FEASIBILITY STUDIES ON MANUFACTURE OF BASUNDI USING THREE STAGE SCRAPED SURFACE HEAT EXCHANGER

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
DAIRYING
(DAIRY ENGINEERING)

BY

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KARNAL-132001 (HARYANA), INDIA

2008

Regn. No. 3040602

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This is to certify that the thesis entitled **"FEASIBILITY STUDIES ON MANUFACTURE OF BASUNDI USING THREE STAGE SCRAPED SURFACE HEAT EXCHANGER"** submitted by **Mr. AMIT KUMAR SINGH** 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 or diploma.

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ACKNOWLEDGEMENT

The present investigation entitled, **“Feasibility studies on the manufacture of Basundi using Three Stage Scraped Surface Heat Exchanger”** has been conducted in session 2008-2009 at National Dairy research Institute, Karnal.

I take the privilege to express my esteem and profound sense of gratitude to my Major Advisor (Guide) & Chairman, Advisory Committee, **Dr. A.K. Dodeja** (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 Prof. Bikram Kumar, Principal Scientists, Dairy Engineering Division, Dr. Dharam Pal, Principal Scientist, Dairy Technology Division and Dr. A.A.Patel, Principal Scientist, Dairy Technology Division, Dr. Sumeet Arora, Senior Scientist, Dairy Chemistry Division for their scholastic guidance, diligent help, continuous inspiration, critical appreciation and perfect patience during course of work.

I extend my sincere thanks to Dr. Sushil kumar (Former Director), Dr. A.K. Srivastava (Director), NDRI, Karnal, and ICAR for awarding the Junior Research Fellowship to me and also thank Dr. S.P. Agrawala (Former Head, Dairy Engineering Division),and Prof. I.K.Sawhney (Head) Dairy Engineering Division, NDRI, Karnal for providing all necessary infrastructure to carry out the present investigation.

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

I thank all teachers, whose guidance became building block and helped me to reach this stage of academic life. My sincere thanks to all the scientists of Dairy Engineering division, Dr.R.K.Kohali, Prof. I.K.Sawhney, Er .S.K.Makker, & Dr. R.L. Chaudhary and the technical staff Er. S.K.Chaudhary, Er.M.P.Singh, Er.Nayyar, Er.J.K.Dabas, Mr. S.S. Bhinder, Mrs.Manju, Mr.Pavan Kumar, Staff of dairy engineering division and experimental dairy.

Token of thanks and appreciation are also due to Gagdish ji, Ramswaroop ji, Keematilal ji, Parveen ji, Veerender ji, Anil ji, Ramesh ji, Subhash ji, jaibhavan ji and all the administrative staff of Dairy Engineering Division.

I am heartfully thankful to Smitha for her constant help, encouragement and cooperation during my dissertation and course work.

I feel pleasure in extending heartfelt thanks to Istyak and Ankitdeep for their brotherly help, heart full co-operation and evergreen company during my dissertation work and stay at NDRI.

I thank to my friends Babu, Kuldeep, Laxmikant and Ashish PC for their wonderful company and cooperation , and also my lovely juniors Raju, Ashish Patel , Istiyak chauhan, Anshuman, Dingle, Saroj, Raghavendra, Devaraju, Mahesh, pankaj, Abhijeet, for their constant help, encouragement and loving company during my stay at NDRI.

My mother and father are earthy god in my life deserve much more than what I can weigh in words. I am extremely thankful to Gudia didi, Raju bhaiya, Aayush and Bhabhi for their adoration and encouragement. I would like to thank them with almighty God, without whose blessings, this would have never success.

Date: December , 2008 *Amit Kumar Singh*

Place: NDRI, Karnal *Reg.no:3040602*

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LIST OF ABBREVIATIONS AND NOTATIONS

LIST OF ABBREVIATIONS

TS	=	Total solid
TFSSHE	=	Thin Film Scraped Surface Heat Exchanger
SSHE	=	Scraped Surface Heat Exchanger
DMB	=	Dry matter basis
UHT	=	Ultra High Temperature
RO	=	Reverse Osmosis
MS	=	Mild steel
LA	=	Lactic acid
SNF	=	Solid not fat
SS	=	Stainless steel
RTD	=	Residence time distribution
rpm	=	Revolutions per minute
FFA	=	Free fatty acids
rps	=	Revolution per second
lps	=	Liters per second
NPRT	=	Normalized particle residence time
SD	=	Standard deviation
PV	=	Peroxide value
WCS	=	White crystalline sugar
CSSS	=	Caramelized sugar syrup solution

LIST OF NOTATIONS

T	=	Circumferential thickness of agitator nearest vessel wall ,m

C	=	Minimum clearance between agitator and vessel ,m
C_m	=	Maximum clearance between agitator and vessel, m
A	=	Cm / C
B	=	Number of blades
K	=	Thermal conductivity of fluid ,W / m K
C_p	=	Specific heat, kJ/kg °K
D	=	Inside diameter of heat exchanger, m
P_c	=	Power consumed in the clearance ,kgm/sec
N	=	Rotor speed ,rpm
S_1	=	Percent total solids in feed
S_o	=	Percent total solids at outlet
S	=	Percent average total solids (S1 +So)/2
E	=	Percentage of feed evaporated or vapour fraction
h_s	=	Scraped film heat transfer coefficient, $W/m^2.K$
L	=	Length of heat exchanger, m
π_m	=	Criterion of film thickness
T_s	=	Temperature of condensing steam, ^{0} C
ΔT	=	Temperature difference between condensing steam and fluid saturation temperature
U_o	=	Overall heat transfer coefficient
G_o	=	amount of feed, kg/s
V_c	=	Circumferential velocity of rotor blades , m/sec
μ	=	Coefficient of viscosity, Pa-sec

ρ	=	Density kg/m^3
σ	=	Surface tension N/m
P	=	Power consumption, Watts
m	=	Average thickness of film, m
M	=	Mass flow rate
R_1	=	Rotor rpm of first stage SSHE
R_2	=	Rotor rpm of second stage SSHE
R_3	=	Rotor rpm of second stage SSHE
P_1	=	Pressure in first stage SSHE
P_2	=	Pressure in second stage SSHE
P_3	=	Pressure in second stage SSHE

DIMENSIONLESS NUMBERS

π_{Re}	=	Reynolds's number = $\rho VL / \mu$
N_u	=	Nusselt number = hL / k
P_r	=	Prandtl number = $\mu Cp / k$
$[N_{re}]G_e$	=	Generalized Reynolds's number
$[P_r]Ge$	=	Generalized Prandtl number
T_a	=	Taylor number
R_{ea}	=	Axial Reynolds number

ABSTRACT

The present investigation was under taken to explore the potential of three stage SSHE for manufacture of Basundi. Trials were conducted to optimize the process parameters such as mass flow rate, type of sugar, and rotor speed. The mass flow rate was varied between125 to 200 kg/hr, two types of sugar were used and four level of scraper blade speed were takenin the first and second stage i.e. 1.968, 2.461, 2.953 and 3.445 m/s. The quality of Basundi so produced was evaluated in terms of proximate composition analysis, physico-chemical analysis and sensory evaluation. Data indicated that the type of sugar has very little effect on the body and texture but gave significant effect on the flavour, colour and appearance and hence the total score.Further studies revealed that Basundi prepared by using caramelized sugar syrup solution has the desired pleasant caramel and nutty flavour and caramel colour. Data also indicated that the type of sugar has very little effect on the proximate composition viz. fat, SNF, Sucrose, total solids, and the physico-chemical properties viz. acidity, specific gravity and viscosity of Basundi. The colour characteristics of Basundi significantly vary for two types of sugar.The mean values of **L***, **a*** and **b*** (**L*** value represents degree of whiteness, varies from 0 (black) to 100 (white), a positive **a*** value represents degree of redness while negative **a*** represents degree of greeness and a positive **b*** value gives the degree of yellowness while negative **b*** value gives degree of blueness),so obtained during study for white crystalline sugar Basundi and the caramelized sugar syrup solution Basundi are L* 88.21, a* -2.02 and b* 12.613, and L* 76.87, a* 0.69 and b* 19.86, respectively. The scraper blade speed has significant effect on flow rate as well as on the quality of Basundi at constant steam pressure and for constant final product concentration. The increase in scraper blade speed increases the rate of heat transfer and thus the evaporation rate at constant steam pressure (1.5 Kg/cm^2). The scraper blade speed has a significant effect on flavour, body & texture & overall acceptability while it does not have significant effect on the colour and appearance. Also scraper blade speeds do not have any significant effect on the proximate composition and the physico-chemical characteristics except viscosity. The best quality of Basundi was prepared by keeping scrapper speed of both the SSHE at 2.461 m/s and flow rate 165 kg/hr and by using caramelized sugar syrup solution.The third stage of SSHE was not used for Basundi manufacture as two stages gave the product of required consistency.

सारांश

वर्तमान जांच के तहत बासुंदी के निर्माण के लिए तीन चरण एस. एस . एच. ई. की क्षमता का पता लगाने के लिए लिया गया था। परीक्षण प्रक्रिया मापदंडों जैसे कि मास प्रवाह दर, चीनी के प्रकार और घूर्णक गति का अनुकूलन करने के लिए किए गए। इस अध्ययन में मास का प्रवाह दर १२५ से २०० किग्रा / घंटा, चीनी के दो विभिन्न प्रकार और खुरचनी ब्लेड गति के चार स्तर अर्थात् १००, १२५, १५० और १७५ आर.पी.एम. का उपयोग किया गया था। आसन्न संरचना विश्लेषण, भौतिक–रासायनिक विश्लेषण और संवेदी मूल्यांकन के संदर्भ में बासुदी की गुणवत्ता का मूल्यांकन किया गया था। अध्ययन संकेत देते है कि चीनी के दो विभिन्न प्रकार का शरीर और बनावट पर बहुत कम प्रभाव पड़ता है, लेकिन स्वाद, रंग और रूप पर महत्वपूर्ण प्रभाव पड़ता है। अध्ययन भी संकेत संकेत देते है कि कारमेल चाशनी का उपयोग करके बनाई गई बासुदी में वांछित सुखद कारमेल है और अखरोट के स्वाद का स्वाद और कारमेल रंग प्रगट है। आंकड़े यह भी संकेत देते है कि चीनी के प्रकार के बासुदी के आसन्न संरचना अर्थात नामतः वसा, एस.एन.एफ., कुल ठोस, और भौतिक–रासायनिक गुणों नामतः अम्लता, विशिष्ट गुरुत्व और दलदलापन पर बहुत कम असर पड़ता है। चीनी के दो विभिन्न प्रकार का बासुदी की रंग विशेषताएं पर महत्वपूर्ण प्रभाव पड़ता है। सफेद क्रिस्टलीन चीनी बासुदी और कारमेल चाशनी बासुदी के लिए अध्ययन के दौरान प्राप्त की भिन्न रंग विशेषताएं क्रमशः इस प्रकार हैं, एल* ८८.२१, ए* -२.०२ और बी* १२.६१३, और एल* ७६.८७, ए* ०.६९ और बी* १९.८६। लगातार भाप दबाव में और अंतिम उत्पाद के निरंतर एकाग्रता के लिए इस खुरचनी ब्लेड गति का प्रवाह दर के साथ–साथ ही बासुदी की गुणवत्ता पर महत्वपूर्ण प्रभाव पड़ता है। लगातार भाप दबाव (१.५ किग्रा / से.मी^{२}) में खुरचनी ब्लेड गति में वृद्धि से गर्मी स्थानांतरण की दर बढ़ जाती है और इस तरह वाष्पीकरण दर बढ़ जाती है। इस खुरचनी ब्लेड गति सुगंध, शरीर और बुनावट एवं समग्र स्वीकार्यता पर एक महत्वपूर्ण प्रभाव पड़ता है जबकि रंग और दिखावट पर महत्वपूर्ण प्रभाव नहीं है । इसके अलावा दलदलापन के अलावा खुरचनी ब्लेड गति के आसन्न संरचना और भौतिक–रासायनिक गुणों पर कोई महत्वपूर्ण प्रभाव नहीं पड़ता है। बासुदी की सर्वोत्तम गुणवत्ता दोनों एस. एस. एच. ई. के खुरचनी ब्लेड गति १२५ आर.पी. एम. पर रख कर और प्रवाह दर १६५ किग्रा/घंटा और कारमेल चाशनी का उपयोग करके तैयार किया गया था।

CHAPTER -1

Introduction

1.O INTRODUCTION

India has emerged as the world's fastest growing market for milk and milk products with an annual growth rate of about 3.01%. The country's milk production which is mostly rural based, recorded 100.8 million tonnes per annum in 2007 (Khanna, 2007). Out of total milk utilization pattern, indigenous dairy products are India's largest selling and most profitable segment after liquid milk accounting for 50% of milk utilization (Pal and Raju, 2007). Traditional Indian Dairy Products are highly valued in the society as a source of nutrition and are an inseparable part of wedding ceremonies, feasts, festivals and religious occasions. The flavor of new millennium is India's ethnic milk based sweets, desserts and puddings. Many traditional dairy products particularly khoa based sweets, chhanna and chhanna based sweets, and paneer have enormous market presence and tremendous consumer base in India and overseas as well. The other popular indigenous milk products such as rabri, shrikhand, *basundi*, palada payasam etc. are region specific (Dairy India, 2007). As the growth rate of dairy industry in India is growing, the demands for energy efficient and highly sophisticated mechanized systems are also growing. Besides higher profitability, traditional dairy products have acquired interest in large scale production of these products. Therefore the large scale manufacture of traditional milk products will enable the dairy plant more economically viable due to their higher profitability and export potential. The GATT agreement from the time it has come into action facilitates free trade through the opening of potential market. It is therefore necessary to give top priority to work on design and development of mechanized systems for manufacture of traditional dairy products.

Basundi is a traditional heat desiccated milk delicacy having sweetish caramel and pleasant aroma, light to medium brown colour, thick body and creamy consistency with or without soft textured flakes that are uniformly suspended throughout the product. It contains all the solids of milk in an appropriate concentration plus additional sugar and dry fruits. It is consumed directly as a delicious sweet dish. It is most popular in Maharashtra, Gujarat and parts of Karnataka and is mainly prepared at home by the housewives on some special occasions like festivals, weddings etc. and relished due to its rich, caramel, pleasant and nutty flavor and thick consistency (Pagote, 2003).

Total annual production of Basundi during 1996 was estimated to be 25000 tonnes and was mainly confined to cottage scale in non-organized sector (Aneja, 1997). Now-a-days, the popularity and demand of Basundi is increasing due to its delicacy. Hence its production and marketing is increasing in a few big cities of the country.

Since, Basundi is an emerging traditional milk delicacy in Indian market, considerable attention has been received by the researchers during last few years. Market survey was conducted in three cities of Gujarat (Patel and Upadhyay, 2001) and one city of Karnataka i.e. in Bangalore (Dharaiya, 2006) regarding chemical composition and organoleptic quality of Basundi sold by different halwais' shops and restaurants. Recently, a traditional method of Basundi making has standardized and an appropriate technology has been developed to obtain most desirable organoleptic and physico-chemical characteristics for Basundi (Pagote, 2005). Traditional process has also been upgraded for medium and large scale production of Basundi by dairy industriy (Pagote, 2005a). Attempt has been made to increase the shelf life of Basundi through retort processing (Raghavendra and Pagote, 2006).

Now-a-days, with rapid expansion of urban and semi-urban areas, the demand for traditional dairy products is increasing at a fast pace. Inspite of the fact that the dairy industry has made rapid strides in the last 3-4 decades, the methods of manufacture of the traditional products have remained essentially unchanged. The small-scale producers find it difficult to cope up with the increasing demand. Therefore, in recent times, attention is being focused either to scale-up the operation or to modify the technology so as to make it amenable to mechanization and continuous operation. These, innovations can best be made by adopting suitable technologies that already exist. Findings of researches on other similar types of foods and use of membrane processes need to explore for their judicious application under the Indian conditions. Moreover, in modern times, packaging has been identified as an integral part of processing in the food industry. Exploitation of combination of some of these areas could be advantageously used to enhance the shelf-life of the product manufactured.

