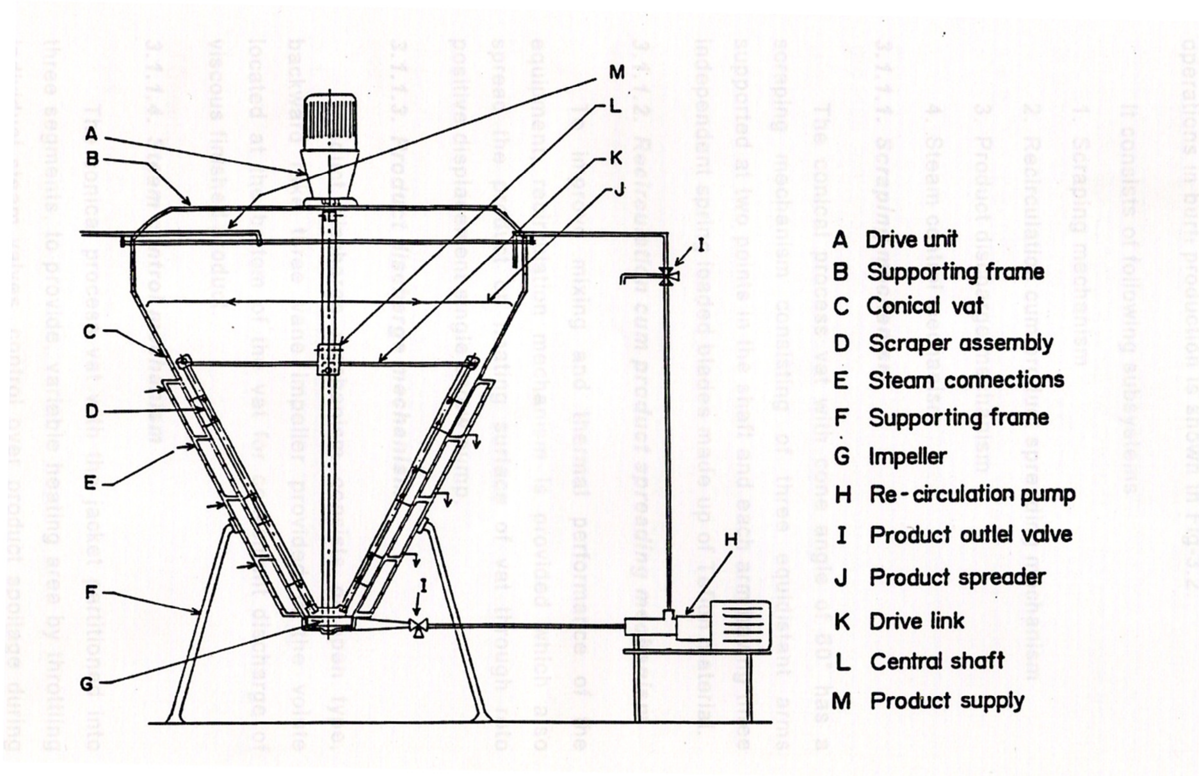


Figure 3.1: Schematic Line Diagram of the Conical Process Vat

3.1.1.7.1 Variable Heating Area:

The steam jacket of the conical processing vat is partitioned into three segments. There are separate connections for steam inlet and condensate outlet for separate jacket segment to control the heat supply to each segment. This helps in providing the variable heating area required during manufacturing of ghee from butter for melting and simmering. This provision was proposed to enhance, energy efficiency, steam economy, and effective process control during operation of the equipment.

3.1.1.7.2 Scraping Mechanism:

The vat has a centrally located vertical stainless steel shaft of 30 mm diameter with 870 mm length and it supports three symmetrically placed arms which are having alternatively arranged scrapper blades on each arm with slight overlapping. These blades are spring loaded for effective scrapping contacts.

3.1.1.7.3 Discharge Mechanism:

A propeller discharge mechanism has been attached to the lower end of the central shaft at the bottom of the vat for continuous and uninterrupted discharge of the product content from the vat with minimum residual hold up.

3.1.1.7.4 Product Recirculation Mechanism:

A positive displacement single screw pump having capacity of 300 liters per hour has been hooked to the discharge line of the vat for the recirculation of the product when required.

3.1.1.7.5 Mixing and Blending Mechanism:

Three designs of standard agitators, viz. anchor type, turbine type, and helical type have been developed for providing effective mixing and blending action in multipurpose conical processing vat. The mixing and blending operation in the existing conical processing vat was optimized by Khojre (1999) by selecting the appropriate processing parameters. Jayendra (2000) redesigned and installed an improvised discharge mechanism for uninterrupted discharge of viscous dairy products at higher concentration from the vat.

3.1.1.8 Pipe fittings:

All pipe lines used from the feed tank to final discharge of product having standard 25.4mm diameter.

3.1.2 Experimental Accessories:

The following accessories were employed during the conduct of trials.

(1) Digital Thermometer:

To monitor the temperature change during the various unit operations of ghee making, a battery operated digital temperature along with probe is used.

(2) Container:

Containers are used for collecting the condensate from CPV and SSHE during various unit operations of ghee making so as to estimate the steam consumption during various unit operations.

(3) Refractometer:

The Abbe refractometer is used for measuring the refractive index between air and liquid fat.It was calibrated at 40^{0}C.

(4) Weighing balance:

Electronic digital balance with a precision of 0.1 mg was used for the determination of moisture and free fatty acid of the ghee sample.

(5) Trays, Cans, and Buckets:

Butter is collected from experimental dairy into the trays and subsequent transportation of ghee is carried out by using cans (40 liters capacity).

3.2 Selection of Raw Material:

3.2.1 Butter:

Butter for ghee manufacturing was collected from experimental Dairy NDRI, Karnal. It is tested for its fat percentage and acidity.

3.2.2 Caustic solution:

Sodium hydroxide flakes LR (having 96% assay) is diluted in water and caustic solution of 0.75% strength was prepared for the CIP of SSHE and conical processing vat.

3.2.3 Water:

Potable water available at Dairy Engineering Division was used for the cleaning and other purpose.

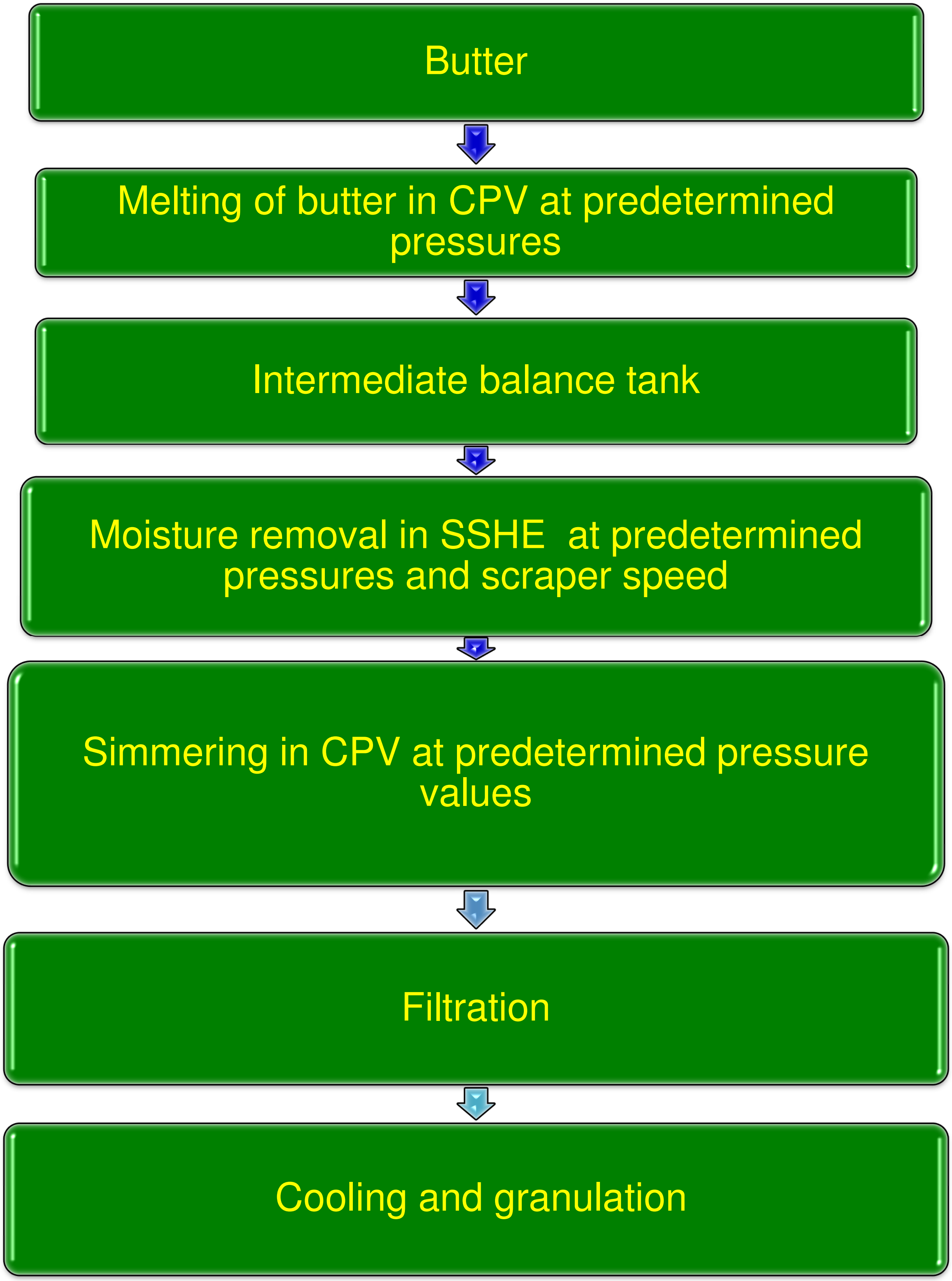
3.4 Methodology

3.4.1 Experimental procedure:

The experimental procedure adopted during present investigation was as follows:

a) CIP cleaning of the scraped surface heat exchanger (SSHE) and conical processing vat (CPV) was done with caustic solution of 0.75% strength and 85^{0}C for 15 minutes.
b) Frozen butter blocks of 60 kg each ware received in crates, cut into small pieces and transferred manually in conical processing vat.
c) Molten butter was transferred in SSHE through the feed tank till the moisture gets evaporated.
d) On attaining temperature of 105ºC, butter was transferred in CPV for the final heating (simmering) for the development of flavor and textural attributes.
e) On attaining the final temperature of 113 to 115ºC, heating was stopped by closing the steam valve of CPV and ghee was allowed to cool at room temperature
f) Following above procedure, trials were conducted at predetermined pressure combinations of CPV and SSHE and scraper speed of SSHE.
g) Product was subjected to sensory evaluation to a panel of expert judges.

Detailed flow chart for in-line production of ghee from butter shown in plate 3.1.



Flow chart for in-line production of ghee from butter

3.5. Measurement and Analysis:

3.5.1 Analysis of butter:

Chemical analysis:

3.5.1.1 Fat:

The fat content of butter was determined by using the Gerber method IS (1227:1997) for the fat estimation as described in IS 3507-1966.

3.5.1.2 Moisture:

The moisture content in butter was determined as described in IS 3507-1966

3.5.1.3 Temperature of the melted butter:

The temperature of the melted butter was measured during various unit operations of ghee manufacturing with the help of digital thermometer.

3.5.2 Analysis of Ghee:

Chemical analysis:

Chemicals and reagents:

3.5.2.1 Chemicals:

Sodium hydroxide pallets, hydrochloric acid and sulphuric acid (AR grade, Qualigens fine chemicals, Mumbai, India), Glycerol (AR grade, Ranbaxy Laboratories Ltd., Punjab, India) phenolphthalein (LR grade, Glaxo laboratories Ltd., Mumbai, India).

3.5.2.2 Reagents:

a) Ethyl alcohol: Ethyl alcohol was neutralized using 0.1 n sodium hydroxide solution in presence of phenolphthalein indicator before its use.

b) Phenolphthalein solution: One gram of phenolphthalein was dissolved in 5 ml of distilled water and then volume was made to 100 ml with absolute distilled water.
c) Sodium hydroxide solution(0.1 N): About 4.2 g of sodium hydroxide was dissolved in distilled water and volume was made to 1000 ml in volumetric flask. The strength of solution was adjusted to 0.1 N with the help of 0.1 N standard oxalic acid solutions.

3.5.2.3 Equipments:

a) Boiling water bath: The laboratory Glassware co., Ambalacantt.,india
b) **Butyrorefractometer:** Naveen scientific industries, Ambala, India.
c) **Digital temperature control oven:** Narang scientific works pvt.Ltd.,new Delhi, India
d) **Elecrical heater**: Bikrant, Jain enterprises, India.
e) **Electronic balance:** Sartorius, England and mettle AT-200, Switzerland.
f) Filter paper: Whatman of number 4 of 12.0 cm diameter, England.
g) **Refrigerated water bath**: J lab Tech, DaihanLabtech Co. Ltd., Korea.

3.6.1 Methods and Analysis:

In this section various methods used for the study of various physic-chemical constants of ghee samples are briefly described.

3.6.1.1 Buytro-refractometer reading:

The temperature of the refractometer was adjusted to 40^{0}C using circulatory water bath and the prism was cleaned and dried completely. The refractometer was calibrated with the standard provided by the company before taking reaing of the different samples. A drop of the molten ghee was placed on the lower prism of the refractometer and were closed and held for two minutes. After adjusting the instrument and light to get the most distinct reading possible and bringing temperature to 40^0C, the BR reading of the fat was recorded.

3.6.1.2 Moisture:

The moisture content of the ghee was determined by the method recommended by BIS for the milk (IS: SP 18, 1981).

The completely dry and cool aluminum dish was taken and approximately 5 g of sample was measured in it. The dish was put into a hot air oven maintained at 105^0C for 1 to 1.5 h. After complete drying, the dish was removed, placed in an efficient desiccator, and allowed to cooland weighed. The process of heating, cooling and weighing was repeated till consecutive weights agreed to within 0.5 mg. The moisture was determined by using the following formula:

$$\text{Moisture (\%, by mass)} = \frac{100 \times (\text{W1} - \text{W2})}{(\text{W1} - \text{W})}$$

Where,

W = weight of empty dish. (g)

W1 = Weight of dish and ghee sample before drying (g)

W2 = Weight of dish and ghee sample after drying. (g)

3.6.1.3 Free fatty acid:

Free fatty acid of the ghee sample was determined by the standard method for % FFA as described in Indian standard (IS: 3508-1966) in terms of oleic acid.

5 g sample was accurately weighed and transfer carefully to 250 ml conical flask. In second conical flask 50 ml of ethyl alcohol of 95% was taken, boiled it on water bath. Ethyl alcohol was neutralized with 0.5 ml phenolphthalein indicator and 0.1 N sodium hydroxide (NaOH). Take 5 g of ghee sample in the flask, pour the neutralized ethyl alcohol in it and mix the content well. Brought the mixture to boil and titrated it with 0.1 N NaOH, shake vigorously during titration. The end point of the titration was reached

when a slight but definite color change is persisting for at least 15 sec .the free fatty acid of the ghee sample is obtained by the following formula:

FFA (% oleic acid) = 2.82 x T/W

Where,

T = The net titration volume,

W = Weight of the ghee sample (g)

3.6.1.4 Sensory Evaluation:

The sensory evaluation of the ghee sample was carried out by 10 members from Dairy Technology, Dairychemistry and Dairy Engineering division. A 100 point descriptive scale was used for sensory attributes like flavor, body and texture, colour and freedom from suspended particles.

CHAPTER - 4

RESULTS & DISCUSSION

RESULTS AND DISCUSSION

In the present investigation systematic attempt has been made to produce ghee using unit operation based in-line production system consisting of conical processing vat and scraped surface heat exchanger. Product obtained was subjected to sensory evaluation using a panel of judges. Operating parameters in relation to desired quality and sensory attributes of the product have been optimized.

Sensory profile of the ghee is a result of complex chemical interactions between constituents during manufacturing. So, variations in the compositional variables due to operational parameters were expected to affect sensory profile of ghee to great extent. The effect of the variable parameters such SSHE, CPV pressures and rpm of SSHE scraper was observed on the sensory as well as on chemical attributes of ghee.

Results obtained were analysed through factorial design and inference were drawn from the experiments carried out to meet the objectives of the study.

4.1.Optimisation of variable parameters for the moisture content of ghee:

The average moisture content of ghee prepared at different pressures and RPM combinations varied from 0.2 to 0.6%. The minimum moisture content obtained at 3 kg/cm^2 and 2.5 kg/cm^{2}pressures of CPV and SSHE respectively at 200 rpm of SSHE scraper. The effect of all the variable parameters on the moisture content of ghee has been shown figures 4.1, 4.2 and 4.3. It has been observed that moisture content of ghee decreased with increase in CPV and SSHE pressures along with increase in rpm of SSHE scraper.