The demand for efficient and labor saving processing of Basundi in the dairy industry attracts the application of continuous processing methods. Scraped surface heat exchanger (SSHE) is the most suitable heat exchanger for handling high viscosity and heat sensitive products, which tend to foam and foul heat transfer surface. The commercial large scale production of Basundi with very good sensory properties has necessitated sincere efforts in the developing suitable equipment for the manufacture of Basundi. Looking over the performance characteristics of Thin Film Scraped Heat Exchanger it can also be used for manufacture of Basundi. Recently three stage SSHE has been designed and fabrication with state of art technology by incorporating various factors. In order to establish the versatility of the equipment for the multiple applications in dairy industry, the investigation was proposed to make feasibility studies on manufacture of Basundi using Three Stage SSHE.

The present investigation was proposed with the following objectives:

1. To optimize process parameters of three stage scraped surface heat exchanger, viz., mass flow rate, and rotor speed.
2. To evaluate the quality of Basundi so produced in terms of sensory, proximate and physico-chemical analysis.

CHAPTER -2

Review of literature

2.0 REVIEW OF LITERATURE

2.1. BASUNDI

2.1.1. DEFINITION AND CHARACTERISATION OF *BASUNDI*

Basundi is a traditional heat desiccated sweetened milk product with a specific type of pleasant aroma. It has great social, cultural and economic importance. The exact origin of *Basundi* is not known, but it has been traditionally prepared over several centuries in the western India particularly in Maharashtra, Gujarat and some parts of southern India (Aneja, 1992; Pagote, 2003).

Recently, the characteristics of *Basundi* have been documented. Its body is similar to condensed milk but less viscous than condensed milk and easy to pour. It has smooth texture with the presence of uniformly distributed soft and very minute flakes. A light brown to medium brown colour of this product is preferable which is developed naturally during processing. It has very pleasant caramel and nutty flavour with desirable level of sweetness (Pagote, 2004).

2.1.2. METHOD OF PREPARATION OF *BASUNDI*

Generally, whole milk is preferred for the preparation of *Basundi.* The milk is kept on open fire in shallow vessel. Then evaporation is continued till to achieve about two-fold times concentration of milk on slow boiling with continuous agitation and scrapping to avoid burning. At this stage sugar is to be added, while cardamom or nutmeg powder and dry fruits are being added at the stage when desired concentration is reached. The product is then cooled and served as a special and delicious sweet dish. It can be consumed as such like kheer or along with specially prepared four-folded chapathi (Pagote, 2003).

Recently, a traditional method of *basundi* making has been standardised and an appropriate technology has been developed to obtain most desirable organoleptic and physico-chemical characteristics for *Basundi* (Pagote, 2005), as shown in Fig. 2.1.

Fresh Milk
↓
Filtration
↓
Standardization
(Fat/SNF= 0.6; Fat= 5.1%; SNF= 8.5%)
↓
Forewarming of milk
(90^0 C/ 10 min.)
↓
Concentration
(~ 2.0X milk solids)
↓ ← Sugar (5% on the milk basis)
Concentration continued
(~2.5X milk solids)
↓
Cooling
↓
Addition of fruits and nuts
↓
Basundi

Fig. 2.1 Flow diagram of *Basundi* manufacture

2.1.3. CHEMICAL COMPOSITION OF *BASUNDI*

Patel and Upadhyay (2001) reported the composition of buffalo milk *Basundi* marketed in three cities of Gujarat which is given in the Table 2.1.

The cow milk *Basundi* was reported to contain 10.38% fat, 7.39% protein, 10.88% lactose, 1.39% ash, 14.12% sucrose and 46.83% of total solids (Patel and Upadhyay, 2003).

Pagote (2005) has reported optimum composition of *Basundi* prepared by adopting the standardised method (Pagote, 2004). It contained 12.44 to 13.02% fat, 17.93 to 18.77% milk SNF, 13.12 to 13.73% sugar and 43.49 to 45.52% total solids.

Table 2.1: Average Proximate Composition of *Basundi* Collected from Different Cities of Gujarat.

Attribute (%)	City			Mean
	Ahmedabad	Anand	Vadodara	
Fat	10.63	10.55	12.90	11.52
Protein	7.85	7.71	7.55	7.70
Lactose	7.28	9.11	8.46	9.64
Ash	1.32	1.48	1.27	1.33
Milk SNF	17.99	20.38	18.50	18.67
Sucrose	15.65	12.79	19.03	16.43
Total solids	44.27	43.71	50.44	46.62
Fat:SNF	0.59	0.52	0.70	0.62

It is seen that fat, protein, ash, SNF and fat: SNF ratio of *Basundi* collected from three cities were alike, whereas lactose, sucrose and TS contents differed significantly among the three cities.

2.1.4. PHYSICO-CHEMICAL PROPERTIES OF *BASUNDI*

The result of the analysis of physico-chemical properties of the market samples has been presented in Table 2.2 (Patel and Upadhyay, 2001).

On comparing the physico-chemical attributes of samples of *Basundi*, it is observed that the products obtained, irrespective of cities, had statistically similar values for acidity, pH, FFA and viscosity, whereas Hydroxy Methyl Furfural (HMF) and specific gravity values differed significantly. The minimum value of acidity implies a very low level of concentration achieved during *Basundi* making and/or adulteration of milk with neutralizer as implied from the high ash and SNF content. The maximum value of 0.52% LA in the sample of Vadodara city suggests use of high acid milk, acid development during storage or higher level of total solids in such samples.

Table 2.2: Physico-chemical Properties of Market Samples of *Basundi* Collected from Different Cities of Gujarat.

Attribute	City			Mean
	Ahmedabad	Anand	Vadodara	
Acidity, %LA	0.36	0.31	0.37	0.36
pH	6.59	6.64	6.58	6.60
FFA, µq/ml	0.56	0.61	0.54	0.56
HMF, µmol/l	19.50	1.85	6.55	10.79
Specific gravity	1.10	1.11	1.15	1.12
Viscosity, mPaS	51.73	85.82	93.46	75.24

FFA: Free Fatty Acid, HMF: 5-Hydroxymethyl furfural

2.2 REFINEMENTS IN PROCESSING PARAMETERS FOR CONCENTRATED MILK PRODUCTS

The process employed by halwais/housewives, on small scale, for preparation of ‘Basundi’, and related milk products consume lot of energy and often results in poor quality due to burning problems. The resultant product has a very short shelf-life. Many researchers have attempted to overcome these limitations and have suggested refinements in the traditional process of manufacture of the indigenous milk products (Chakraborty, 1978b, Ganguli, 1979; Heldman, 1981; Gupta and Patil, 1987; Gupta et. A. 1987; Balachandran and Rajorhia 1988; Punjrath, 1991; Rajorhia, 1995).

These refinements are discussed hereunder.

2.2.1 USE OF DIFFERENT EQUIPMENT/SYSTEMS FOR MILK CONCENTRATION

A simplified process has been reported for the manufacture of condensed milk for use under village conditions (Anon, 1943). In the process, milk was heated in a double jacketed deep pan to a temperature between 88-99^{0}C until the desired consistency was reached. Uniform temperature in the pan was maintained by keeping fine sand in the space between the two jackets. The condensed milk produced was sterilized before cold storage and in case of sweetened condensed milk making cane sugar was added to the milk prior to heating.

Bandyopadhyay and Mathur (1987) reported use of a steam jacketed kettle for desiccating milk in the preparation of concentrated milk products.

More (1987), designed and developed a batch type semi-mechanized SSHE. This system consisted of a jacketed drum, with vapour exhaust and scraper assembly. The system consisted of scraper assembly with spring-loaded blades, rubber boots and central shaft. A gland packing is provided on auxiliary shaft in order to avoid the leakage of milk. Studies were carried out on the effect of scraper speed and heating temperature for better quality product. The results showed that the most suitable operating condition for dehydration of milk is to keep heating temperature at 121ºC and scraper speed at 28 rpm. During the investigation, a batch size of 4 kg milk is used.Use of this scraped surface heat exchanger (SSHE) was suggested for the manufacture of concentrated milk/ Basundi.

For large scale production of Rabri, vacuum concentration of milk followed by blending it with required quantities of sugar and malai was attempted by Gayen and Pal (1991).

A mechanized system involving three stage concentration of milk in a horizontal scraped heater and two-steam jacketed pans has been elaborated by Chakraborty (1978c).

Membrane processes such as ultrafiltration and reverse osmosis (RO) can also be advantageously used for the manufacture of concentrated milk products since they are energy efficient. Alvarez et al. (1979) reported the application of ultrafiltration in the production of sweetened condensed milk. The process was beneficial since the product had high calcium to phosphate ratio and had more available lysine than the conventional SCM.

RO concentrate (1.5-2 X concentration, 25-33 per cent TS) obtained from buffalo milk can serve as an intermediate in the preparation of rabri. The lipids, protein, minerals and lactose in concentrated milk increased by an extent equal to the concentration factor. The process did not exert any adverse effect on the titratable acidity, pH, free fatty acids, free fat and microbial load. The sensory quality of the product was similar to that of fresh buffalo milk and at 2.0 X concentration, the sizes of fat globules were found to be less than 2.5μ (Gupta and Pal. 1993).

In future, organized sector may find wide applications of SSHE for direct conversion of milk into concentrated product in a single pass, or use of pressurized steam jacketed kettle integrated with packaging system (Bandyopadhyay and Mathur, 1987). Use of RO as an intermediate process could also be used as an adjunct with the conventional method for preparing such products.

2.3 HEAT TRANSFER STUDIES IN SSHE

SSHEs are most often used for products that are highly viscous in nature. For evaporation, thin film operation is used where process liquid moves along the heat transfer surface as a thin film. The greatest advantage of SSHEs for either heating or cooling is the constant removal of the stagnant film near the wall and subsequent increase in the heat transfer coefficients and reduction in fouling at the wall. Investigations were also carried out to find the type of heat transfer mechanisms occurring in SSHEs during evaporation. Two types of mechanisms were suggested.

First mechanism was suggested by Kramers *et al*. (1955). On the basis of studies conducted it was concluded that heat transfer takes place by conduction across the vapour films combined with evaporation of the more volatile component at the surface of the film. During evaporation of liquid film in the SSHE, force of gravity, internal friction, and peripheral forces are the principal forces created by rotation and acting on the film.

The second mechanism explaining that heat transfer takes place due to vapour bubbles formation at heat transfer surface and at overheated spots inside the film was given by Ziolkowski and Skoczylas (1965). On the basis of trials conducted, the workers observed that the liquid film which is the resultant of forces of internal friction, gravitational force and the peripheral forces, is affected by formation and release of vapour bubbles and is expected at higher values of specific heat flux and with turbulent flow of film.

Abichandani (1985) conducted heat transfer studies in thin film evaporator using water, buffalo milk and cream as working fluids. Different process variables selected were in the range – flow rates 0.025 to 0.075 kg/s; scraped speed, 1.78 to 5.338 m/s ; number of blades 2,4,6 and 8 ; and temperature of steam 110 ^{0}C , 120^{0}C ,and 130^{0}C. The conclusions drawn were:

1. Increase in mass flow rates caused overall heat transfer coefficients to increase for milk and cream only at low rotor speed (1.78 m/s) .At higher rotor speed the effect of mass flow rates on overall heat transfer coefficient (U_0) was insignificant.
2. Overall heat transfer coefficient increased with increasing rotor speed especially in the range 100-150 rpm. Increasing the rotor speed beyond 150 rpm did not result in appreciable increase in overall heat transfer coefficient for fluids with fouling tendencies.
3. The overall heat transfer coefficient decreased with increasing ΔT at all rotor speed for milk and cream. It was mainly due to the formation of a tenacious layer of milk constituents on the surface of SSHE, which offered additional resistance.
4. The over all heat transfer coefficient was expressed by the relationship:

U_0 = 620.083 – 2.181 (E) – 32.313 (S)+ 585.562 (V_c)+ 133.336 (B) – 11.67 (ΔT) – 0.234 $(E)^2$ + 0.483 $(S)^2$ – 73.616 $(V_c)^2$ – 6.293 $(B)^2$ – 0.168 $(\Delta T)^2$ – 0.246 (E) (S) + 0.641 (E) (V_c) – 0.029 (E) (B) + 0.706 (E)(ΔT) + 2.242 (S) (V_c) + 0.758 (S) (B) – 0.21(S) (ΔT) – 11.987 (V_c)(ΔT) – 0.464 (V_c) (ΔT) - 0.302 (B) (ΔT).

It was inferred that the system could be suitably adopted for continuous manufacture of indigenous milk products.

Dodeja (1987) conducted the performance study of the thin film scraped surface heat exchanger for concentration of milk to higher concentration using parameters that were optimized by Abichandani (1985). Following conclusions are drawn

1. Milk was concentrated upto 70 % total solid using thin film scraped surface heat exchanger. The obtained product was browning free. This inferred that thin film scraped surface heat exchanger could be successfully used for manufacture of indigenous milk products.
2. The data generated from experiments were analysed and following correlation was developed (Dodeja et al., 1990):

$$Nu = 6615.0619\ (NRe)_{Ge}^{\ 0.1331}\ (Pr)_{Ge}^{\ 0.0764}\ (\Delta T/Ts)^{0.2843}$$

$$19 \leq So \leq 70\ \%$$

Number of blades = 4

Vc = 3.558

   Above correlation, which was found to predict the scraped film coefficient with reasonably accuracy must be useful in design the thin film scraped surface heat exchanger in applications such as concentration of milk to high solid contents and in manufacture of indigenous milk products.
3. The over all heat transfer coefficient decreased with increasing in steam condensing temperature. However the scraped film coefficient increased with increasing steam condensing temperature until the product attained concentration of about 45 per cent total solids. Beyond this concentration, scraped film

coefficient decreased rapidly with increasing steam condensing temperature.

Badshah (1999) used a horizontal TFSSHE for evaporation under vacuum in the manufacture of sweetened condensed milk. A correlation was developed for evaporation of water in TFSSHE:

$$Nu = 0.1427\ (Re_f)^{1.6527}\ (Re_r)^{0.1865}\ (P_r)^{-3.73}\ (\Delta T / Ts)^{-0.1121}$$

2.4 ARRANGEMENT OF ROTOR BLADES

In the thin film heat exchangers there are mainly two types of blades that can be used according to the investigation to be carried out:

1. Fixed clearance blades
2. Variable clearance blades

The overall thermal performance of the continuous khoa making unit is improved by increasing the heat transfer rate with the help of blades by violently agitating the liquid, eliminating any channeling of liquid, decrease in apparent viscosity by shearing effect and forming a thin film of liquid on its heat transfer surface. To balance hydrodynamic force developed by liquid to the centrifugal force, the clearance of the blades should be selected.

The blade arrangement can be made in two fashions:

1. Straight blades
2. Staggered blades

Kohli *et al.* (1993) worked on thin film scarped surface heat exchanger system for the concentration of milk and reported that, staggered blades are highly advantageous from viewpoint of heat transfer and hydrodynamics. It caused high turbulence due to more frequent interruption of fluid film by blades.

Bag (1994) studied the influence of various parameters on quality and type of khoa in continuous khoa making unit. The workers varied the parameters like number of blades, rotation speed, and mass flow rate and steam pressure. On the basis of study, the worker suggested that the performance of machine with regards to heat transfer and product outflow was better in case of 4-4 staggered blades compared to four straight blades.

2.5 APPLICATIONS OF THIN FILM SCRAPED SURFACE HEAT EXCHANGER

Processing of various products in the food industry is primarily carried out in kettles, where the possibilities to control and optimize heat treatment processes generally are very limited. The demand for efficient and labour saving processing in food industry attracts the application of continuous processing methods in heat exchangers. For handling of high viscosity products with or without particles, the products that tend to foam and foul the heat transfer surface and heat sensitive products, the scraped surface heat exchanger is the most suitable. High heat transfer coefficients are 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 operations can be carried out simultaneously. This subhead critically reviews the current understanding and application of thin film scraped heat exchanger.

Kapil *et al.* (1991) studied heat transfer during concentration of whey in thin film scraped heat exchanger. The thermal performance of thin film scraped surface heat exchanger was evaluated for concentrating deproteinized paneer whey to high solids with process variables such as mass flow rate, steam temperature, rotor speed, number of blades, etc. Appropriate correlation was developed in the form of Box Wilson model to predict overall heat transfer coefficient.

Upadhyay et *al.* (1993) studied manufacture of khoa based sweets and other food products on scraped surface heat exchanger to standardize the process line for these products. It was found that products like carrot halwa, dudhi halwa, kheer, basundhi,and tomato ketchup could be successfully prepared, and their quality as determined by sensory evaluation was declared excellent using SSHE.