Moisture content of ghee as affected by variable parameters has been shown in table 4.1., Fig., 4.1., Effect of SSHE pressures and rpm on moisture content of ghee

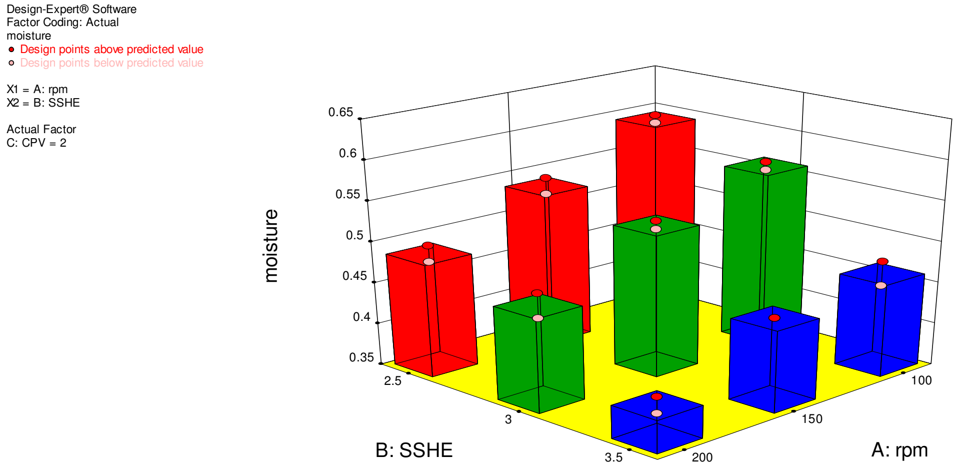


Fig., 4.2 Effect of CPV pressures and rpm on moisture content of ghee

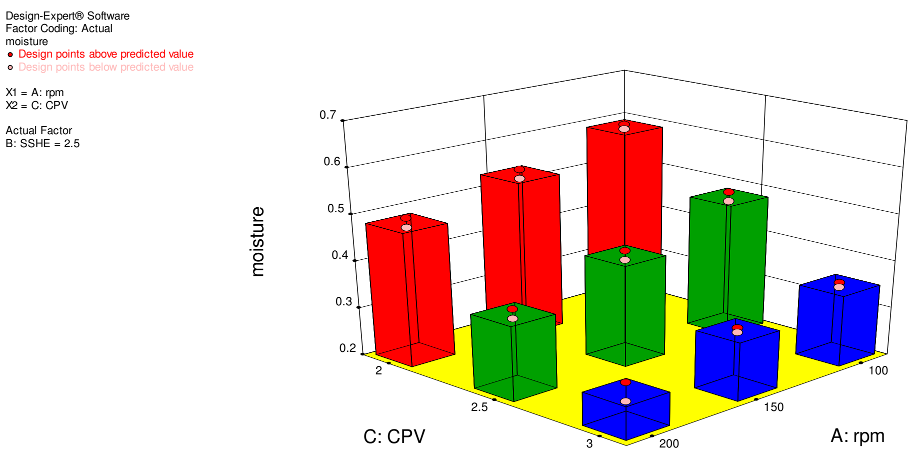
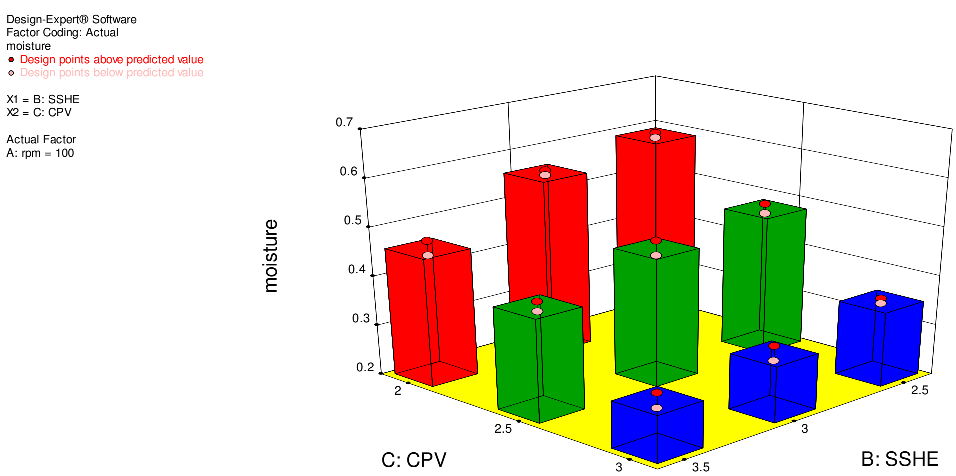


Fig., 4.3 Effect of CPV and SSHE pressures on moisture content of ghee



ANOVA for Moisture						
Source	Sum of Squares	Df	Mean Square	F Value	p-value Prob> F	
Model	0.538704	26	0.020719373	96.45225	< 0.0001	significant
A-rpm	0.061715	2	0.030857407	143.6466	< 0.0001	Significant
B-SSHE	0.065137	2	0.032568519	151.6121	< 0.0001	Significant
C-CPV	0.345626	2	0.172812963	804.4741	< 0.0001	Significant
AB	0.011252	4	0.002812963	13.09483	< 0.0001	Significant
AC	0.020496	4	0.005124074	23.85345	< 0.0001	Significant
BC	0.014507	4	0.003626852	16.88362	< 0.0001	Significant
ABC	0.01997	8	0.002496296	11.62069	< 0.0001	Significant
Pure Error	0.0058	27	0.000214815			
Cor Total	0.544504	53				

Table 4.1. ANOVA table for moisture of ghee

It was found that all the variable parameters and their interactions have a significant effect on the ghee moisture content. Thus for optimizing the variable parameters, means were calculated and compared with CD (critical difference)

4.1.1Optimization of rpm, SSHE pressuresand their interactions for moisture content of ghee:

The means for the moisture of ghee at various rpm,SSHE pressures and their interactions are shown in table 4.2

rpm	SSHE Pressures (kg/cm^2)			Means
	2.5	3	3.5	
100	0.480	0.448	0.390	0.439
150	0.428	0.412	0.313	0.384
200	0.373	0.367	0.335	0.358
Means	0.427	0.409	0.346	

Table 4.2. Means for moisture at various rpm, SSHE pressures and their interactions

The values of CD for SSHE pressures, rpm and their interactions were found to be 0.0100, 0.0100 and 0.01736 respectively. Thus the optimized value of SSHE pressure was 3.5 kg/cm^2, for rpm, 200 and their interaction was 3.5 kg/cm^2 and 200 rpm.

4.1.2Optimization of CPV pressures and its interactions with rpm for moisture content of ghee:

The means for the moisture content of ghee at various CPV pressures and interactions of CPV pressures with rpm are shown in table 4.3

rpm	CPV pressures (kg/cm^2)		
	2	2.5	3
100	0.542	0.455	0.322
150	0.505	0.34	0.308
200	0.448	0.345	0.282
Means	0.498	0.380	0.304

Table 4.3. Meansfor ghee moisture at various CPV pressures and its interaction with rpm

The values of CD for CPV pressures and interaction of it with rpm was found to be 0.0100 and 0.01736. Thus, the optimized CPV pressure was 3 kg/cm^2 and the optimum interaction was 3 kg/cm^2 and 200 rpm of SSHE scraper.

4.1.3 Optimization for interactions of CPV and SSHE pressures for moisture content of ghee:

The means of moisture for the interactions of CPV and SSHE pressures are shown in table 4.4

CPV pressures (kg/cm^2)	SSHE pressures (kg/cm^2)		
	2.5	3	3.5
2	0.542	0.518	0.435
2.5	0.423	0.402	0.315
3	0.317	0.307	0.288

Table 4.4. Means of ghee moisture for the interaction of CPV and SSHE pressures

The CD for the interaction of CPV and SSHE pressures was found to be 0.5593. Thus the optimum interaction was 3.5 $kg/cm^2$and 3 kg/cm^2 Of SSHE and CPV pressure respectively

4.2 Optimisation of variable parameters for the ghee flavour:

The average score for the ghee flavour varied from 34 to 45. The optimum results obtained at 3 kg/cm^2 and 2.5 kg/cm^2 pressures of CPV and SSHE respectively at 200 rpm. The effect of all the variable parameters on the ghee flavour has been shown in fig., 4.4, 4.5 and 4.6. It has been observed that score for ghee flavour increased with increase in CPV and SSHE pressures along with increase in rpm of SSHE scraper.

Ghee flavour as affected by variable parameters has been shown in ANOVA table 4.5.

Fig., 4.4 Effect of SSHE pressures and rpm on flavour score of ghee

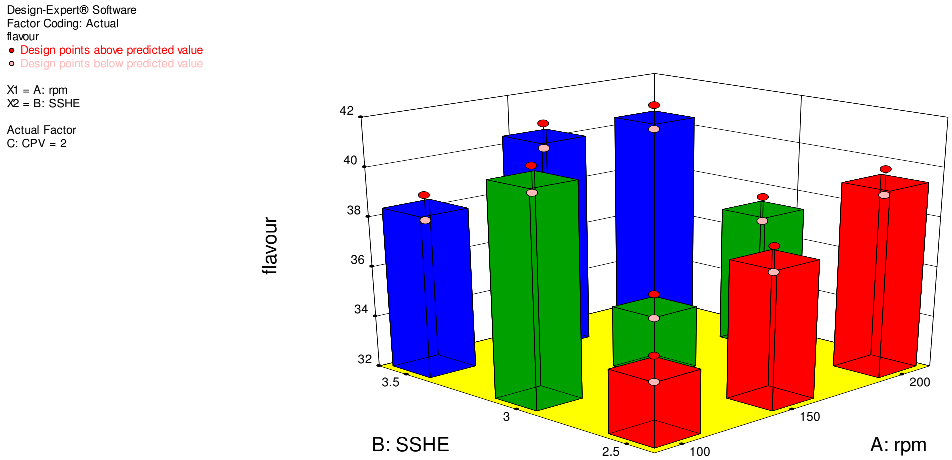


Fig., 4.5 Effect of rpm and CPV pressures on flavour score of ghee

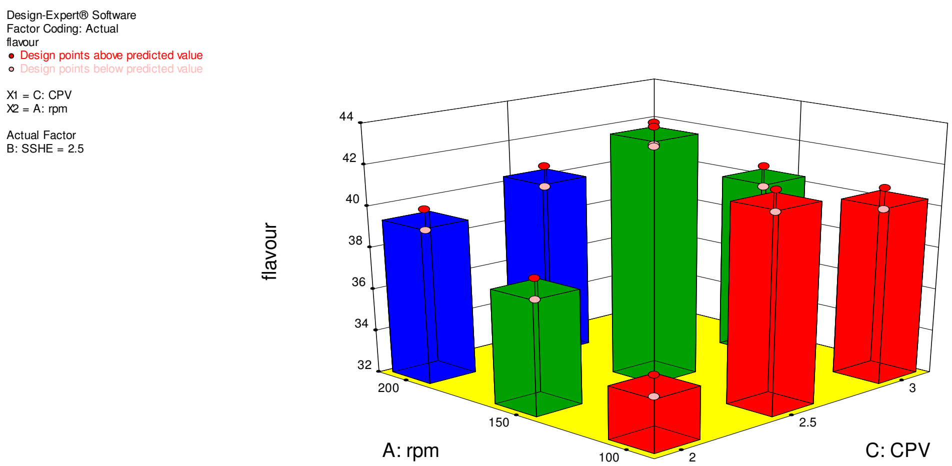
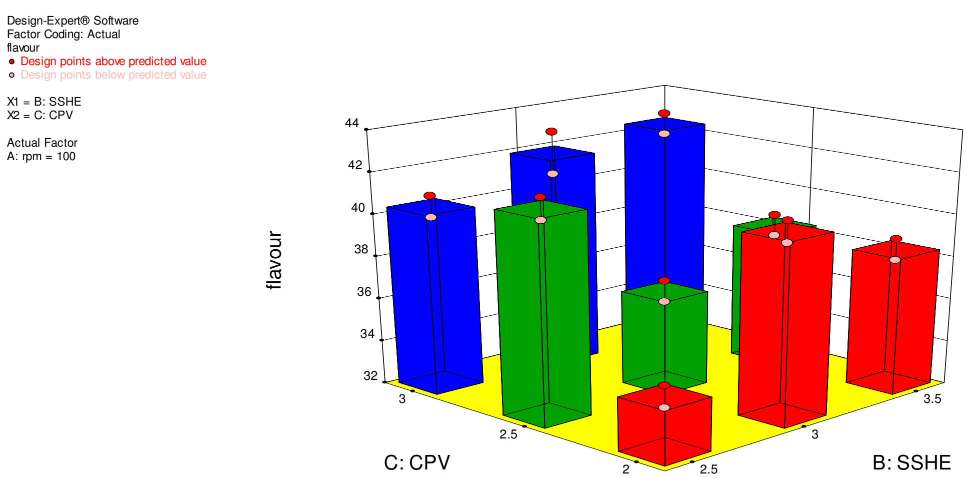


Fig., 4.6 Effect of CPV and SSHE pressures on flavour of ghee



ANOVA for flavour of ghee						
Source	Sum of Squares	Df	Mean Square	F Value	p-value Prob> F	
Model	357.5926	26	13.75356	21.84389	< 0.0001	Significant
A-rpm	23.14815	2	11.57407	18.38235	< 0.0001	Significant
B-SSHE	31.59259	2	15.7963	25.08824	< 0.0001	Significant
C-CPV	145.8148	2	72.90741	115.7941	< 0.0001	Significant
AB	24.85185	4	6.212963	9.867647	< 0.0001	Significant
AC	41.62963	4	10.40741	16.52941	< 0.0001	Significant
BC	31.51852	4	7.87963	12.51471	< 0.0001	Significant
ABC	59.03704	8	7.37963	11.72059	< 0.0001	Significant
Pure Error	17	27	0.62963			

Table 4.5. ANOVA for ghee flavour

It was found that all the variable parameters and their interactions have a significant effect on ghee flavour. Thus the CD was calculated and compared with the means of flavour scores at different variable parameters and their interactions for optimization.

4.2.1 Optimization of rpm, SSHE pressures and their interactions for ghee flavour:

The means for ghee flavour at various rpm, SSHE pressures and their interactions are as shown in table 4.6

rpm	SSHE Pressures (kg/cm^2) 2.5	3.0	3.5	Mean
100	38.833	39.667	39.833	39.444
150	40.500	39.000	43.000	40.833
200	40.500	40.500	41.300	40.833
Means	39.944	39.722	41.444	

Table 4.6., Means for ghee flavour at various rpm, SSHE pressures and their interactions

The values of CD for SSHE pressures, rpm and their interactions were found to be 0.5427, 0.5427 and 0.0.9400 respectively. Thus the optimized value of SSHE pressure was 3.5 kg/cm^2, for rpm 150 & 200and their interaction was 3.5 kg/cm^2 and 150 rpm.

4.2.2Optimization of CPV pressures and its interaction with rpm for ghee flavour:

The means for the ghee flavour at various CPV pressures and itsinteraction with rpm are shown in table 4.7

rpm	CPV pressures (kg/cm^2) 2	2.5	3
100	37.833	38.833	41.667
150	37.500	43.000	42.000
200	39.167	40.667	42.667
Mean	38.167	40.833	42.111

Table 4.7.Means for ghee flavour at various CPV pressures, and its interaction with rpm

The values of CD for CPV pressures and its interaction with rpm were found to be 0.5427 and 0.0.9400. Thus optimized CPV pressure was 3 kg/cm^2 and the optimum interaction was 2.5kg/cm^2 and 150 rpm forghee flavour. While the interaction combination of CPV pressure 3 kg/cm^2 and 200 rpm was statistically at par.

4.2.3Optimization for interaction of CPV and SSHE pressures for ghee flavour:

The means of flavour scores for the interaction of CPV and SSHE pressures are as shown in table 4.8

CPV pressures (kg/cm^2)	SSHE pressures (kg/cm^2)		
	2.500	3.000	3.500
2	37.167	37.500	39.833
2.5	41.833	39.333	41.333
3	40.833	42.333	43.167

Table 4.8. Means for the ghee flavour at various interactions of CPV and SSHE pressures

The CD for the interaction of CPV and SSHE pressures was found to be 0.9400. Thus the optimum interaction for ghee flavour was 3.5 kg/cm^{2}and 3 kg/cm^2 of SSHE and CPV pressure respectively

4.3Optimization of variable parameters for ghee colour:

Colour of the cow ghee has a golden yellow colour while that of buffalo ghee is white due to the lack of carotene enzyme. The average score for ghee colour varied from 7.5 to 10. The optimum result obtained at 3 kg/cm^2 and 2.5 kg/cm^2 pressures of CPV and SSHE respectively at 200 rpm. The effect of all the variable parameters on ghee colour has been shown in figures 4.7, 4.8 and 4.9. It has been observed that ghee colour increased with increase in CPV and SSHE pressures along with increase in RPM.