Alfa Laval (1993) developed Alfa Lavel blend process line for the production of Bregott spread and for blended products with varying fat content with the help of scraped surface heat exchanger for blending various ingredients to produce water in oil emulsion.

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 retinal, it-E, and Phospholipids content and increase in peroxide value (P Value) and Free Fatty Acids (FFA) was observed. Shelf life of continuously prepared ghee was comparable to that of ghee made of batch process.

A project to investigate the suitability of scraped surface heat exchanger for crystallization of dark chocolate during different tempering processes was undertaken by Loisel *et al.* (1997). During the course of investigation, it was concluded that due to the linear relationship between torque and viscosity, it would be possible to control the chocolate crystallization during tempering in scraped surface heat exchanger.

A new recombined sweetened condensed Milk (RSCM) having TS in the range of 73-74 % using SSHE for cooling and crystallization of lactose was developed by APV Nordic dairy (1999).

Kishore Kumar (1999) investigated the acceptability of three stages TFSSHE for the continuous manufacture of burfi. During the investigation the two stage SSHE was hooked upto third stage SSHE and sugar dosing mechanism was incorporated at inlet of third stage SSHE. The burfi produced in small quantity was found to have acceptable quality. Optimum parameters for best quality burfi were found out rotor speed of 150 rpm and 4 blades in the third stage.

Kunju (2002) evaluated the performance of new rotor blade assembly for mechanization of *Burfi* making. The new rotor blade assembly was provided with skewed blades for continuous outflow of product from SSHE. The trials indicated that skewed blade arrangement did not improve the product discharge as expected. The *burfi* produced showed pastiness and lacking in flavour.

Nangal (2003) studied the application of scraped surface heat exchanger for bypass fat production. On the basis of FFA and Ca content in the bypass fat parameters such as mass flow rate, steam pressure, scraper blade speed was optimized. It was found that minimum FFA was available in the product at feed rate of 15 l/ hr, steam pressure of 2.0 Kg / cm^2 and with rotor speed of 175 rpm.

Manufacture of basundi was tried at NDRI using conical process vat and two-stage thin film SSHE with standardized buffalo milk. Basundi prepared in conical process vat were good in body and texture, appearance and overall acceptabiliy for processing time between 80 to 100 min (Ranjeet 2003).The SSHE was modified for the recirculation of the product from SSHE back to feeding tank in order to continue heating till desired consistency and olor is achieved. The various process parameters of SSHE were used for the manufacture of basundi. The trials indicated that product was getting concentrated to desired consistency but desired colour required for basundi could not be obtained. The colour was therefore supplemented by adding burnt sugar of required concentration.The sensory evaluation reports of the product indicated no foul smell. The product so obtained gave desired colour and body and texture.It was also recommended that processing time in conical process vat can also be reduced by integrating it with SSHE.

Vijay Pal (2004) optimized the parameters of TFSSHE and observed that a good quality *burfi* could be obtained by using two-stage thin film SSHE and this method can be adopted for commercial production.

Bhadania *et al.* (2004) investigated the effect of heat transfer on physico- chemical and sensory qualities of khoa manufactured using a continuous khoa making machine. The unit consisted of three individual scraped surface heat exchanger equipped with Teflon coated spring loaded rotor – scraper assembly. The overall heat transfer coefficients, steam and product side film heat transfer coefficient s were determined under various operating conditions of SSHE.

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

Sushanta Kumar *et al.* (2005) investigated the performance evaluation of two stage thin film scraped surface heat exchanger for manufacture of khoa using low fat milk. It was found that good quality khoa can be made raw buffalo milk having 4% fat. In this study it was observed that due to problem of scaling, khoa could not be made from raw buffalo milk having fat less than 4%. Milk having 3% fat can also be suitable for manufacture of khoa using TFSSE if it can be pre- concentrated upto 21 – 24 % TS. The sensory score of khoa made from TFSSHE was comparable to that made from conventional method. Water evaporation rate ranges from 48 -55 Kg / m^2 / hr. during manufacture of khoa using raw buffalo milk having fat in the range of 2- 4%. In this study it was observed that due to problem of scaling water evaporation rate decreased with decrease in fat percentage.

Sunil Patel (2006) developed continuous Basundi making machine based on the principle of thin film SSHE. This equipment was energy efficient and quality of the product was better compared to traditional products.

2.6 INFERENCES DRAWN FROM REVIEW OF LITERATURE

The literature revealed that SSHEs are commonly used in food, chemical and pharmaceutical industries for heat transfer, crystallization, and other continuous processes. They are ideally suited for highly viscous, sticky, heat sensitive, that contain particulate matter. The thermal performance of the equipment has shown that it can handle wide viscosity range products without appreciable falling in its heat transfer coefficient. The equipment has been found very successful for manufacture of khoa and burfi.Thus it can be inferred from review of literature that thin film SSHE can be used for the mechanization of Basundi manufacture.

CHAPTER -3

Materials and methods

3.0 MATERIALS AND METHODS

This chapter deals with various materials including ingredients, instruments used, and the methods employed in the preparation of samples with their analysis are described here under.

3.1 EXPERIMENTAL SET- UP

The experimental set up was three stage scraped surface heat exchanger developed by Dodeja *et al.* (2007). The system includes:

3.1.1 Thin Film Scraped Surface Heat Exchangers

3.1.2 Variable speed drives

3.1.3 Balance Tank

3.1.4 Feed Pump

3.1.5 Valves for steam supply

3.1.6 Instrumentation

3.1.1 Thin film scraped surface heat exchanger

The unit is consisted of three thin film scraped surface heat exchanger (TFSSHE). All heat exchangers are identical in length, diameter and effective heating length. The heat exchanger is made from SS 304 shell having 37.6 cm inner diameter, 45.1 cm outer diameter, 0.5×10^{-2} m wall thickness and 136.3 cm length. Each heat exchanger is provided with MS jacket of 41×10^{-2} m inner diameter and 100×10^{-2} m length. The jacket of third heat exchanger is provided with partition at the middle. All the jackets are insulated with glass wool of thickness 4×10^{-2} m for minimizing the heat losses. All three TFSSHEs are provided with end covers fabricated from 0.7×10^{-2} m thick SS 304 sheet. Vapour outlet of 23.7 cm diameter was provided on the top of all the three heat exchanger.

The rotor assembly of first two heat exchangers is identical but altogether different from rotor assembly of third TFSSHE. The scraper assembly consisted of solid SS shaft of 2.5×10^{-2} m diameter. The first and second stages TFSSHE had four variable clearance blades each of 133.2 cm length, 0.5 cm thickness and 4 cm width and are hinged between cross supports in each scraper at 140.5 cm distance from front end and 35.6 cm from rear end. The rotor of third stage TFSSHE consisted of two variable clearance blades of size same as above and two skewed blades. In order to rotate two hinged blades as thin film formation mode at low rpm (0-100) a spring loaded support was incorporated. The scraper assembly was mounted on a type roller bearing housed in end cover of TFSSHE. The third stage TFSSHE is also provided with sugar with sugar dosing device. This consists of hopper and auger driven by variable speed drive for varying feeding rate. All TFSSHE'S jackets are provided with spring loaded safety valves and vent coke on different desired locations.

3.1.2 Variable speed drives

The driven end of the scraper assembly was coupled to a variable speed drive through flexible coupling. The drive consisted of geared three phase, fan cooled induction motor. The required speed adjustment was done with the help of gear units, which are splash-lubricated. With the help of these

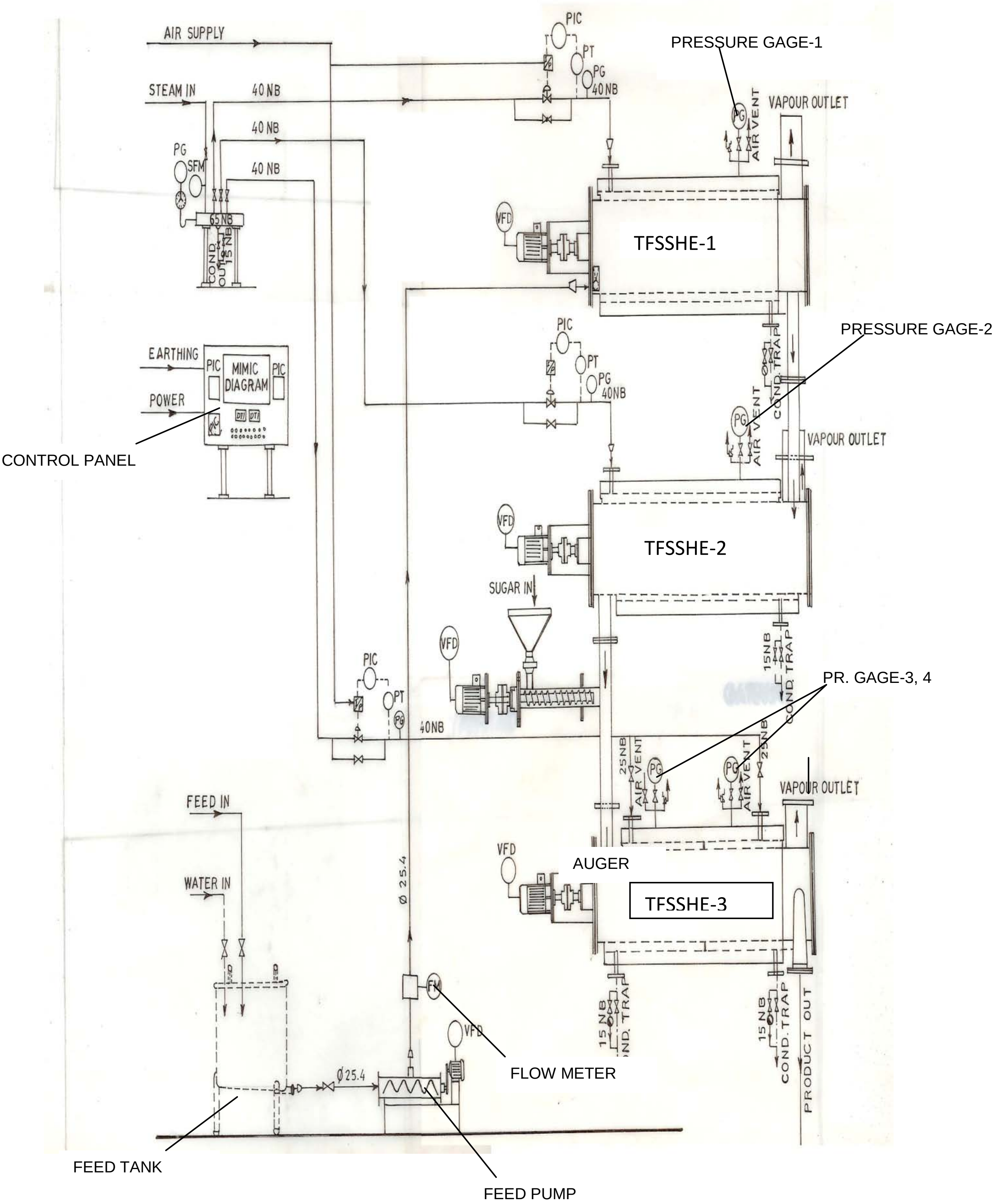

FIGURE 3.1: Schematic Diagram of Experimental Set Up

A

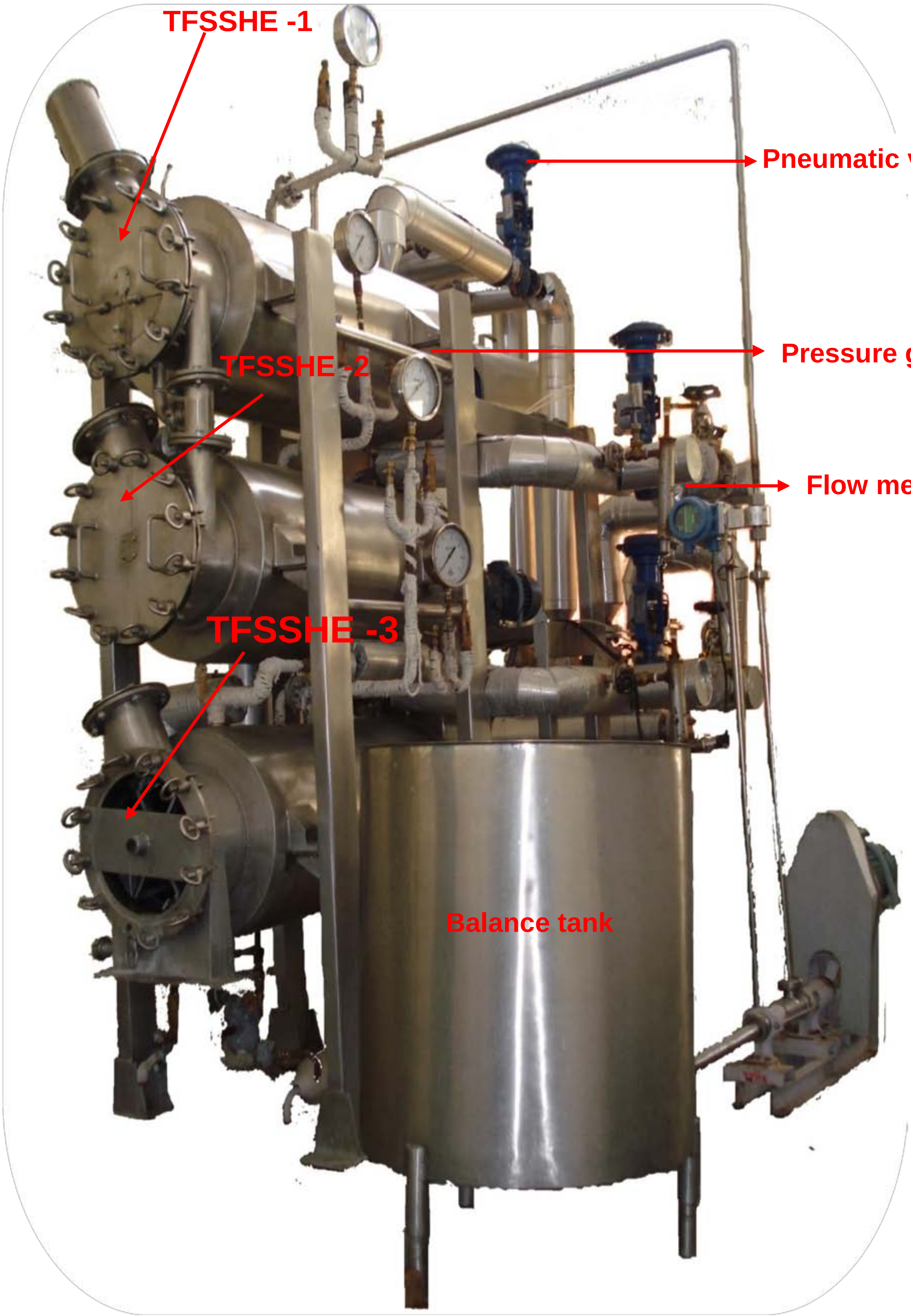

PLATE 3.1: EXPERIMENTAL SETUP – THREE STAGE TFSSHE

arrangements, the rotor speed of first, second stage and third stage TFSSHE rotors as well as augur speed was adjusted from 20 to 200 rpm.

Specification of TFSSHE rotor motor of all three TFSSHE:

Make	:	REMI
Speed	:	303 rpm
Kw	:	1.5
Power	:	3.71 A, 50Hz
Efficiency	:	77 %
Reduction gear box	:	Reduction gear box was used to reduce the Motor rpm.

3.1.3 Balance Tank

A cylindrical SS tank with a capacity of 250 lts was used as the feed tank. It was connected to the feed pump through a SS pipe. The outlet of the pump is connected to the first TFSSHE.

3.1.4 Feed pump

Screw type 'FAS' Series ROTOMAC progressive cavity pump, a special type of positive displacement pump, in which flow through the pumping element is truly axial was used. It is ideal for handling viscous/ non-viscous fluids and pulped material in suspension, viz., milk, cream, sugar syrup, beverages, and fruit juices. It has a uniform pulse-free output in strict linear dependence on the rotational speed. It is the intermeshing of the threads and close fitting of the surrounding housing, which create one or more sets of moving seals between pump inlet and outlet. These sets act as a labyrinth and provide the screw pump with its positive pressure capability. The successive sets of seals form fully enclosed cavities, which move from inlet to outlet. These cavities trap liquid at inlet and carry it along to the outlet, providing a smooth flow. They are accurate, compact, efficient and comparatively silent in operation. It has improved efficiency because of better volumetric and mechanical efficiency.