Fig., 4.7 Effect of rpm and SSHE pressures on colour of ghee

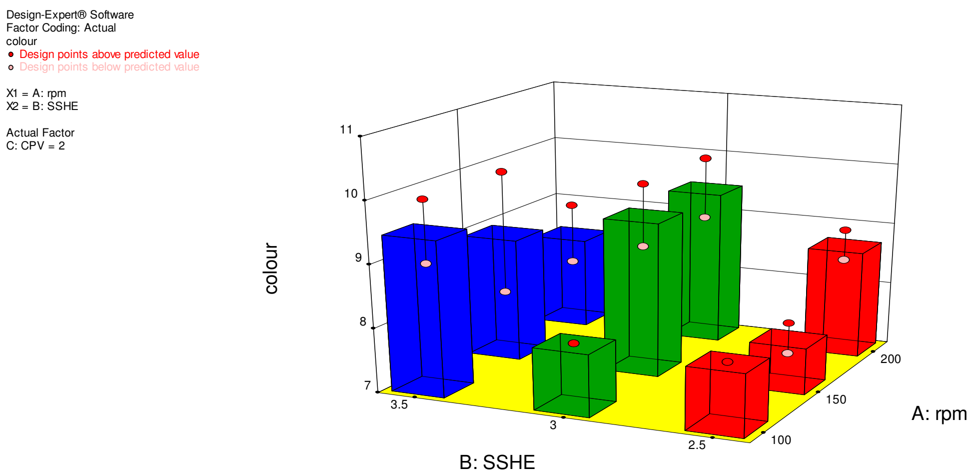


Fig.,4.8 Effect of rpm and CPV pressures on colour score of ghee

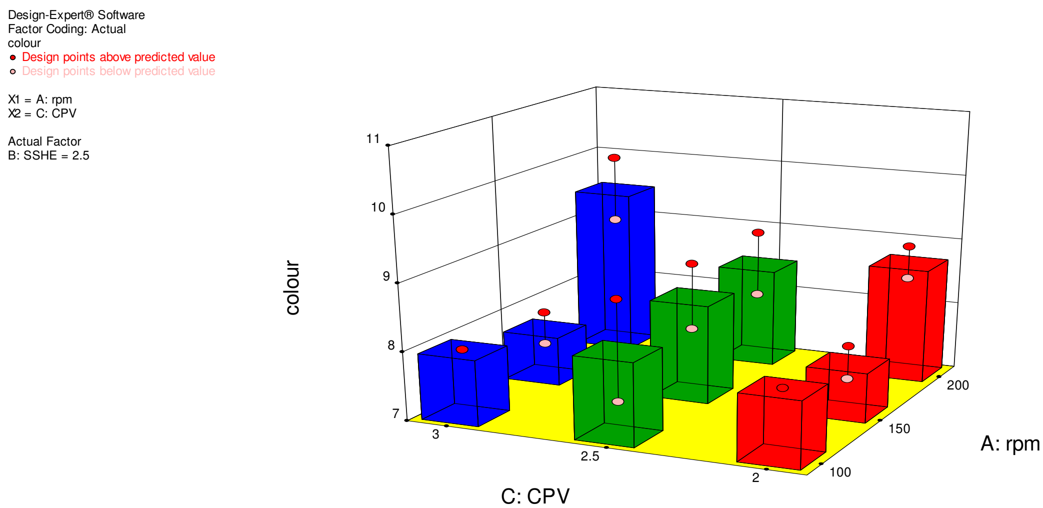
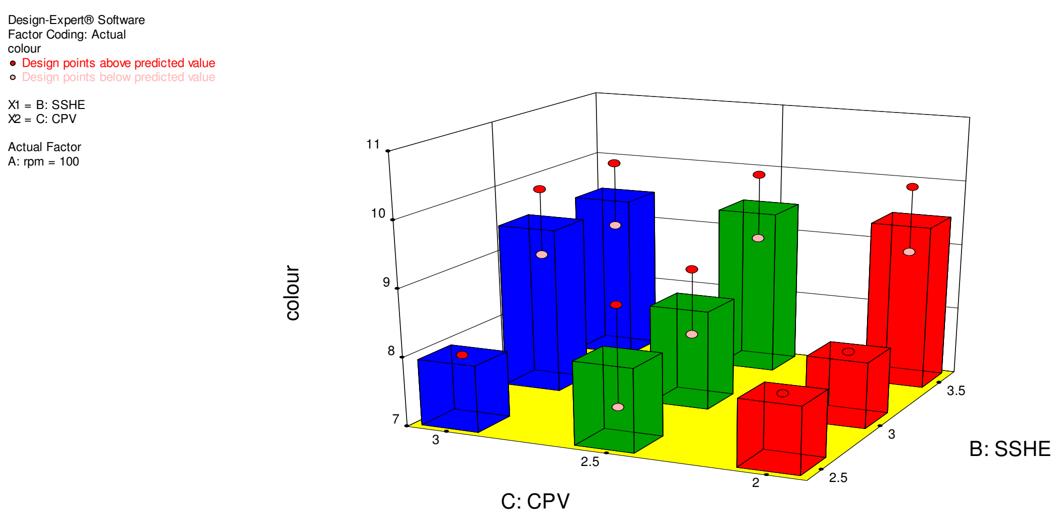


Fig., 4.9 Effect of CPV and SSHE pressures on colour of ghee



Ghee colour as affected by variable parameters has been shown in table 4.9

ANOVA for Colour of ghee						
Analysis of variance table [Classical sum of squares - Type II]						
	Sum of		Mean	F	p-value	
Source	Squares	Df	Square	Value	Prob> F	
Model	25.39815	26	0.976852	2.268817	0.0193	Significant
A-rpm	1.37037	2	0.685185	1.591398	0.2222	
B-SSHE	9.842593	2	4.921296	11.43011	0.0003	Significant
C-CPV	1.564815	2	0.782407	1.817204	0.1818	
AB	6.518519	4	1.62963	3.784946	0.0144	Significant
AC	1.296296	4	0.324074	0.752688	0.5650	
BC	1.490741	4	0.372685	0.865591	0.4971	
ABC	3.314815	8	0.414352	0.962366	0.4849	
Pure Error	11.625	27	0.430556			
Cor Total	37.02315	53				

Table 4.9.ANOVA table for ghee colour

It was found that SSHE pressures and its interaction with rpm have a significant effect on ghee colour. Thus the CD was calculated and compared with the means of colour score at different SSHE pressures and its interaction with rpm.

4.3.1 Optimization of SSHE pressures and its interactionwith rpm for ghee colour:

The means for ghee colour at various SSHE pressures and its interaction with rpm are shown in table 4.10

rpm	SSHE pressures (kg/cm^2)		
	2.500	3.000	3.500
100	8.083	8.667	9.500
150	8.000	9.500	9.250
200	8.917	9.667	8.333
Mean	8.333	9.278	9.194

Table4.10. Means for ghee colour at various SSHEpressures and its interaction with rpm.

The values of CD for SSHE pressures and its interaction with rpm were found to be 0.4488 and 0.7773. Thus optimized SSHE pressure was 3 kg/cm^2 fallowed by 3.5 kg/cm^2 which was statisticallyat par while the optimum interaction was 3 kg/cm^2& 200rpm fallowed by 3.5 kg/cm^2,100 rpm, 3.5 kg/cm^2& 150 rpm, 3 kg/cm^2& 150 rpm and 2.5 kg/cm^2& 200 rpm which were statistically at par

4.4Optimization of variable parameters for body and texture of ghee:

Texture is one of the most important quality attribute of ghee. After flavour, it is the texture of ghee that determinesits overall acceptability. A good quality of ghee has a granular texture at room temperature. Ghee should not store at refrigerated temperatures as it tends to form the greasy texture.The average score for theghee texture varied from 7.5 to 10. The maximum score obtained at 2.5 kg/cm^2 and 3.5 kg/cm^2 pressures of CPV and SSHE respectively at 150 rpm. The effect of all variable parameters on ghee texture has been shown in figures 4.10, 4.11 and 4.12

Fig., 4.7 Effect of rpm and SSHE pressures on colour of ghee

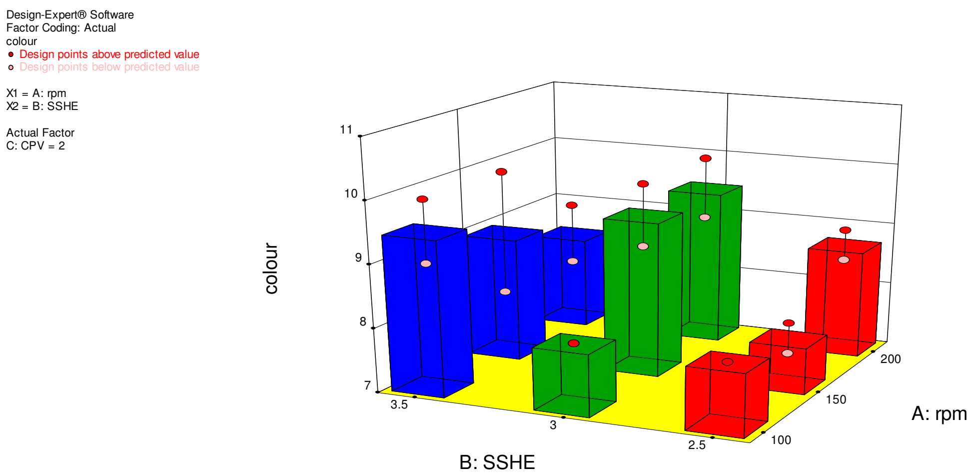


Fig.,4.8 Effect of rpm and CPV pressures on colour score of ghee

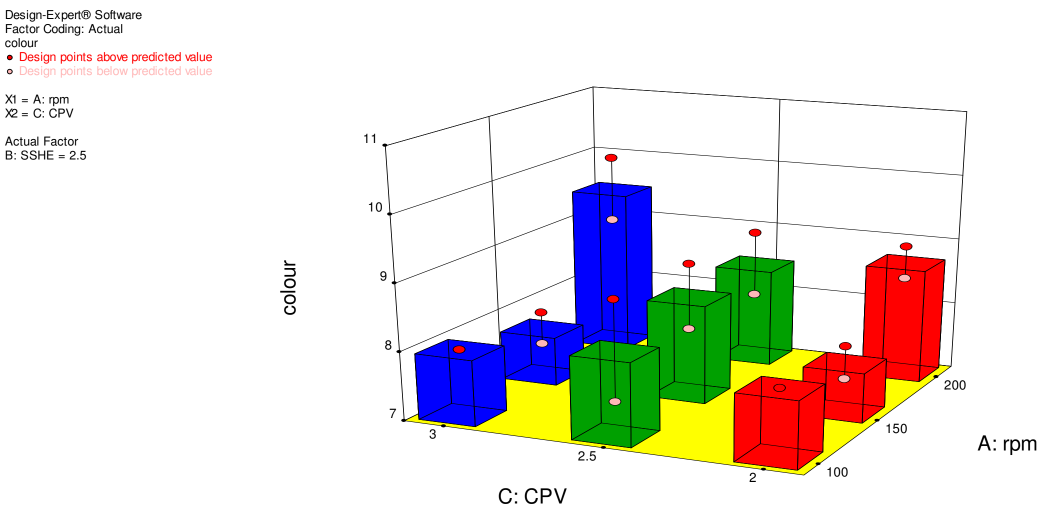
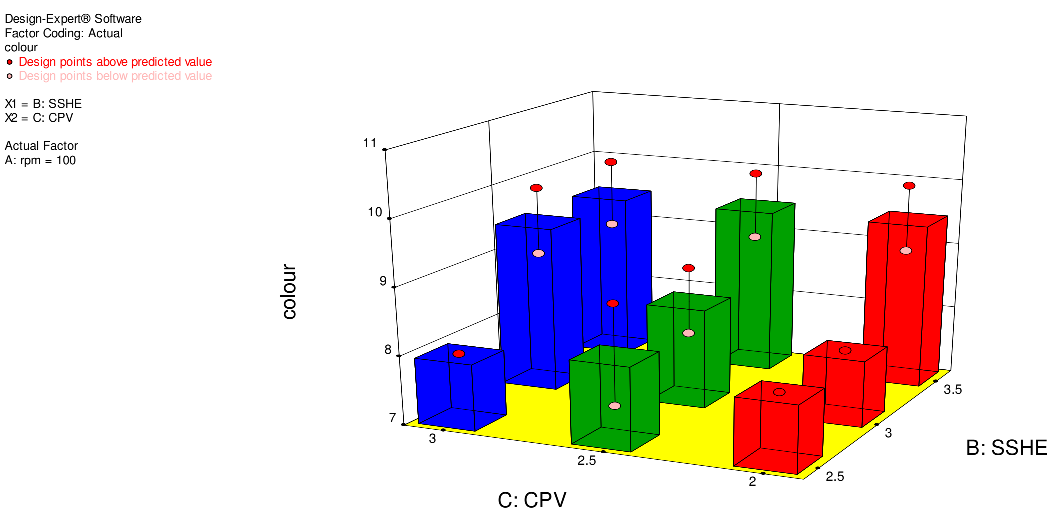


Fig., 4.9 Effect of CPV and SSHE pressures on colour of ghee



Body and texture as affected by variable parameters has been shown in table 4.11

ANOVA for Body and texture of ghee						
Source	Sum of Squares	Df	Mean Square	F Value	p-value Prob> F	
Model	38.75926	26	1.490740741	5.111111	< 0.0001	significant
A-rpm	0.898148	2	0.449074074	1.539683	0.2327	
B-SSHE	1.148148	2	0.574074074	1.968254	0.1592	
C-CPV	9.953704	2	4.976851852	17.06349	< 0.0001	Significant
AB	6.796296	4	1.699074074	5.825397	0.0016	Significant
AC	0.407407	4	0.101851852	0.349206	0.8422	
BC	11.99074	4	2.997685185	10.27778	< 0.0001	
ABC	7.564815	8	0.945601852	3.242063	0.0102	Significant
Pure Error	7.875	27	0.291666667			
Cor Total	46.63426	53				

Table 4.11. ANOVA table for body and texture of ghee

It was found that CPV pressures and the interaction of rpm and SSHE pressures have a significant effect on the body and texture of ghee. Thus the CD was calculated and compared with the means of body and texture scores at different CPV pressures and interaction of SSHE pressures with rpm.

4.4.1Optimization of interaction of SSHE pressures with rpm for the body and texture of ghee:

The means for the body and texture of ghee at various interactions of SSHE pressures and rpm are as shown in table 4.12

	SSHE pressures (kg/cm^2)		
rpm	2.500	3.000	3.500
100	8.417	8.25	7.083
150	8.250	8.000	8.417
200	8.083	7.667	8.250

Table 4.12. Means for body and texture of ghee at various interactions of SSHE pressures and rpm

The values of CD for the interactions of SSHE pressures with rpm were found out to be 0.6398. Thus optimized interaction was 2.5 kg/cm^2& 150 rpm and 3.5 kg/cm^2& 200 rpm followed by 3.5 kg/cm^2&150rpm, 3 & 150 rpm, 3 kg/cm^2& 100, 200 rpm which were statistically at par.