Flow of milk through the pump was regulated by varying the speed of feed pump with the help of frequency controller provided on the control panel.

Specification of feed pump motor:

Make	:	ABB
Type	:	3 phase induction motor
Efficiency	:	68.0
RPM	:	910
Weight	:	22 Kg
Power	:	50 Hz, 2.1 A, 0.75 kW
Amb	:	45^{o} c

3.1.5 Valves for steam supply

Steam supply valves are provided at the inlet of each TFSSHE with following details:

Make	:	Micro valves India Pvt.Ltd, Noida
No	:	7
Size	:	40 mm
Type	:	globe valve
Spindle	:	13 % CR
Stopper	:	hard faced

3.1.6 Instrumentation

Instrumentation plays an important role in process control and automation for continuously monitoring the process variables. Following instruments were used in the set up to measure and control the process variables.

3.1.6.1 Magnetic flow meter

To measure the flow rate of the working fluid, a magnetic flow meter that works on the Faraday's Law of electromagnetic induction, which states that a voltage will be induced in a conductor moving through a magnetic field. The Rosemount magnetic flow meter specifically designed for food, beverages and pharmaceutical application. In Rosemount magnetic flow meter, the output voltage is directly proportional to the liquid velocity, resulting linear output. Following specification was used:

Make	:	Rosemount (Brazil)
Maximum power	:	input- 5W, output-1MW
Maximum current	:	input- 0.5 A, output- 0.20 MA
Maximum voltage	:	input- DC only, output- 5 volts
Maximum process temp.	:	160º C
Ambient temp.limits	:	- 34.0ºc to +66ºC
Maximum process pressure	:	2.06 MPA
Accuracy	:	± 0.005
Repeatability	:	±0.1 % of reading
Response time	:	0.2 seconds maximum response

3.1.6.2 Pressure gauges

Pressure gauges are used to indicate the steam pressure inside the shell maintained to carry out the present investigation at different locations of the three stage TFSSHE, with following specifications:

Make	:	H. Guru North
Range	:	0-7 kg/cm^2
Accuracy	:	± 1.0 % of range span
Dial size	:	150 mm

Dial marking	:	black and white
Standard fitments	:	Micro adjustable pointer, blow out disc
Tested against	:	Budden Berg Master Gauge
No of gauges	:	5

3.1.6.3 I / P converter

The electro pneumatic signal converter is used as a linking component between electric or electronic and pneumatic systems. It converts standard electric signals (mA) into standard pneumatic signals (psi / kg / cm^2). Due to its innovative construction principle based on a fixed coil and a low- mass moving permanent magnet , it is highly resistant to shock and vibration and had following specification :

Make	:	ABB Limited, Faridabad
Input	:	4 – 20 mA
Output	:	0.2 – 1.0 kg / cm^2
Supply	:	20± 1.5 psi / 1.4±0.1 kg / cm^2

3.1.6.4 Transmitters

The transmitter was used to transmit the converted pneumatic signals from I / P converter to the controller to convey the message for the variation of process variables to optimize the whole process with following details:

Make	:	WIKA Alexander Wigand GmbH
No	:	3
Pressure range	:	0 – 6 bar
Power	:	4 – 20 mA
Voltage	:	10 – 30 volts

3.1.6.5 Pneumatic valves

A control valve positioner is the heart of most accurate and efficient control systems, by ensuring the valve responds to the controller commands and adopts the precise position. It works on the principal of force balance to position the control valve stem in accordance to a pneumatic signal received from a controller or manual loading station. The instrument signal is applied to the signal diaphragm. An increasing signal will derive the diaphragm and flapper – connecting stem to the right. The flapper – connecting stem will then open the supply flapper admitting supply pressure into the output which is connected to the actuator diaphragm. The exhaust flapper remains closed when the flapper is connected to the right. The effect of increasing signal is to increase the pressure in the actuator. When the valve reaches the position called for by the controller, the compression in the range spring will give a balance force resulting in the closure of both the flapper. It had the following specification:

Make	:	PNEUCON valves Pvt Ltd, Thane
No	:	3
Size	:	25 mm
Spring range	:	0.2 – 1.0 KSC
Travel	:	28 mm
Trim material	:	SS 316
Body material	:	WCB + 1 BR
Flange rating	:	150 ANSI
Characteristic	:	equal

3.1.6.6 Air pressure indicators

The air pressure indicators are used to indicate the pressure supplied to the pneumatic valves to regulate the steam pressure in the cylinder shell with following specifications:

Make : Denvar

Range : 0 – 2.5 kg / cm^2

3.1.6.7 Digital panel meter

The digital panel meter was used to indicate the readings of rpm of all the three rotors of the three stage TFSSHE unit and had the following specifications:

Make : R / R electronics

Display : 3.5 digits, 7 – segment red LED display

Supply : 220 V AC

Input : 10 V DC

Range : 0 to 1500 RPM

Dimensions (W×H×D): 96 ×48 ×110 mm

Panel cutout : 92 ×44 mm

3.1.6.8 Process controller

The process controller of YOKOGAWA is an integral part of the automatic process control system assembled on the control panel of three stage TFSSHE. It had three different modes such as operator mode (standard controller, heat / cooler controller, remote set point controller, profile controller), set up mode (level 2 –tuning, level3 – set points, level4 – profile) and configuration mode and is used for observing the process variable value that was attained during investigation and control set point value that is fixed by the operator according to the requirement so that the process variable value can’t exceed this limit.

3.2 ACCESSORIES / MATERIAL

3.2.1 Digital Thermometer

To monitor the temperature change during the production process at Basundi, a battery operated digital temperature indicator alongwith probe has been used.

3.2.2 Pocket Refractometer

Pocket Refractometer was used to measure the consistency of product during preparation. Two range of pocket refractometer were used, one was in the range of 0-32^{0}Brix and other in the range of 28-62^{0}Brix.

3.2.3 Other material

Digital weighing balance, milk can, milk container, etc.

3.3 INGREDIENTS

3.3.1 Milk

Fresh buffalo milk was procured from Experimental dairy NDRI, Karnal.

3.3.2 Sugar

Two forms of sugar have been used in this present investigation:

3.3.2.1 White crystallline sugar

Commercial grade white crystalline sugar purchased from local market has been used.

3.3.2.2 Caramellized sugar syrup solution

Caramellized sugar syrup solution having 50-52% TS was prepared from white crystalline sugar.First of all, white crystalline sugar 5% w/w of the initial amount of milk was taken in a vessel.It was then heated over the heater with continuous stirring.With passage of time the temperature increased and the sugar started to change its colour.Finally the sugar liquified and the colour of the sugar turned caramel around a temperature of 160^{0}C. At that point water was added in the ratio 1:1; followed by vigorous stirring to make it a caramellized sugar syrup solution (50-52% TS).

3.3.3 Dry-fruits

Nuts and dry-fruits were purchased from the local market and used in Basundi.

3.4 METHOD OF MANUFACTURE OF BASUNDI

3.4.1 PREPARATION OF CONTROL BASUNDI SAMPLE

Fresh Buffalo Milk

↓

Filtration

↓

Standardization
(Fat/SNF= 0.6; Fat= 5.1%; SNF= 8.5%)

↓

Preheating of milk
(90^0 C/ 10 min.)

↓

Open pan concentration (8Kg milk/batch)

↓

Partial Concentration
(~ 2.0X milk solids)

↓ ← Sugar (5% on the milk basis)

Concentration continued

↓

Final concentration
(~2.5X original TS including sugar)

↓

Cooling (~10^0C)

↓

Addition of dry fruits and nuts

↓

Basundi (Refrigerated Storage ~ 7±2^0C)

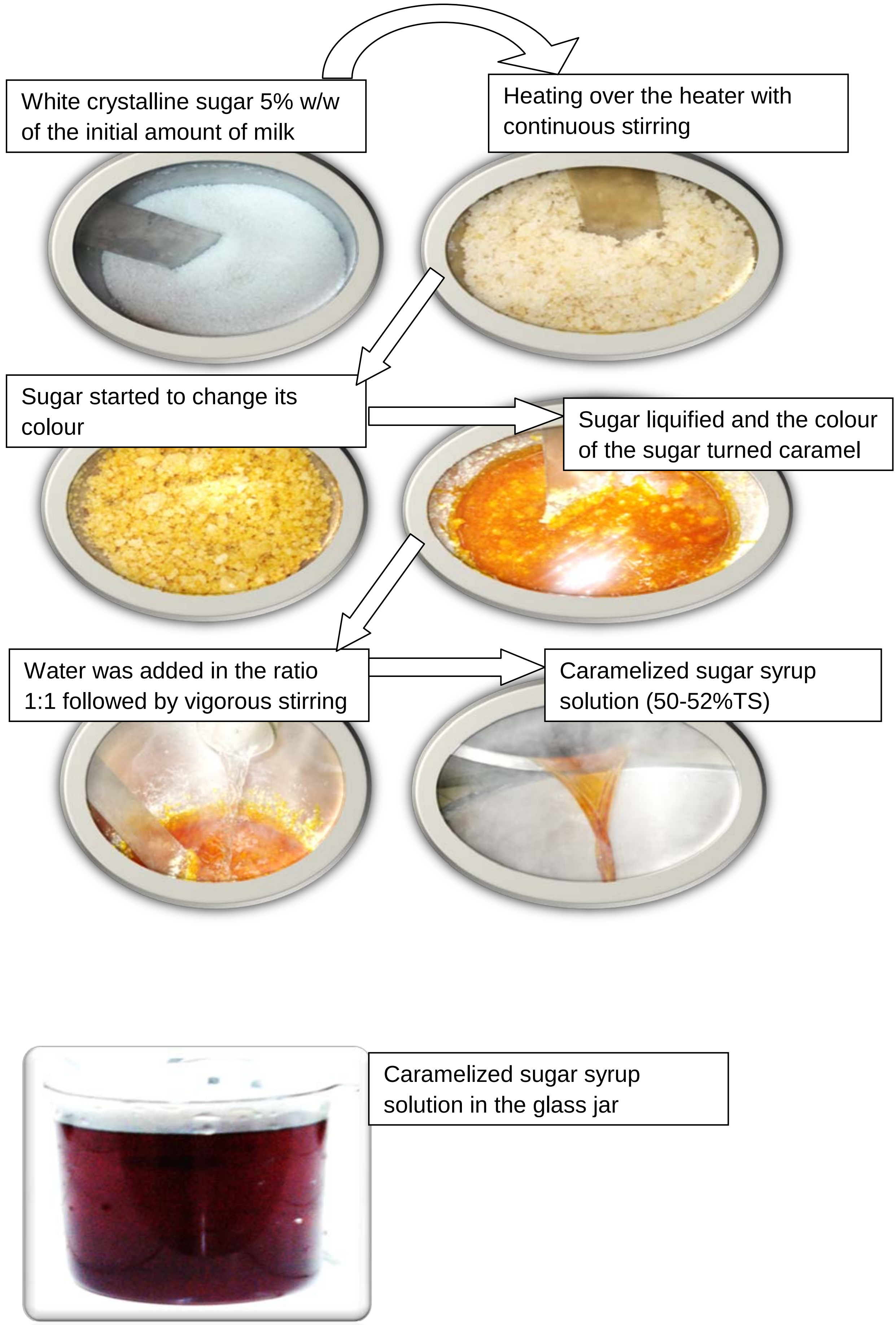

PLATE 3.2: PREPATION OF CARAMELIZED SUGAR SYRUP SOLUTION

3.4.2 PREPARATION OF BASUNDI IN THREE STAGE SCRAPED SURFACE HEAT EXCHANGER

Fresh Buffalo Milk

↓

Filtration

↓

Standardization
(Fat/SNF= 0.6; Fat= 5.1%; SNF= 8.5%)

↓

Preheating of milk

↓ ← Sugar (5% on the milk basis), either white crystallline sugar or caramellized sugar syrup solution

Balance Tank

↓

Concentration in TFSSHE

↓

Final concentration
(~2.5X original TS including sugar)

↓

Cooling (~10^{0}C)

↓

Addition of dry fruits and nuts

↓

Basundi (Refrigerated Storage ~ 7±2^{0}C)

First the buffalo milk is taken, filtered and standardized to a fat: SNF ratio. It is then preheated to 80^{0}C for few seconds.This preheated milk is mixed with either white crystalline sugar or caramellized sugar syrup solution in the balance tank. Then the steam valves of the steam header and three TFTFSSHEs, which were located at the rear side of three stages TFTFSSHE, are opened manually. The feed pump is then started and flow is varied between 100-200 kg/hr with the help of electromagnetic flow meter by controlling the rpm of feed pump from the control panel. The rotor blade assembly of first and second TFSSHE is switched on and the speed of both

TFSSHE`s are kept between 100 to 175 rpm. Milk is first concentrated in first stage TFSSHE and then enters into the second stage where it is further concentrated. The mass flow rate is approximately so adjusted to get the concentration required in the Basundi. From second stage TFSSHE, the product formed is collected and cooled to 10^0C and then dry fruits were added to it @ 1.5% w/w of the Basundi.

3.5 ANALYTICAL PROCEDURES

3.5.1 Analysis of milk

- Initially the raw milk was tested for fat, SNF and total solids (TS) by using standard methodologies
- The fat content was determined by Gerber method (IS: 1224, 1977).
- SNF content was found out by lactometer.

Total solid (%) = SNF + Fat

3.5.2 Analysis of Basundi

3.5.2.1 Chemical analysis

The Basundi manufactured using three stage TFSSHE by selecting process variables under consideration was analyzed for proximate composition and physico-chemical characteristics.

3.5.2.1.1 Gross Chemical Composition

a) Total Solids

Total solids content of *basundi* was determined by the method recommended by BIS for the milk (IS: SP-18, 1981) with slight modification in quantity of sample taken.

Approximately 3 gm of sample was accurately weighed into an aluminium dish. Then the dish was placed on a boiling water bath for about 60 min. with careful stirring of mixture. Then the bottom of the dish was wiped and transferred into hot air oven maintained at 102 ± 1^0C for 1.5 h. After complete drying, the dish was removed, placed in an efficient desiccator, allowed to cool and weighed. The process of heating, cooling and weighing was repeated till consecutive weights agreed to within 0.5 mg.

TS (%, by mass) = 100 X $(W_3-W_1)/(W_2-W_1)$

where,

W_1 = weight of dish with glass rod (g)

W_2 = weight of dish with *basundi* before drying (g)

W_3 = weight of dish with *basundi* residues after drying (g)

b) Fat

Fat in milk and cream was determined by Gerber method as described in IS: 1479, Part I (1960).