4.5 Optimization of variable parameters for suspended particles in ghee:

The score for the suspended particles in ghee was varied from 3 to 5. The maximum score for suspended particles in the ghee was obtained at 3 kg/cm^2 and 2.5 kg/cm^2 pressures of CPV and SSHE respectively at 200 rpm. The effect of all the variable parameters on suspended particles in ghee has been shown in figures 4.13, 4.14 and 4.15

Score for suspended particles in ghee as affected by variable parameters has been shown in table 4.13

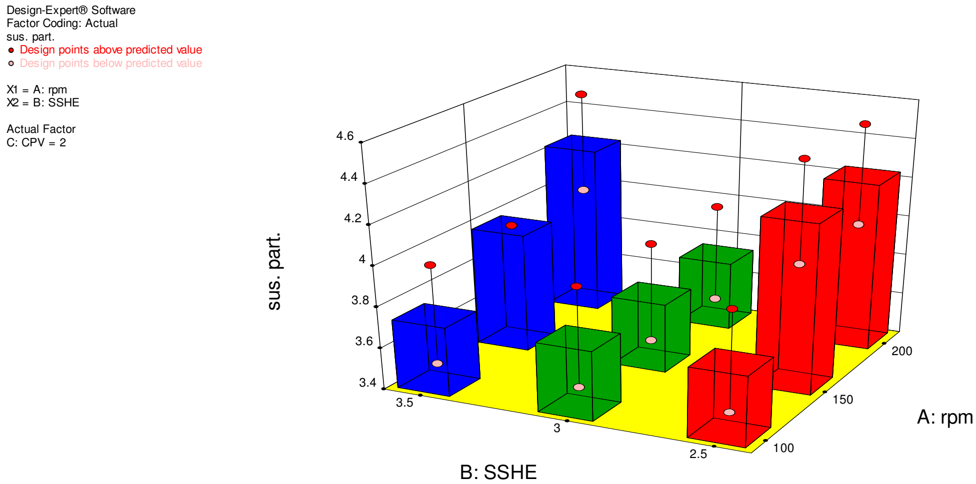


Fig., 4.13 Effect of SSHE pressures and rpm on score of suspended particles in ghee

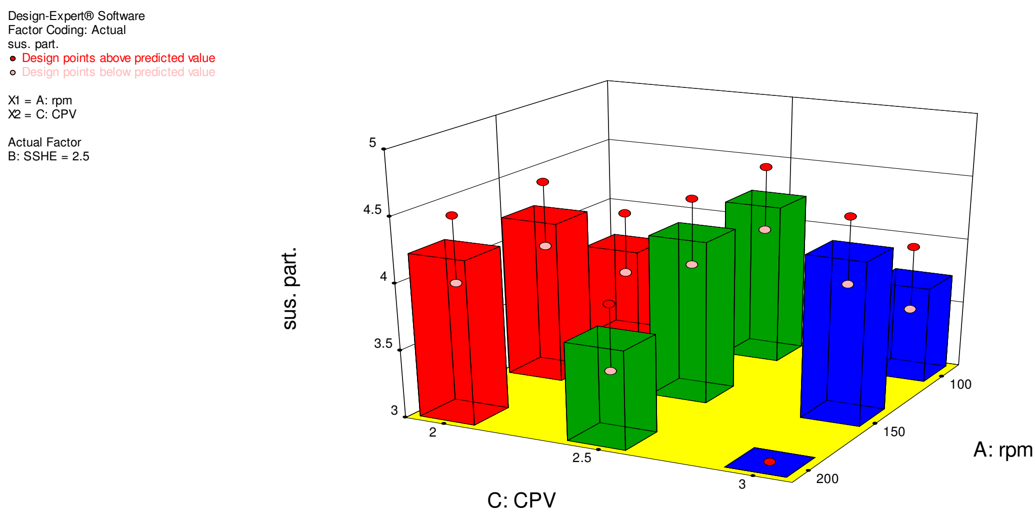


Fig., 4.14 Effect of CPV pressures and rpm on suspended particle score of ghee

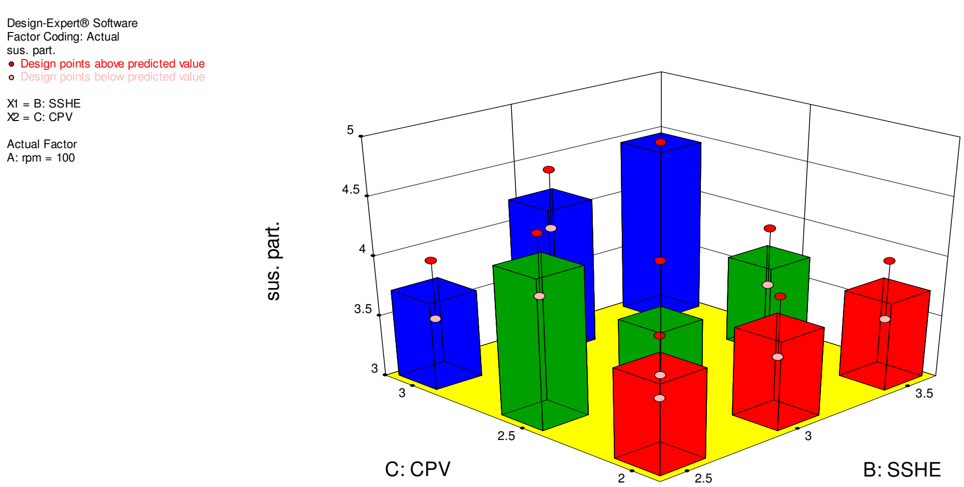


Fig.,4.15 Effect of CPV and SSHE pressures on suspended particle score of ghee

ANOVA for suspended particles in ghee						
Source	Sum of Squares	Df	Mean Square	F Value	p-value Prob> F	
Model	8.333333	26	0.320513	2.884615	0.0040	significant
A-rpm	0.861111	2	0.430556	3.875	0.0332	Significant
B-SSHE	1.333333	2	0.666667	6	0.0070	Significant
C-CPV	0.361111	2	0.180556	1.625	0.2156	
AB	0.972222	4	0.243056	2.1875	0.0973	
AC	1.111111	4	0.277778	2.5	0.0661	
BC	1.972222	4	0.493056	4.4375	0.0069	Significant
ABC	1.722222	8	0.215278	1.9375	0.0951	
Pure Error	3	27	0.111111			
Cor Total	11.33333	53				

Table 4.13. ANOVA table for suspended particles in ghee

It was found that the pressures and rpm of SSHE and interaction of CPV andSSHE pressures have a significant effect on suspended particles in ghee.

4.5.1 Optimization of pressures and rpm of SSHE for the suspended particles in ghee:

The means for the score of suspended particles in ghee at different pressures and rpm of SSHE are as shown in table4.14

rpm	SSHE pressures (kg/cm^2)			
	2.500	3.000	3.500	Mean
100	3.917	3.833	4.000	3.917
150	4.250	4.000	4.417	4.222
200	3.667	4.000	4.417	4.028
Mean	3.994	3.994	4.278	

Table 4.14.Means for suspended particle score at different pressures and rpm of SSHE

The value of CD for the pressures and rpm of SSHE was found out to be 0.2279. Thus optimized SSHE pressure was 3.5 kg/cm^2 and rpm is 150 rpm fallowed by 200 rpm which was statistically at par.

4.5.2 Optimisation for interaction of CPV and SSHE pressures for suspended particles of ghee:

The means for the suspended particle score of ghee at various interactions of SSHE and CPV pressures are as shown in table 4.15

SSHE Pressures (kg/cm^2)	CPV pressures (kg/cm^2)		
	2	2.5	3.
2.5	4.083	4.083	3.667
3	3.75	3.833	4.250
3.5	4.000	4.500	4.333

Table 4.15 Means for suspended particles of ghee at various interactions of SSHE and CPV pressures.

The value of CD for the interaction of CPV and SSHE pressures was found to be 0.3949. Thus, the optimised interaction for the suspended particles was 2.5 kg/cm^2 & 3.5 kg/cm^2 of SSHE and CPV pressures fallowed by 3.5 kg/cm^2& 3 kg/cm^2 and 3 kg/cm^2&3 kg/cm^2 which were statistically at par.

CHAPTER - 5

SUMMARY & CONCLUSION

SUMMARY AND CONCLUSION

Ghee is a pure clarified fat derived solely from milk or Desi (cooking) butter or from cream to which no colouring matter is added. The unique position occupied by ghee may be ascribed to its being not only the best form for preservation of milk fat under tropical climates, but to its constituting, in addition, the only source of animal fat in an otherwise predominantly vegetarian diets. The large production of ghee is due to its long keeping quality under tropical storage conditions and ordinary packaging.

Conventionally ghee is prepared in an open kettle. The product is mainly manufactured by unorganized dairy sector. The present dissertation work aimed at producing high quality ghee based on unit operations involved by integrating scraped surface heat exchanger and conical processing vat. The investigation was carried out to optimize various process parameters in relation to quality attributes. During the present investigation, the melting of butter was carried out in conical processing vat followed by moisture removal in scraped surface heat exchanger and simmering again in conical processing vat at various pressures and rpm combinations. The product quality was evaluated in terms of physico-chemical parameters and sensory evaluation using a panel of judges. Factorial design was employed for optimizing the variable parameters. Design expert (Version 8.0.7.1) software was used during optimizing the variable parameters and trends indicated were used to study the effect of all variable parameters on the sensory and quality attributes of ghee.