Fat percentage in *Basundi* was estimated by Mojonnier method (IS: SP-18, 1981) with slight modification in the quantity of sample taken. The procedure in brief is as follows:

About 1 gm of sample was accurately weighed into a small beaker followed by addition of 1 ml of conc. ammonia and swirled gently for dispersion. With 10 ml of alcohol, the above contents were transferred to the mojonnier fat extraction apparatus. Diethyl ether (25 ml) was added and shaken vigorously for one minute followed by addition of 25 ml of petroleum ether (40-60^{0}C) with repeated vigorous shaking. The mojonnier tube contents were allowed to settle for 15 min. The ethereal layer was decanted into a pre-weighed dish along with the few pumice stones. The extraction of aqueous layer was repeated twice using 30 ml ether mixture (1:1). The solvent in the dish was evaporated on steam bath and residual fat was further dried in the oven at 100 ± 1^0C for 1 hr followed by cooling in desiccator and then weighed. Fat percentage was calculated as follows:

Fat (%, by mass) = W_2 x $100/W_1$

where, W_1 = weight of sample (g)

W_2 = weight of fat residue after drying (g)

c) Sucrose

Sucrose content of *Basundi* sample was determined as per BIS procedure (IS: SP-18, 1981) for condensed milk. A well mixed sample of *basundi* was accurately weighed (40 g) followed by addition of hot water at 80-90^{0}C. The contents were mixed thoroughly and transferred to a 200 ml measuring flask, washing it with distilled water at 60^{0}C, till the volume was 120 to 150 ml. The mixture was cooled to room temperature and 5 ml of dilute ammonia solution was added. Then it was mixed and allowed to stand for 15 min. followed by neutralization with dilute acetic acid. Then 12.5 ml of zinc acetate solution was added followed by addition of 12.5 ml potassium ferrocyanide solution. It was mixed and volume was made to 200 ml mark. Solution was allowed to settle and filtered. This solution was marked as B1. Fifty ml of B1 solution was hydrolyzed with 5 ml of concentrated hydrochloric acid by heating at 68^{0}C for 5 min. Hydrolyzed solution was cooled and neutralized with sodium hydroxide solution. Then the volume was made up to 100 ml. This solution was marked as A1. The solution A1 and B1 were diluted to such a concentration that volume required to react with 10 ml of Fehlings' solution was between 15 to 50 ml. These solutions were marked as A2 and B2 respectively. These solutions were filled in the burette and titrated against a mixture of 5 ml each of Fehling's- A and Fehling's- B solutions in boiling conditions using methylene blue as an indicator. The titre values were noted down to compute the sucrose content of *Basundi* sample. The sucrose content of *basundi* samples was calculated using following formula:

Sucrose (%, by mass) = $20\ m/M \times (2f_2/v2 - f_1/v_1) \times 0.95$

where,

m = mass in mg of invert sugar corresponding to 10 ml of Fehlings' solution

M = mass in g of materials taken for determination

f_2 = dilution factor for solution A2 from A1

v_2 = volume in ml of A2 corresponding to 10 ml Fehlings' solution

f_1 = dilution factor for solution B2 from B1

v_1 = volume of B2 corresponding to 10 ml Fehlings' solution

d) Solids-not-fat (SNF)

For SNF content of milk aand skim milk samples, they wer tempered at 29^{0}C, and determined by using BIS lactometer (IS: 10083, 1982).The following formula was used for calculating SNF:

$$\text{Per cent SNF} = 0.25F + CLR/4 + 0.44$$

where, F= fat percent of sample and CLR = corrected lactometer reading

3.5.2.1.2 Physico-chemical Characteristics

a) pH

The pH of *basundi* samples was determined at 25^{0}C by potentiometric method using a digital pH meter. The electrode assembly was calibrated against pH 7.0 and pH 4.0. Approximately, sample of 100 g was taken in clean 100 ml beakers and electrode was inserted into the sample. Two to three readings were taken to eliminate the error.

b) Acidity

Approximately, 10 gm of well mixed sample was weighed into 100 ml porcelain dish; 10 ml of hot distilled water was added to it followed by addition of few drops of 0.5% phenolphthalein indicator. Contents were mixed well with a glass rod and titrated against 0.1 N NaOH with continuous stirring till a faint pink color persisting for 30 sec. appeared. Average of two consecutive readings was taken for calculating the acidity. Acidity was expressed as % lactic acid.

$$\text{Acidity (\%)} = V/W \times 0.9$$

Where, V = volume of NaOH used (ml) and

W = weight of *basundi* sample taken (g).

c) Specific gravity

Specific gravity of *basundi* sample was determined at 30^0C using a specific gravity bottle according to method described by Ling (1956).

d) Viscosity

The viscosity of milk and Basundi samples was dtermined using Contrave's RHEOMAT RM-108 E/R viscometer. Viscosity was measured by single point measurement mode with the following paarameters.

Sample temperature	25^0C
Time Interval	30 sec
Shear rate	280/S
Measuring system	1, 1
Mode	11
Measuring tube	1 (Φ=32.54 mm)
Measuring bob	1(Φ=30 mm, 1=45 mm)

Samples were tempered to 25^0C and filled in the measuring tube.The machine was run with the above parameters and the dynamic viscositywas noted after 30 sec.

e) Color Characteristics

Colour characteristics of Basundi were measured by Color Flex instrument.

3.5.2.2.1 Sensory evaluation

The Basundi made from fresh standardized buffalo milk have typical sensory attributes, which depends on the process variables under study, viz., type of sugar, rotor rpm, and mass flow rate. The Basundi samples were subjected for sensory evaluation by a panel of 5-7 judges selected from Dairy Technology and Dairy Engg. Division. A 100-point descriptive scale was used (Appendix I) for sensory attributes like Flavour, Body & Texture and Colour & Appearance.

3.6 TECHNICAL PROGRAMME

PROCESS VARIABLES USED

There are various process variables of three stage scraped surface heat exchanger that were selected for designed research project under study for manufacture of Basundi :---

Mass flow rate : 125 – 200kg / hr

I^st Stage TFSSHE

Pressure : 1.5 kg/cm^2

No. of Blades : 4

Blade Speed : 1.968 m/s (100 rpm), 2.461 m/s (125 rpm), 2.953 m/s (150 rpm), 3.445 m/s (175 rpm)

II^nd Stage TFSSHE

Pressure : 1.5 kg/cm^2

No. of Blades : 4

RPM : 1.968 m/s (100 rpm), 2.461 m/s (125 rpm), 2.953 m/s (150 rpm), 3.445 m/s (175 rpm)

Type of sugar : White crystalline sugar, caramellized sugar syrup solution

The quality of Basundi so produced was evaluated in terms of --

1. Proximate composition analysis
2. Physico-chemical analysis
3. Sensory evaluation

PLATE 3.3: FINAL PRODUCT BASUNDI PREPARED BY USING THREE STAGE THIN FILM SCRAPED SURFACE HEAT EXCHANGER

CHAPTER -4

Results and discussion

4.0 RESULTS AND DISCUSSION

The present study is undertaken to explore the potential of three stage TFSSHE for continuous manufacture of Basundi. Three stage TFSSHE is developed with the state of the art technology by incorporating many processing features as already described in the description of the equipment. It is basically developed for continuous manufacture of Khoa where milk is concentrated in the first stage around 30% TS and further concentrated to around 60-63% TS in the second stage. In third stage rotor is having two fixed scraper blades and two skewed blades and is rotated at low speed in the range of 20-40 rpm. This stage which is having poor thermal efficiency provides suitable body and texture to the final product. In order to evaluate its performance for Basundi making third stage of TFSSHE was not used as two stages were enough to provide required consistency to the product.

Various parameters required to be optimized are the rotor speeds and the steam pressures of the first and the second stage and the mass flow rate. In order to minimize the number of trials the steam pressure of first and second was fixed at 1.5 kg/cm^2 to get final product of consistency in the range of 50±1% TS. Results obtained from different sets of experiments carried out according to the objectives mentioned above and following the procedure described in Chapter-3, have been presented in the following pages under following headings:

1. Effect of scraper speed on the flow rate
2. Effect of type of sugar on the quality of Basundi
3. Effect of scrapper blade speed on quality of Basundi
4. Comparison between the Conventional batch process Basundi and the Basundi made by three stage TFSSHE

The results obtained during the course of investigation are presented and discussed as follows:

4.1 EFFECT OF SCRAPER BLADE SPEED ON THE FLOW RATE

One of the primary objective of the study was to establish a flow rate to get the final concentration of Basundi 50±1%TS at different scraper blade speed under the condition that the steam pressure kept constant @1.5 kg/cm^2.

With the intension to see the effect of different scraper blade speed in the TFSSHE viz. 1.968 m/s (100), 2.461 m/s (125), 2.953 m/s (150) and 3.445 m/s (175) rpm on flow rate of the milk so as to maintain the final concentration of the Basundi 50±1% TS trials have been done. Table 4.1 shows the effect of variation of scraper blade speed on the mass flow rate for getting fixed concentration of the product .It is observed from the table that with increase in scraper blade speed the flow rate is to be increased to get the final product of same concentration i.e. 50±1% TS. As evident that increase in scraper blade speed increases the rate of heat transfer and thus evaporation rate at constant steam pressure. In order to compensate increased heat transfer rate, the mass flow rate is consequently increased to get final product of fixed concentration. Abhichandani et al. (1985) has also shown the same results.

4.2 EFFECT OF TYPE OF SUGAR ON THE QUALITY OF BASUNDI

With the objective of getting Basundi having desired characteristics, investigation was done and trials were taken by using two forms of sugar.The Basundi made by adding the two types of sugar were tested and the effect of type of sugar on properties of Basundi were recorded and the data so obtained were statistically analysed using two sample t-test with the help of SYSTAT software.

4.2.1 Effect on the sensory attributes of Basundi:

Table 4.2 shows the sensory score of Basundi with different kind of sugar and with different scrapper blade speed during manufacture of Basundi.Data indicated that the type of sugar has very little effect on the body and texture but gave significant effect on the flavour , colour and appearance and hence the total score.

TABLE 4.1: Effect of Scraper Blade Speed on the Flow Rate of Initial Milk to Keep Final Concentration Constant

TFSSHE1-scraper speed m/s (rpm)	TFSSHE2-scraper speed m/s (rpm)	Flow Rate (Kg/hr)	Total solids (%w/w)
1.968 m/s (100)	1.968 m/s (100)	125	50.13
	2.461 m/s (125)	150	50.25
	2.953 m/s (150)	165	50.05
	3.445 m/s (175)	170	50.0
2.461 m/s (125)	1.968 m/s (100)	152	49.0
	2.461 m/s (125)	164	50.25
	2.953 m/s (150)	169	50.5
	3.445 m/s (175)	175	49.54
2.953 m/s (150)	1.968 m/s (100)	168	50.2
	2.461 m/s (125)	171	49.5
	2.953 m/s (150)	177	50.5
	3.445 m/s (175)	180	50
3.445 m/s (175)	1.968 m/s (100)	170	49.5
	2.461 m/s (125)	174	50.0
	2.953 m/s (150)	178	50.9
	3.445 m/s (175)	185	49.1

TABLE 4.2: Effect of Type of Sugar on Sensory Attributes of Basundi

TFSSHE1 RPM	TFSSHE2 RPM	Flavour (45)		Body and texture(35)		Colour and appearance (15)		Total score (100))	
		WCS	CSSS	WCS	CSSS	WCS	CSSS	WCS	CSSS
100	100	35.25	42	27.12	29	10.5	13.5	77.87	87.5
100	125	35.1	42.5	27.5	30.5	10.25	13.5	77.85	89.5
100	150	33.2	41	27.1	28	10.75	14	76.05	86
100	175	32.5	39	23.15	24	10.8	13	71	79
125	100	35.5	43.4	28.25	32	11.5	14	79.25	93.4
125	125	35.7	**43.9**	28.5	**33**	11.75	**14**	79.95	**94.9**
125	150	35.2	42.1	28.1	31	12	14	80.03	91.1
125	175	32.25	38.1	23	23	11.25	14	71.5	79.5
150	100	35.2	42	27.5	30.2	12	14	79.7	90.2
150	125	35.5	42.5	27.53	30.5	12	13.5	80.03	90.5
150	150	35	41.2	26.5	28.1	11.75	13.5	78.25	86.8
150	175	32.1	38	22.7	23.6	11.5	14	71.3	78.6
175	100	34.5	40.5	24.2	24.5	10.75	14	74.45	82
175	125	34.25	39.7	24	24.2	10.73	13.5	73.98	80.4
175	150	34.52	39.2	23.75	23.5	10.62	13.5	72.89	79.2
175	175	32.12	37	22.79	23	10.57	13	70.59	76

(WCS-White crystalline sugar, CSSS- Caremelized sugar syrup solution)

TABLE 4.3: Two sample t-test on sensory attributes of Basundi grouped by sugar type

T- Value	Flavour	Body & Texture	Colour & Appearance	Overall Acceptability
t-calculated	10.616*	1.558	14.201*	5.331*
t-tabulated	1.661	1.661	1.661	1.661

*(5% level of significance)

4.2.1.1 Effect on the flavour:

The type of sugar has significant effect on the flavour of Basundi. Basundi made by using caramelized sugar syrup solution has desired caramel and nutty flavour while the Basundi made by using white crystalline sugar lacks this sensory attribute.The data obtained from sensory panel were recorded and were statistically analysed using two sample t-test (table 4.3).It was observed that type of sugar has significant effect on the flavour.Basundi prepared by using caramelized sugar syrup solution has mean sensory score of **40.756 ± 2.058SD** while white crystalline sugar has mean sensory score of **34.243 ± 1.336SD**.

4.2.1.2 Effect on the body and texture:

The type of sugar has little effect on the body and texture of Basundi. Basundi made by using caramelized sugar syrup solution has similar body and texture as compared to Basundi made by using white crystalline sugar.The data obtained from sensory panel were recorded and were statistically analysed using two sample t-test.It was observed that type of sugar has no significant effect on the body and texture (table 4.3). Basundi prepared by using caramelized sugar syrup solution has mean sensory score of **27.381 ± 3.601SD** while white crystalline sugar has mean sensory score of **25.731 ± 2.232SD**.

4.2.1.3 Effect on the colour and appearance:

The type of sugar has pronounced effect on the colour and appearance of Basundi. Basundi made by using caramelized sugar syrup solution has caramel colour while Basundi made by using white crystalline sugar has dull white with greenish tinge colour.The data obtained from sensory panel were recorded and were statistically analysed using two sample t-test(table 4.3).It was observed that the colour and appearance of Basundi differ significantily Basundi prepared by using caramelized sugar syrup solution has mean sensory score of **13.688 ± 2.058SD** while white crystalline sugar has mean sensory score of **11.170 ± 1.336SD.**

4.2.1.4 Effect on the overall acceptability:

The type of sugar remarkedly influenced the overall acceptability of Basundi. Basundi made by using caramelized sugar syrup solution has a high level of overall acceptability with mean value **85.287 ± 6.025 SD** while Basundi made by using white crystalline sugar has low consumer acceptability with mean value **75 ± 3.624 SD**.The data obtained from sensory panel were recorded and were statistically analysed using two sample t-test (table 4.3).It was observed that sensory score obtained for Basundi made by using two types of sugar vary significantily.

4.2.2 Effect on proximate composition of Basundi:

Table 4.4 shows the proximate composition of Basundi with different kind of sugar and with different scrapper blade speed during manufacture of Basundi.Data indicated that the type of sugar has very little effect on the proximate composition viz. fat, SNF, Sucrose, total solids, of Basundi.

4.2.2.1 Effect on the fat%:

The type of sugar has no effect on the fat percentage of Basundi.The data obtained from chemical analysis were recorded and were statistically analysed using two sample t-test (table 4.5). Basundi prepared by using caramelized sugar syrup solution has mean fat% of **13.826 ± 0.112SD** while white crystalline sugar has mean fat% of **13.811 ± 0.149SD**.

TABLE 4.4: Effect of type of sugar on proximate composition of Basundi

TFSSHE1 RPM	TFSSHE2 RPM	Fat %		SNF%		Sucrose %		Total Solids %		FAT/SNF ratio	
		WCS	CSSS	WCS	CSSS	WCS	CSSS	WCS	CSSS	WCS	CSSS
100	100	14.13	13.98	23.55	22.55	12.45	13.66	50.13	50.19	0.6	0.62
100	125	13.98	13.65	23.3	22.75	12.97	13.1	50.25	49.5	0.6	0.6
100	150	13.64	13.73	22.36	22.51	14.05	13.89	50.05	50.13	0.61	0.61
100	175	13.7	13.82	22.46	22.66	13.84	13.79	50	50.27	0.61	0.61
125	100	13.62	13.94	21.97	23.23	13.41	13.12	49	50.29	0.62	0.6
125	125	13.82	13.98	23.03	23.3	13.4	13.45	50.25	50.73	0.6	0.6
125	150	13.92	13.82	22.82	22.66	13.76	13.87	50.5	50.35	0.61	0.61
125	175	13.65	13.79	22.75	22.98	13.14	13.46	49.54	50.23	0.6	0.6
150	100	13.81	13.68	22.27	22.8	14.12	13.65	50.2	50.13	0.62	0.6
150	125	13.63	13.74	22.34	22.52	13.53	13.03	49.5	49.29	0.61	0.61
150	150	13.94	13.85	22.85	23.08	13.71	13.32	50.5	50.25	0.61	0.6
150	175	13.9	13.91	23.17	22.44	12.93	13.14	50	49.49	0.6	0.62
175	100	13.78	13.98	22.59	22.92	13.13	13.31	49.5	50.21	0.61	0.61
175	125	13.85	13.68	23.08	22.06	13.07	13.99	50	49.73	0.6	0.62
175	150	13.92	13.79	23.2	22.24	13.9	13.48	50.9	49.51	0.6	0.62
175	175	13.69	13.88	22.08	23.13	13.33	13.18	49.1	50.19	0.62	0.6

*(WCS-White crystalline sugar, CSSS- Caremelized sugar syrup solution)

TABLE 4.5: Two sample t-test on proximate composition of Basundi grouped by sugar type

T-VALUE	FAT%	SNF%	SUCROSE%	TS%
t-calculated	.322	.004	.314	.410
t-tabulated	1.661	1.661	1.661	1.661

*(5% level of significance)

4.2.2.2 Effect on the SNF%:

The type of sugar has no effect on the SNF percentage of Basundi.The data obtained from chemical analysis were recorded and were statistically analysed using two sample t-test(table 4.5). Basundi prepared by using caramelized sugar syrup solution has mean SNF% of **22.739 ± 0.353SD** while white crystalline sugar has mean SNF% of **22.739 ± 0.465SD**.

4.2.2.3 Effect on the Sucrose%:

The type of sugar has no effect on the sucrose percentage of Basundi.The data obtained from chemical analysis were recorded and were statistically analysed using two sample t-test(table 4.5). Basundi prepared by using caramelized sugar syrup solution has mean sucrose% of **13.465 ± 0.313SD** while white crystalline sugar has mean sucrose% of **13.421 ± 0.461SD**.

4.2.2.4 Effect on the TS%:

The type of sugar has no significant effect on the total solid percentage of Basundi.The data obtained from chemical analysis were recorded and were statistically analysed using two sample t-test (table 4.5). Basundi prepared by using caramelized sugar syrup solution has mean TS% of **50.031 ± 0.399SD** while white crystalline sugar has mean TS% of **49.964 ± 0.516SD**.

4.2.2.5 Effect on the FAT: SNF ratio:

The type of sugar has no significant effect on the FAT: SNF ratio of Basundi.The data obtained from calculation were recorded and were statistically analysed using two sample t-test (table 4.5). Basundi prepared by using caramelized sugar syrup solution has mean FAT: SNF ratio of **0.608 ± 0.008SD** while white crystalline sugar has mean FAT: SNF ratio of **0.607 ± 0.008SD.**

4.2.3 Effect on Physico-chemical characteristics of Basundi

The table 4.6 shows that the type of sugar does not have any significant effect on the acidity, specific gravity and viscosity (5% level of significance).

TABLE 4.6: Two sample t-test on physico-chemical characteristics of Basundi grouped by sugar type

T- VALUE	ACIDITY	SPECIFIC GRAVITY	VISCOSITY
t-calculated	1.091	.350	-0.343
t-tabulated	1.661	1.661	1.661

*(5% level of significance)

The mean acidity % L.A. for caramelized sugar syrup Basundi was **0.463 ± 0.008 SD** while for white crystalline sugar Basundi it was **0.459 ± 0.011SD**.

The mean specific gravity for caramelized sugar syrup Basundi was **1.121 ± 0.006 SD** while for white crystalline sugar Basundi it was **1.120 ± 0.005 SD**.

The mean viscosity for caramelized sugar syrup Basundi was **149.58 mPa.s ± 64.174 SD** while for white crystalline sugar Basundi it was **158.137mPa.s ± 76.338 SD**.

4.2.4 Effect on Colour characteristics of Basundi

The colour characteristics were measured by using the instrument Colorflex.The result obtained from this instrument gives three values in term of **L***, **a*** and **b***.

L* value represents degree of whiteness.It varies from 0 (black) to 100 (white). A positive **a*** value represents degree of redness while negative **a*** represents degree of greeness. Positive **b*** value gives the degree of yellowness while negative **b*** value gives degree of blueness.

The colour characteristics of Basundi significantily vary for two types of sugar.The mean values of **L***, **a*** and **b***, so obtained during study for white crystalline sugar Basundi and the caramelized sugar syrup solution Basundi is given in the table 4.7

TABLE 4.7 Mean Colour Characteristics of two types Basundi

Type of Sugar	L*	a*	b*
White crystalline sugar	88.21	-2.02	12.613
Caramelized sugar syrup solution	76.87	0.69	19.86

4.3 EFFECT OF THE SCRAPER BLADE SPEED ON THE BASUNDI

With the objective of getting Basundi having desired characteristics investigation was done and trials were conducted, keeping four different scraper blade speeds in the first and second TFSSHE.So there were a total 16 combination using four different scaper blade speed. The four set of scraper blade speed were 1.968 m/s (100), 125, 2.953 m/s (150) & 3.445 m/s (175). The Basundi made by taking different sets of scraper blade speed were tested and the effect of blade speed on the quality of Basundi was recorded and the data so obtained were statistically analysed by using two-way ANOVA using MS EXCEL software.

4.3.1 Effect on the sensory attributes of Basundi

The table 4.8 shows the values of Fratio obtained while performing the two-way ANOVA based on the sensory score.

TABLE4.8: F ratio obtained during statistical analysis (two-way ANOVA, 95% level confidence)

ATTRIBUTE	*FLAVOUR*		*BODY & TEXTURE*		*COLOUR & APPEARANCE*		*OVERALL ACCEPTABILITY*		*F CRITICAL*
SUGAR TYPE	**WCS**	**CSSS**	**WCS**	**CSSS**	**WCS**	**CSSS**	**WCS**	**CSSS**	
TFSSHE1RPM	**17.9***	**17.5***	**9.6***	**9.02***	**.78**	**2.2**	**10.77***	**17.96***	**3.6825**
TFSSHE2RPM	**22.7***	**41.6***	**17.1***	**10.4***	**.6762**	**1**	**24.51***	**22.75***	**3.6825**

It can be observed from the table 4.8 that the scraper blade speed has a significant effect on flavour, body & texture & overall acceptability while it does not have significant effect on the colour and appearance.

4.3.1.1 Effect on the Flavour:

Figure 4.1 and Figure 4.2 has been plotted to see the effect of scraper blade speed on the flavour score for Basundi prepared by white crystalline sugar (WCS) and caramelized sugar syrup solution (CSSS), respectively.It can be analysed from the graph that flavour score significantily started to decrease when the scraper blade speed increased above 2.953 m/s (150) rpm.The increase in the scraper blade speed resulted in the development of metallic flavour.The maximum flavour score of **43.9** was obtained by keeping both the scraper blade speed at 2.461 m/s (125) rpm.

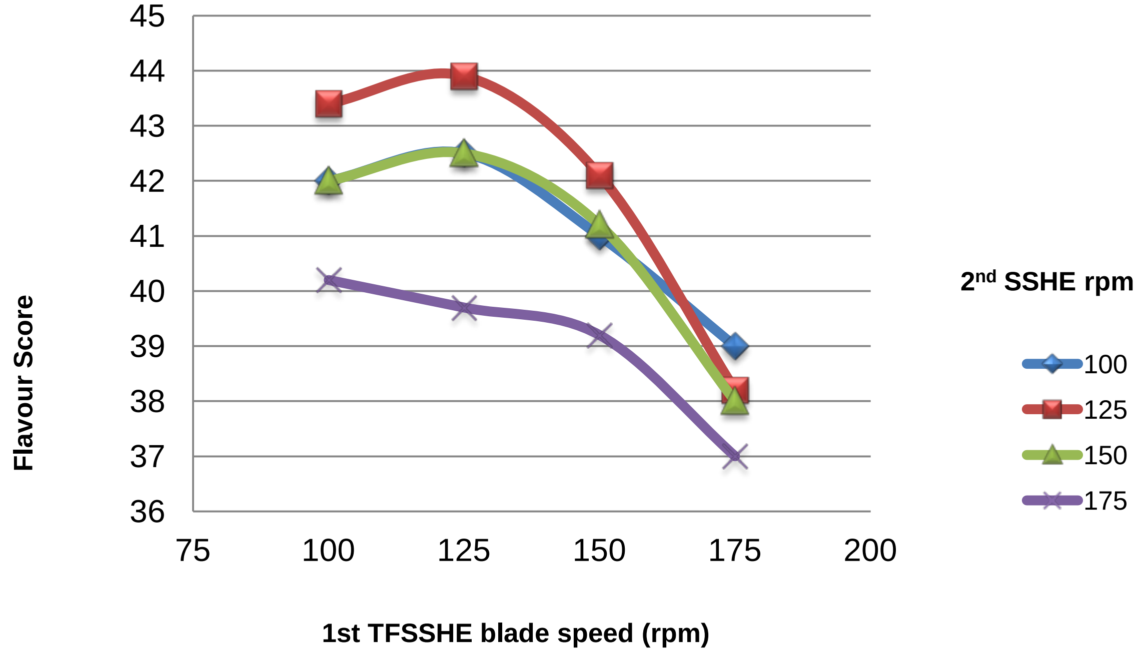

FIGURE 4.1 Effect of Blade speed on flavour(CSSS)

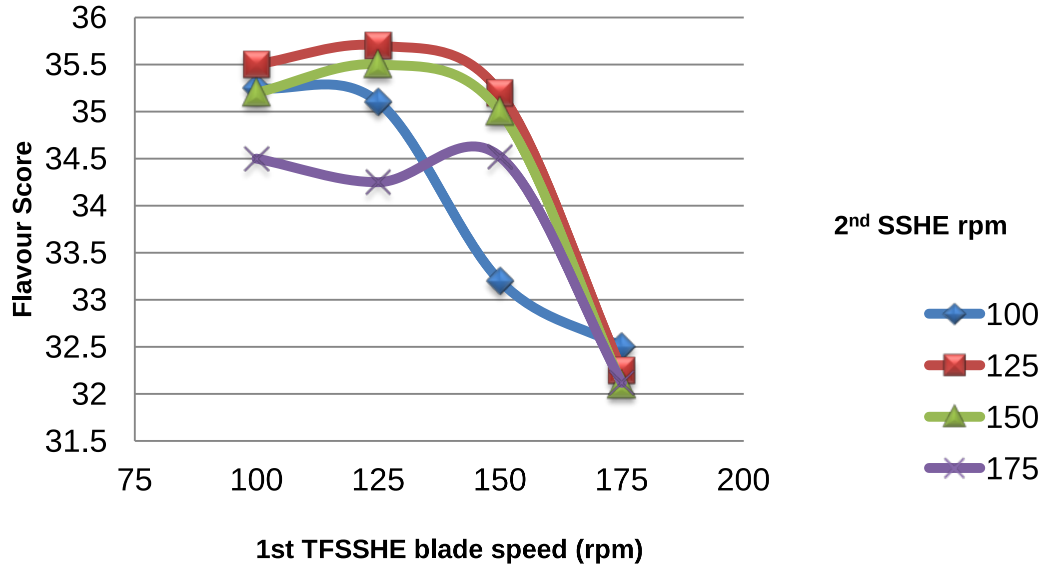

FIGURE4.2 Effect of Blade Speed Flavour(WCS)

4.3.1.2 Effect on the Body and texture

Figure 4.3 and Figure 4.4 has been plotted to see the effect of scraper blade speed on the body and texture score for Basundi prepared by white crystalline sugar (WCS) and caramelized sugar syrup solution (CSSS), respectively.It can be analysed from the graph that body and texture score significantily started to decrease when the scraper blade speed increased above 2.953 m/s (150) rpm.The increase in the scraper blade speed resulted in the denaturationof milk protein which resulted in the powdery body and texture.The maximum sensory score for body and texture was obtained by keeping both the scraper blade speed at 2.461 m/s (125) rpm.

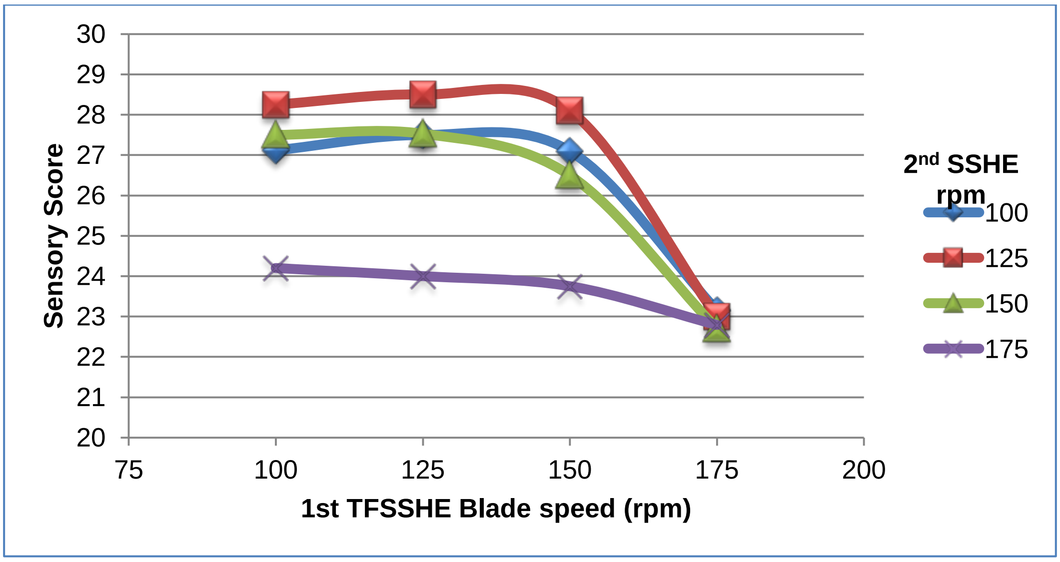

FIGURE 4.3: Effect on Body and Texture (WCS)

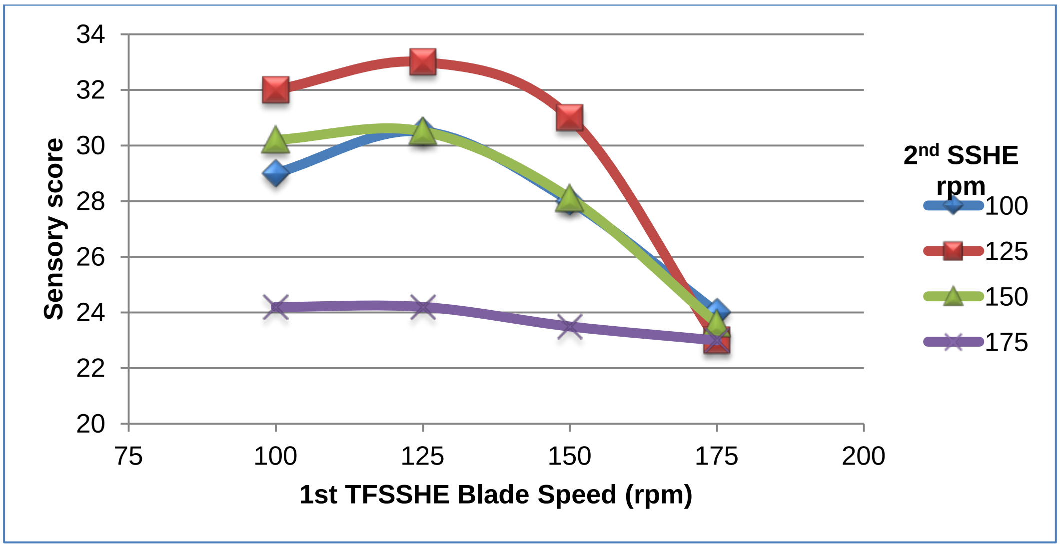

FIGURE 4.4: Effect on Body and Texture (CSSS)

4.3.1.3 Effect on the Colour and Appearance

The scraper blade speed has not any singificant effect on the colour and appearance of Basundi.

4.3.1.4 Effect on the Overall acceptability

Figure 4.5 and Figure 4.6 has been plotted to see the effect of scraper blade speed on the total sensory score for Basundi prepared by white crystalline sugar (WCS) and caramelized sugar syrup solution (CSSS), respectively.Summing up all the sensory attributes and analysing this graph it can be concluded that overall acceptability significantily started to decrease when the scraper blade speed increased above 2.953 m/s (150) rpm.The best overall acceptability was obtained by keeping both the scraper blade speed at 2.461 m/s (125) rpm.