The conclusions drawn from different sets of experiments are as follows:

(1) Unit operation based in-line ghee production system produces highly acceptable quality of ghee in terms of sensory and quality attributes.

(2) The process parameter optimization study has indicated that the most acceptable ghee can be produced by using following operating parameters.

  (a) CPV steam pressure: 3 kg/cm^2

  (b) SSHE steam pressure: 2.5 kg/cm^2

  (c) rpm of SSHE scraper: 200

(3)The sensory scores of the ghee prepared at optimized parameters were as follows:

(a) Flavour: 41.5
(b) Colour: 9.5
(c) Body and texture: 8.5
(d) Freedom from suspended particles: 3

(4) The average moisture content of ghee varied from 0.2 to 0.6%. The minimum moisture content was observed at 2.5 kg/cm^2 and 3.5 kg/cm^2 of CPV and SSHE pressures respectively at 150 rpm.

(5) The average values of BR readings varied from 41 to 43.5. The value of BR reading at optimized parameter was 41

Through this dissertation work it has been established that ghee with desired quality attributes could be produced using in-line production system, which has the potential to be scaled up to any extent for maximum capacity utilization of plant machinery.

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APPENDICES

APPENDIX-I

Evaluation card for sensory evaluation of Ghee

Parameter	Undesirable characteristics/defects	Intensity of undesirable characteristics/ defects				Your Deduction
		Suspicion	Slight	Definite	Pronounced	
Flavor (60)	Curdy	1	3	8	15	
	Burnt	3	5	8	15	
	Oxidized	1	3	8	15	
	Rancid	3	5	8	15	
	Smoky	1	3	6	10	
	Acidic	1	3	6	10	
	Lacking	-	5	6	15	
Body & Texture (25)	Greasy	3	5	7	10	
	Hard	3	5	7	10	
Color (10)	Brown	1	3	4	5	
Freedom from suspended particle (5)	Ghee Residue	1	3	4	5	

After, computation of data recorded in the above table by the panelists, the following gradation should be specified:-

Quality	**Maximum Score**	**Grades**
Excellent	90 or more	A
Good	80-89	B
Fair	70-75	C
Poor	Below 70	D

APPENDIX-II

Standards of Ghee under PFA Rules (2009)

Sr. No.	Name of the State & U.T.	BR Reading at 40°C	RM (Reichert Meissl) value (Min)	Percentage of	
				FFA (as Oleic acid) (Max)	Moisture (Max)
1.	Bihar, Chandigarh, Delhi, Punjab, Haryana (Areas other than cotton tract areas), West Bengal (Areas other than Bishnupur sub-division), Sikkim, Jharkhand.	40-43	28	3.0	0.5
2.	Manipur, Meghalaya, Mizoram, Arunachal Pradesh, Orissa, Uttaranchal, Nagaland, Tripura, Assam, Goa, Kerala, Himachal Pradesh, U.P., J & K, Rajasthan (Areas other than Jodhpur Divn), Haryana (Cotton tract areas), Lakshadweep, Maharashtra(Areas other than cotton tract areas).	40-43	26	3.0	0.5
3.	Karnataka (Belgaum district), Madhya Pradesh (Areas other than cotton tract areas), Pondicherry, Chhatisgarh.	40-44	26	3.0	0.5
4.	Andhra Pradesh, Daman & Diu, Dadar & Nagar Haveli, Karnataka (Areas other than Belgaum district)	40-43	24	3.0	0.5
5.	Andaman & Nicobar Island, Tamil Nadu.	41-44	24	3.0	0.5
6.	Gujarat (areas other than cotton tract).	40-43.5	24	3.0	0.5
7.	Gujarat (cotton tract areas), Madhya Pradesh (Cotton tract areas), Maharashtra (cotton tract areas), Rajasthan (Jodhpur sub division), West Bengal (Bishnupur sub division).	41.5-45	21	3.0	0.5

a) Baudouin test shall be negative
b) By cotton tract is meant the areas in the state where cotton seed is extensively fed to the cattle and so notified by the State Govt. concerned.
c) Usually such cotton tract areas ghee has low RM value and high BR reading compared to other areas
d) Ghee may contain BHA not more than 0.02% as antioxidant.

APPENDIX-III

Standards of Ghee under AGMARK Rules (1981)

S.No	Characteristics	All India	Regional *	
			Winter (Sep.-Feb.)	Summer (Mar.-Aug.)
1	Baudoin test		Negative	
2	Phytosterol acetate test		Negative	
3	BR reading at 40°C	40.0 – 43.0	41.5 – 44.0	42.5 – 45.0
4	Reichert – Meissl value	Not less than 28.0	Not less than 23.0	Not less than 21.0**
5	Polenske value	1.0 – 2.0	0.5 - 1.2	0.5 – 1.0
6	Moisture (%)	Not more than 0.3		
7	Percentage of free fatty acids (as oleic acid)			
a	Special Grade (Agmark Red Label)	Not more than 1.4		
b	General Grade (Agmark Green Label)	Not more than 2.5		

*Normal physical and chemical constants of Ghee produced in recognized cotton tracts@ (of Saurashtra and Madhya Pradesh) to which grade designation marks may be applied.

@ By cotton tract is meant that area where cotton seed is extensively fed to the cattle.

**Ghee with Reichert Meissl value between 19 and 21 shall be graded only after a Phytosterol Acetate test has been performed and the result thereof found to be negative.

N.B. - Percentage of Free Fatty Acids (as Oleic acid) shall not exceed 3.0 for Standard Grade Ghee.

Moisture content and Sensory scores for ghee samples prepared at different variable parameter combinations

rpm	SSHE	CPV	Replications	Moisture	Flavour	Texture	colour	suspended particles
100	2.5	2	1	0.6	35	9	8	4
			2	0.59	34	8	8	3.5
150	2.5	2	1	0.55	38	9	8	4.5
			2	0.53	37	8.5	7.5	4
200	2.5	2	1	0.5	40	8	9	4.5
			2	0.48	39	7.5	8.5	4
100	3	2	1	0.57	41	8.5	8	4
			2	0.56	40	8	8	3.5
150	3	2	1	0.53	35	7	10	4
			2	0.52	34	6.5	9	3.5
200	3	2	1	0.48	38	7	10	4
			2	0.45	37	6.5	9	3.5
100	3.5	2	1	0.48	39	6	10	4
			2	0.45	38	5	9	3.5
150	3.5	2	1	0.45	41	8	10	4
			2	0.45	40	6	8	4
200	3.5	2	1	0.4	41	8	9	4.5
			2	0.38	40	7.5	8	4
100	2.5	2.5	1	0.5	42	8	9	4.5
			2	0.48	41	7.5	7.5	4
150	2.5	2.5	1	0.41	44	8	9	4.5
			2	0.43	43	7	8	4
200	2.5	2.5	1	0.37	41	8	9	4
			2	0.35	40	8	8	3.5
100	3	2.5	1	0.48	37	8	9	4
			2	0.45	36	8	8	3
150	3	2.5	1	0.41	41	8.5	10	4
			2	0.39	40	8	9	4
200	3	2.5	1	0.35	42	8.5	10	4
			2	0.33	40	8	10	4
100	3.5	2.5	1	0.42	39	8.5	10	4
			2	0.4	38	8	9	3.5
150	3.5	2.5	1	0.2	45	10	10	5
			2	0.2	45	10	10	5
200	3.5	2.5	1	0.34	41	9	10	4.5
			2	0.33	40	8	9	5
100	2.5	3	1	0.36	41	9	8	4
			2	0.35	40	9	8	3.5
150	2.5	3	1	0.33	41	9	8	4.5

Moisture content and Sensory scores for ghee samples prepared at different variable parameter combinations

			2	0.32	40	8	7.5	4
200	2.5	3	1	0.29	42	9	10	3
			2	0.25	41	8	9	3
100	3	3	1	0.33	43	9	10	4.5
			2	0.3	41	8	9	4
150	3	3	1	0.32	43	9	10	4.5
			2	0.3	41	9	9	4
200	3	3	1	0.3	43	8	10	4.5
			2	0.29	43	8	9	4
100	3.5	3	1	0.31	43	8	10	4.5
			2	0.28	42	7	9	4.5
150	3.5	3	1	0.3	44	8	9	4.5
			2	0.28	43	8.5	8.5	4
200	3.5	3	1	0.29	44	9	9	4.5
			2	0.27	43	8	8	4