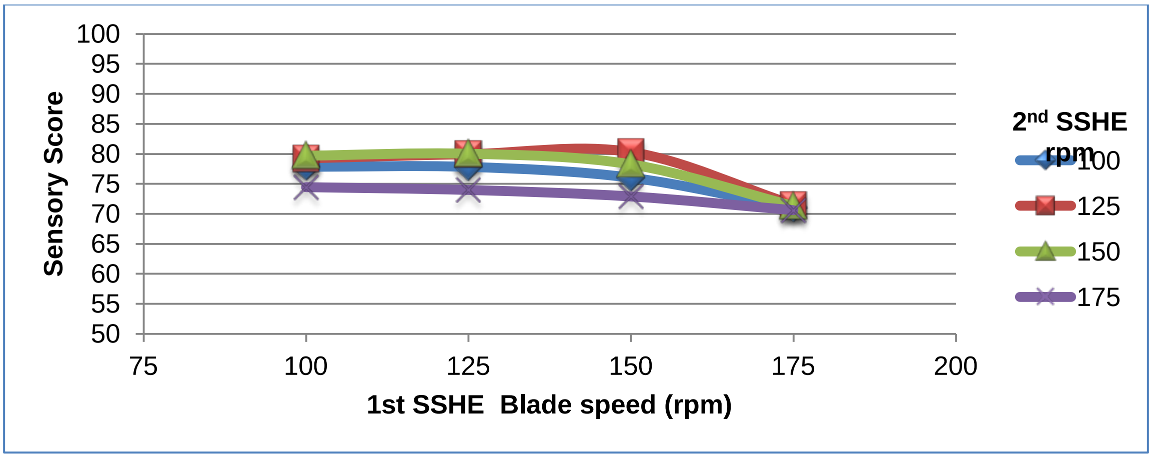

FIGURE 4.5: Effect on Overall acceptability (WCS)

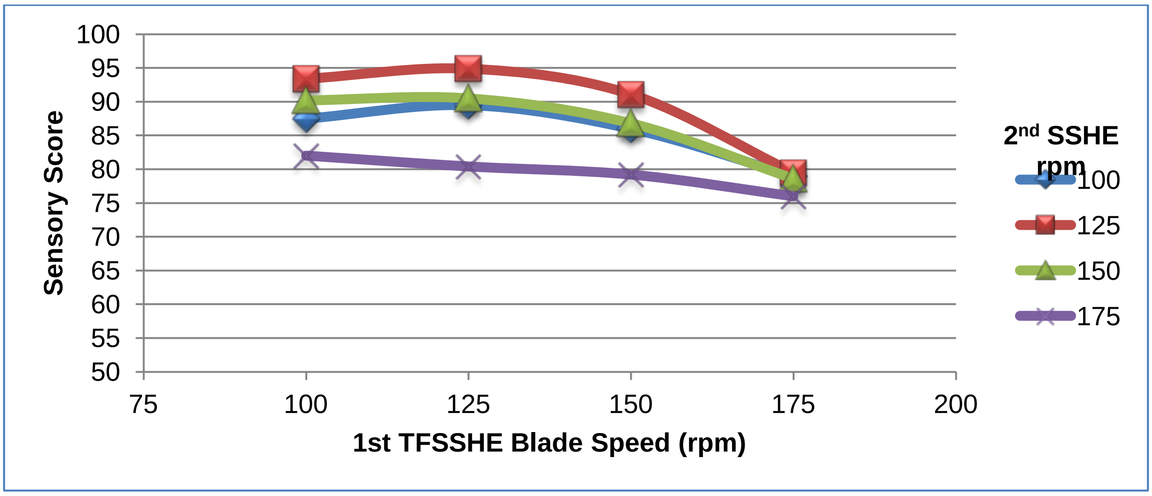

FIGURE 4.6: Effect on overall acceptability (CSSS)

4.3.2 Effect on proximate composition of Basundi

The table 4.9 shows the values of Fratio obtained while performing the two-way ANOVA based on the proximate composition analysis.

Table 4.9: F ratio obtained during statistical analysis (two-way ANOVA, 95% level of confidence)

ATTRIBUTE	***FAT %***		***SNF %***		***SUCROSE %***		***TS %***		***FAT:SNF***		***F CRITICAL***
SUGAR TYPE	***WCS***	***CSSS***	***WCS***	***CSSS***	***WCS***	***CSSS***	***WCS***	***CSSS***	***WCS***	***CSSS***	
TFSSHE1 RPM	***0.26***	***0.49***	***0.21***	***1.33***	***0.21***	***0.59***	***0.33***	***2.02***	***0.23***	***0.81***	***3.6825***
TFSSHE2 RPM	***0.36***	***0.97***	***0.35***	***0.43***	***1.49***	***0.46***	***2.55***	***0.76***	***0.92***	***.069***	***3.6825***

It can be observed from the table 4.8 that the scraper blade speeds do not have any significant effect on the proximate composition of the Basundi.

4.3.3 Effect on physico-chemical characteristics of Basundi

The table 4.10 shows the values of F ratio obtained while performing the two-way ANOVA based on the results obtained while performing physico-chemical analysis.

TABLE 4.10 F ratio obtained during statistical analysis (two-way ANOVA, 95% level of confidence)

ATTRIBUTE	**ACIDITY**		**PH**		**SPECIFIC GRAVITY**		**VISCOSITY**		**F CRITICAL**
SUGAR TYPE	**WCS**	**CSSS**	**WCS**	**CSSS**	**WCS**	**CSSS**	**WCS**	**CSSS**	
TFSSHE1RPM	**.529**	**1.577**	**2.89**	**2.074**	**2.68**	**2.96**	**66.63***	**96.75***	**3.6825**
TFSSHE 2RPM	**2.41**	**.092**	**2.6**	**.101**	**2.34**	**.56**	**59.44***	**120.57***	**3.6825**

It can be observed from the table 4.9 that scraper blade has significant effect on the viscosity while on other physico-chemical characteristics the effect was not significant.

4.3.3.1 Effect on the viscosity

Figure 4.7 and Figure 4.8 has been plotted to see the effect of scraper blade speed on the viscosity for Basundi prepared by white crystalline sugar (WCS) and caramelized sugar syrup solution (CSSS), respectively. It can be observed from these graphs that viscosity increased significantily on increasing the scraper blade speed.This increase in viscosity is due to the denatuartion of milk protein at high scraper blade speed.The optimum viscosity was obtained by keeping the scraper blade speed below 2.953 m/s (150) rpm.

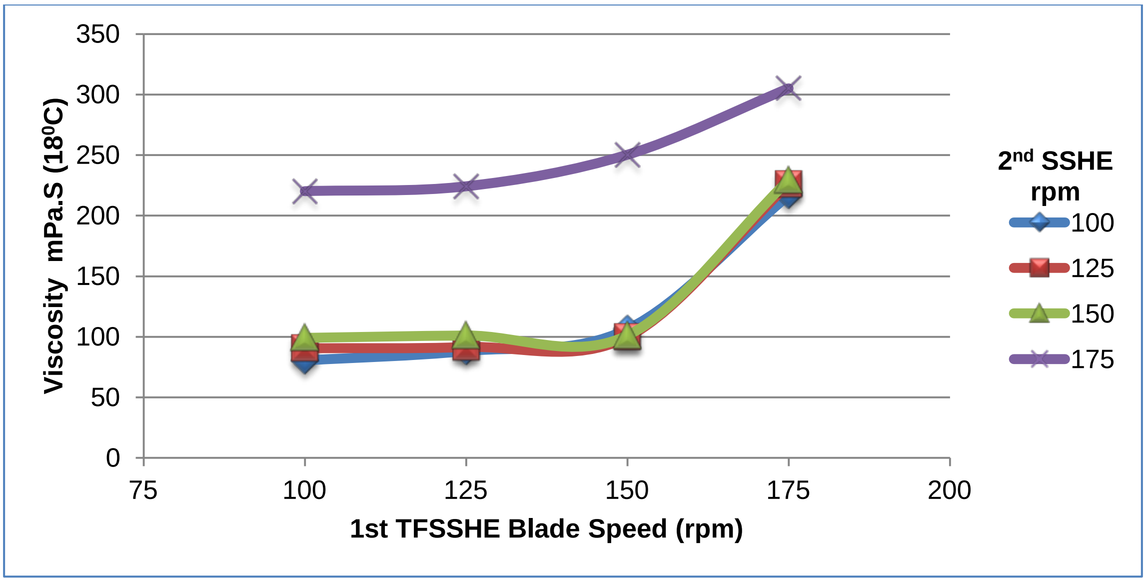

FIGURE 4.7: Effect on Viscosity (WCS)

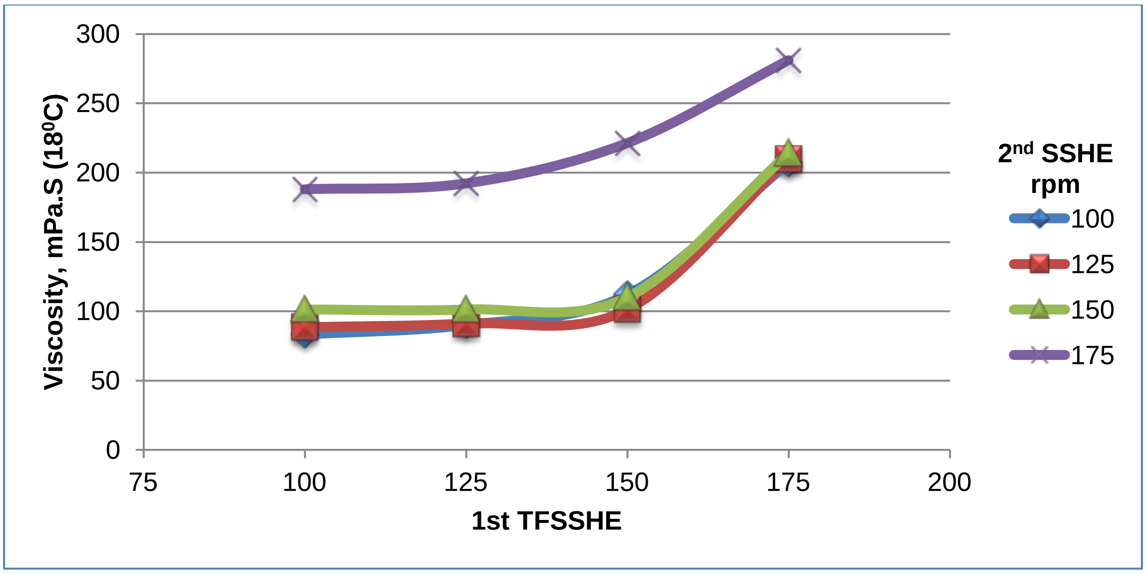

FIGURE 4.8: Effect on Viscosity (CSSS)

4.4 COMPARISON BETWEEN THE CONVENTIONAL BATCH PROCESS BASUNDI AND THE BASUNDI MADE BY THREE STAGE TFSSHE

As discussed previously different combinations of scraper blade speed with differerent types of sugar were undertaken to get the best possible Basundi out of TFSSHE. The result obtained while perfoming statistical analysis based on the sensory score, proximate composition analysis and physico-chemical analysis concluded that the best possible combination for preparing Basundi was as follows:

- TFSSHE1 scraper blade speed: 2.461 m/s (125)rpm
- TFSSHE2 scraper blade speed: 2.461 m/s (125)rpm
- Type of sugar : Caramelized sugar syrup solution
- Steam pressure :1.5 kg/cm^2(both TFSSHE)
- Flow rate :165 kg/hr

The Basundi prepared by best possible combination of operating parameters in TFSSHE has been compared with the Basundi prepared by conventional process in the table 4.11, 4.12 and 4.13.It was analysed that the proximate composition and physico-chemical characteristics of both types of Basundi were almost similar.

TABLE 4.11: Comparison based on proximate composition

ATTRIBUTE	CONVENTIONAL PROCESS	TFSSHE PROCESS
FAT, %	13.93	13.98
SNF, %	23.00	23.3
SUCROSE, %	13.06	13.45
TOTAL SOLIDS, %	50.19	50.73

TABLE 4.12: Comparison based on physico-chemical characteristics

ATTRIBUTE	CONVENTIONAL PROCESS	TFSSHE PROCESS
FAT TO SNF RATIO	0.61	0.60
ACIDITY, % LA	0.45	0.45
pH	6.57	6.5
SPECIFIC GRAVITY (200C)	1.12	1.121
VISCOSITY, mPa.s (18^0C)	91.33	91.31

It can also be analysed from the table 4.13 that Basundi prepared by conventional batch process had slightly better body and texture as compared to the Basundi prepared in TFSSHE.The other sensory attributes like flavour and colour & appearance was better in slightly better in case of Basundi prepared in TFSSHE.

TABLE 4.13: Comparison based on Sensory Evaluation

SENSORY ATTRIBUTES	CONVENTIONAL PROCESS	TFSSHE PROCESS
Flavour(45)	42.01	43.9
Body & Texture (35)	33.5	33
Colour & Appearance(15)	13.5	14
Total score (100)	94.1	95.9

So it can be concluded that Basundi prepared in TFSSHE was having similar quality as compared to Basundi prepared by conventional process.

The batch process almost takes an hour to prepare Basundi from 6 kg of milk while TFSSHE can process 165 kg/hr of milk for preparing Basundi.

CHAPTER -5

Summary and conclusions

5.0 SUMMARY AND CONCLUSION

Basundi is a traditional heat desiccated milk delicacy having sweetish caramel and pleasant aroma, light to medium brown in colour, thick body and creamy consistency with soft textured flakes that are uniformly suspended throughout the product. It contains all the solids of milk in an appropriate concentration plus additional sugar and dry fruits and nuts.

The traditional method for Basundi preparation is more time consuming and energy intensive. Basundi prepared by traditional method has low shelf-life and poor quality.The demand for efficient and labor saving processing of Basundi in dairy industry attracts the application of continuous processing methods. The commercial large scale production of Basundi with very good sensory properties has necessitated sincere efforts in the developing suitable equipment for manufacturing Basundi. Scraped surface heat exchanger (SSHE) is the most suitable heat exchanger for handling high viscosity and heat sensitive products, which tend to foam and foul heat transfer surface. Looking to the performance characteristics of thin film scraped surface heat exchanger; it can be used for manufacture of Basundi. Recently three stage TFSSHE has been designed and fabricated with state of art technology by incorporating various processing parameters.

In light of above facts, it was planned to investigate the feasiblity for manufacture of Basundi using three stage scraped surface heat exchanger. The investigation was carried out to optmize the various process parameters to get the best quality of Basundi. There are various process variables of three stage scraped surface heat exchanger that were elected for designed research project under study for manufacture of Basundi.The mass flow rate was varied between125 to 200 kg/hr, two types of sugar were used and four level of scraper blade speed were taken in first and second stage i.e. 1.968 m/s (100 rpm), 2.461 m/s (125 rpm), 2.953 m/s (150 rpm) and 3.445 m/s (175 rpm).The third stage SSHE was not used for Basundi manufacture as two stages gave the product of desired consistency. The quality of

Basundi so produced was evaluated in terms of proximate composition analysis, physico-chemical analysis and sensory evaluation.

The conclusions of the results obtained from different sets of experiments during studies are as follows:

1. Basundi can be successfully processed using three stage thin film scraped surface heat exchanger.

2. Proximate composition analysis, physo-chemical analysis and sensory evaluation analysis reports indicated that Basundi made using three stage TFSSHE was comparable to that made by conventional method.

3. The scrapper blade speed has significant effect on flow rate as well as on the quality of Basundi at constant steam pressure and for constant final product concentration.

4. The Basundi prepared by using Caramelized sugar syrup solution has the desired caramel colour and flavour, and hence overall consumer acceptability.

5. The process parameter optimization study has indicated that the best quality Basundi can be produced by keeping following parameters :

   Mass flow rate = 165 kg / hr

   Ist Stage SSHE Pressure : 1.5 kg/cm^2
   Scraper blade speed: 2.461 m/s (125 rpm)

   2nd Stage SSHE Pressure : 1.5 kg/cm^2
   Scraper blade speed: 2.461 m/s (125 rpm)

   Type of sugar = Caramelized sugar syrup solution

Bibliography

BIBLIOGRAPHY

A.O.A.C. (1975). Official methods of Analysis of the Association of Official Analytical Chemist; Pub. Association of Official Analytical Chemists, Washington, U.S.A.

Abichandani, H. (1985). Heat transfer correlations for mechanically formed thin film heat exchangers. Ph.D. Thesis, Kurukshetra University, Kurukshetra.

Abichandani, H., Dodeja, A.K. and Sarma, S.C.(1996). A unique system for continuous manufacture of ghee and khoa. *Indian Dairyman*, **48**(10): 11-12

Abichandani, H.,Dodeja, A. K. and Sarma, S. C. (1989). Application of thin film scraped surface heat exchangers. *Indian Dairyman*, **41 (**1): 21-24

Abichandani,H.andSarma,S.C.(1988).Heat Transfer and power requirement during concentration of milk and cream in horizontal thin film scraped surface heat exchanger. *Chem.Engg.Sci., 43(4):871-881.*

Abichandani,H.andSarma,S.C.(1989).Power requirement during concentration of milk and cream in horizontal thin film scraped surface heat exchanger. *Indian J. Dairy Sci*., **42**(2):155– 158

Agrawal, S. P., Sawhney, I.K. and Bikram Kumar. (1987). Mechanized Conical Process Vat. Patent No. 165 440.

Agrawal,S.P.,Sawhney,I.K. and Bikram Kumar(1987). Mechanized Conical Process Vat. Patent No.165440

Agrawala, S.P., Sawhney, I.K. and Bikram Kumar (1987) National seminar on ‘Recent Advances in Dairy Processing ‘, April 26-27, 1987

Alam, A.A. 1988. Process Equipment manufacture.Indian Dairyman. **40**:285-290.

Altiokka, M.R. (1992). Power Consumption for Scraped Surface Heat Exchanger with “no-leak” reactor. *Ind. Eng. Chem. Res.*, 31(10):2385-2388

Alvarez, D.S.; Dennasan, M.; Tarodo de La F uente B. (1979): Appliacation of ultra filtration to production of Sweetened condensed milk. Lait, 59(587); 376-386.

Anant Krishnan, C.P. and Kothavalia, Z.R. (1947). Investigation on evaporated buffalo milk, Indian Journal of Veterinary Science, 17(2) ; 105-111.

Aneja R.P. (1991) Dairy Product and Process development under operation flood. Indian Dairyman, 43(2):53-59.

Aneja R.P., Mathur B.N., Chandan R.C. and Banerjee A.K. (2003) Desiccated Milk BasedProducts. In: *Technology of Indian Milk products*, 2003, Ed. P.R. Gupta, Pub. P.R. Gupta, A Dairy India Publication, Delhi, India, pp: 126-127.

Annon(1983). Dictionary of Dairy technology. Intl. Dairy Fed., Elsevier Scientific Publ. Company. P.20.

Annual Report (1965-66). Microbiological studies on indigenous sweetened milk products. Annual Report, N.D.R.I., Karnal, 15.5,12

Anon(1943) Manufacture of condensed milk by open pan method in the Imperial Dairy Research Institute, Banglore. Mon. Bull. Banglore Dairy Cattle Soc.,2(3) 20-21. Cited in Dairy Sci. Abstr.,8;73

APV Nordic Dairy(1999). A new recombined sweetened condensed milk. 3rd International Symposium on recombined milk and milk products. pp -41-42

Arora, J.R. and Bindal,.M.P. (1981) Lipids of Khoa at various stages during its preparation from cow and buffalo milk. Indian Journal of Dairy Science, 34:315

Azoory, S. and Bott, T.R.(1970). Local heat transfer coefficients in a model falling film scraped surface heat exchanger. *Can. J. Chem. Eng*., 48:373-377.

Badshah, J.(1999). Studies on forewarming and evaporation in scraped surface heat exchangers for production of sweetened condensed milk. Ph.D. Thesis, National Dairy Research Institute, Karnal, Haryana.

Bag, S.K.(1994). Influence of machine parameters on quality and type of khoa in continuous khoa making system. M.sc. Thesis, National Dairy Research Institute, Karnal, Haryana.

Bandopadhyay, A.K. and Mathur B.N. (1987),"Indian milk product.A compedium."In Dairy india" 1987 Pub. R.P. Gupta., Rekha Printer Pvt Ltd. Delhi Pp.213, 217.

Banerjee, A.K. (1997). Processes for Commercial Production. Dairy India (5^{th} ed.), pp 387-392.

Banerjee, A.K., Verma, I.S. and Bagchi, B. (1968). Pilot plant for continuous manufacture of Khoa. *Indian Dairyman*, **20**: 81.

Baxi, J.J.(19910. Dairy products mix of Indigenous modern Dairy Industry. Indian Dairyman, 43(2):102-105.

Bector, B.S. (1996). Comparison between batch process and continuous ghee making system using horizontal TFSSHE. *Indian Dairyman*, **26**:78-611.

Bell, R.W. Curan , H.R. and Evan, F.R.(1944) Effects of temperature and time of sterilization upon properties of evaporated milk. Journal of Dairy Research, 27:913.

Bender, V.H.(1972). Journal of Food Technology.7:239. Cited by Gothwal, P.P. and Bhavadasan, M.K.(1992) in "Studies on the browning characteristics in dairy products. Indian Journal of Dairy Science, 45(3): 146-151.

Bhadania, A.G., Shah, B.P. and Shah, U.S. (2004). Effect of heat transfer on physico- chemical and sensory qualities of khoa manufactured using scraped surface heat exchanger. *J. Food Sci. Technol*., **41(**6): 656-660

Bhalerao, V.R. and Iya, K.K.(1964). The chemistry and technology of milk concentration, Journal of Food Science Technology.,1(3):46-53.

Bhanumurthi, J.L.; Trehan, K.S. and Srinivasan, M.R. (1972). Viscosity changes in sweetened condensed full cream buffalo milk during storage. Indian Journal of Dairy Science.,25(3): 164-166.

Bhatacharya, B.C.(1970). Design Characteristics of Mechanically formed Thin Film Evaporation, *Chem.Proc.Equip.Sem*., pp:1-6

Bloore, C.G. and Boag, I.F. (1981) Some factors affecting the viscosity of concentrated skim milk, NZ. Journal of Dairy Science Technology 16(2):143-154

Boghra ,V.R.(1979). Utilization of concentrated and dried milk for khoa making. M.Sc. Thesis submitted to Kurukshetra university, Kurukshetra, India.

Boghra, V.R. and Mathur, O.N.(1996). Physico-chemical status of major milk constituents and mineral at various stages of khoa preparation. Indian Journal of Dairy Science 44(4) 286-292.

Boghra, V.R. and Rajorhia, G.S. (1979). Utilization of concentrated and dried milk for khoa making M.Sc. Thesis No.546, NDRI, Karnal

Boghra, V.R. and Rajorhia, G.S. (1982). Utilization of preconcentrated milk for khoa making. Asian Journal of Dairy Research, 1:6

Boghra, V.R. andRajorhia, G.S. (1982). Utilization of preconcentrated milk for Khoa making. Asian Journal of Dairy Research. 1;6.

Brunner, J.R. (1962) Protein-lipid interections and their relation to the physical-chemical stability of concentrated milk – a review. Journal of Dairy Science, 45(8), 943-951.

Burton, H. (1969) Ultra- high temperature processed milk. Dairy Science Abstract. 31(6):287

Chakraborty, B.K. 1978. Process Innovations in Selected Indian Dairy Products. Indian Dairyman 30(9):619-628.

Chakraborty, M.N. (1978). Method used for concentration of products. Indian Journal of Dairy Science, 42;365

Chetan, S. R. and Richard, W. H. (2006). Scraped surface heat exchangers.Food Sci. Nutrition, 46: 207- 219

Choudhary, P.P. (1989) Related research on concentrated milk products, Indian Journal of Dairy Science, 42:268

Christie, I.S. and Shah, U.S. (1990). Development of a khoa making machine. *Indian Dairyman*, **42**(5): 249-252.

Christie, I.S. and Shah, U.S. (1992). Development of three stage continuous khoa making machine. *Indian Dairyman*, **44**(1): 1-4

Costin,C.M., Rotan, G. and Sas, I. (1973). Effect of heat treatment on nitrogenous substances of ewes milk, Ind. Anim., 24:16. Cited from Dairy Science Abstract., 36; 3665

Couds, A. (1976) The denaturation of food proteins. Literature survey, British food manufacturing Industries Research Association (13):18. Cited in Dairy Sci. Abst. 38; 8191

Craig, J. C.(Jr.), Acets, N.C. and Della Monica, E.S.(1961), Occurance of 5 hydroxy methyl furfural in vacuum foam dried whole milk and its relation to processing and storage. J. Dairy Sci., **44**:1827.

Dalaya, H.M. and Patel, I.M. (1971). The problem of the use of buffalo milk for milk products. Indian Dairyman, 23 (10): 199-202

Dastur, N.N. (1956). Dairy Science Abstract 18;967. Cited by Ganguli, N.C. (1979). “Physico-chemical make up of buffalo milk in the standardization of technique of handling, processing and manufacture of products,” In XIX. Intl. Dairy Congress Proceedings Vol.II, P-358.

Davies, D.T. and White, J.C.D.(1959) Proc.XV Intl. Dairy Congress (London),3:1859

Davies, W.L. (1948). Indian Indigenous milk products. Pub. Thacker, Spink & Co. Ltd., 3- Esplanade East, Calcutta. 96 pp. De, S.(1980). “Indian Dairy Products” In “Outline of Dairy Technology”, Pub. Oxford University Press. Delhi pp. 382-466.

De and Singh(1970). All India coordinated research programme on production, packaging and preservation of indigenous milk products. Annual Report, National Dairy Research Institute, Karnal, Haryana.

De Goede and De Jong(1993). Heat transfer properties of a scraped-surface heat exchanger in the turbulent flow regime. *Chem Engg. Sci*.48: 1393-1404.

De, S and Ray, S.C. Studies on the Indigenous methods of khoa making. Indian J. Dairy Science. 5:147

De, S(1980). “Indian Dairy Products` in Outline of Dairy Technology”. Pub. Oxford University Press, Delhi pp. 382-466.

De, S. (1980). Indian Dairy Products. In: outlines of Dairy Technology. First Edn. Oxford University Press. pp-389.

De, S. and Gupta, P.K. (1971) Rheology of Dairy products.Indian Dairyman 23(1), 13.

De, S. and Ray, S.C. (1952). The effect of abnormalities in milk supply on khoa production with a note on shelf-life of khoa. *Indian J. Dairy Sci*., **6**:47.

Deeth, H.C. and Fitz-Gerald, C.H. (1976) Experimental details of Methods for determining the extent of lipolysis in dairy products (b) Extraction-titration method. In “Lipolysis in Dairy products- A review”. The Aust. J. Dairy Technology’, 31(2); 62-63.

Deysher, E.F. Webb, H.B. and Holm, G.E. (1944). The viscosity of evaporated milks of different solids concentration, J. Dairy Sci., 30; 837

Dharam Pal and Cheryan, M (1987). Application of reverse osmosis in the manufacture of khoa. Process optimization and product quality. *J. Food Sci. & Tech*., **24**(5): 233-238.

Dharam Pal and Gupta S.K. (1984). Sensory evaluation of Indian milk products. Indian Dairyman, **37** (10): 465-474

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

Dodeja, A.K. (1987). Application of scraped surface heat exchanger for processing of milk and its products. Ph.D. Thesis, Kurukshetra University, Kurukshetra (Haryana).

Dodeja, A.K. Sharma,S.C. and Abhichandani, H. 1990. Heat transfer during evaporation of milk to high total solids in thin film scraped surface exchanger, Jr. of Food Process Eng. U.S.A. 12, (3), 211-225.

Dodeja, A.K., Abichandani, H., Sarma, S.C. and Dharam Pal. (1992). Continuous Khoa making system-Design, operation and performance. *Indian J. of Dairy Sci*., **45**(12) 671-674.

Dodeja, A.K., Abichandani, H., Sarma, S.C., Pal, D. and Verma, R.D. (1990). Performance of thin film SSHE for continuous manufacture of khoa. *Indian J. Dairy Sci*., **43**(4):625– 627.

Dodeja, A.K., Sarma, S.C. and Abichandani, H. (1989). Development of thin film scraped surface heat exchanger for UHT processing of milk. *Indian J. Dairy Sci*., **42**(4):760– 764.

Dudani, A.T. and Iya, K.K. (1963) Problems raised by the use of buffalo milk. Intl. Dairy Fed. Ann. Bull. 5:4.

Dumont (2000). Flow regimes and wall shear rates determination within scraped surface heat exchanger. *J.Food Engg.*, 45(4):195-207.

Dunckwerts(1952) and Levenspiel(1962). Residence time distribution in horizontal in thin film scraped surface heat exchanger cited by Abichandani, H. and Sarma, S.C.(1988). *J.Food Proc. Engg*., 10(2):71-80.

Eilers, H. (1947) Physical and Chemical investigation on Dairy products, Elsevier Publishing company Inc., NewYork

Ellertson M.E. and Pearce, S.J. (1964). Some observations on the physical-chemical stability of sterile concentrated milks. J. Dairy Sci, 47, 564.

Ellis, G.P. (1959) 'Advances in carbohydrate chemistry' Vol.14, Academic Press Inc. New York.

Emundson, L.F.; Mucha, T.J. and Willworth, L.S. (1959), Intl. Dairy Congr.,1; 446. Cited by Bhalerao, V.R. and Iya, K.K. (1964). J. Food Sci. Technol. 1(3): 46-53.

Fox, P.F.(1981). Heat-induced changes in milk preceding coagulation. J. Dairy Sci., 64:2127-2137.

Gayen, D. and Pal, D. (1991). Sensory, chemical and microbiological qualities of Delhi and Karnal market sample of Rabri.II, Studies on the manufacture and storage of Rabri, Indian J. of Dairy Sci.,44(1):94

Gupta, S.K.; Agrawala, S.P.;Patel, A.A. and Sawhney, I.K. 1987. Development of Equipment for Indigenous Dairy Products. Indian Dairyman. 39(9):419-425.

Heldman, D.R. 1981. Trends in Dairy Food Engineering.J. Dairy Sci. 64(6):1096-1102.

Indian Standards: 10083 (1982) Method of Test for the determination of SNF (Solids-not-fat) in Milk by the use of the Lactometer. Bureau of Indian Standards, New Delhi

Indian Standards: 1479, Part I (1960) Methods of Test for Dairy Industry.Rapid Examination of milk. Bureau of Indian Standards, New Delhi

Indian Standards: 1479, Part II (1961) Methods of Test for Dairy Industry.Rapid Examination of milk. Bureau of Indian Standards, New Delhi

Kapil V and Dodeja A.K.1991. Heat transfer during concentration of whey in thin film scraped surface heat exchanger. Journal of Food Science and Technology 28(5): 267

Kapil V and Dodeja A.K.1991. Manufacture of lactose- Effect of processing parameter on the yield and purity. Journal of Food Science and Technology 28(3).

Kumar R. 1998. 'Development of single screw extruders for continuous production of Sandesh.' Ph.D. Thesis,IIT, Kharagpur.

Kunju Cinnie. 2002, Performance evaluation of new rotor blade assembly using SSHE. M.Sc. Thesis NDRI, Karnal.

Laboratory Manual (1959) Method of analysis of milk and its products.3rd edn, Milk Industry Foundation, Washington

Ling ER (1956) Determination of the specific gravity of milk. In:A Text Book of Dairy Chemistry, Vol.2,Practical, Chapter IV, Quantitative Analysis of Milk. Exp.No.20. Chapman and Hall Ltd. London p 44

Pagote C.N. (2005a) Process upgradation for manufacture of basundi. Annual Report NDRI, Karnal (2004-05):40.

Pagote, C.N. (2003) Basundi- A Traditional Delicious Milk Product. *Beverage and Food World*, **30**(6): 29.

Pagote, C.N. (2004) Characterization of traditional *Basundi* prepared from buffalo milk.*16th Indian Convention of Food Scientists and Technologists*, held at CFTRI- DFRL, Mysore on 9-10 December, 2004.

Pagote, C.N. (2004) Some Aspects of Sensory Evaluation of Basundi. Indian J. Dairy & Biosciences, 15(1&2),2004. 132-134

Pagote, C.N. (2005) Optimization of ingredients level for the most acceptable basundi made from buffalo milk. *XXXIV Dairy Industry Conference*, held at Bangalore on 23-25 November, 2005.

Pal D. (2007) New Innovations in the processing of Traditional Indian Dairy Products. *Indian Dairyman*, **60**(3): 127-131.

Pal D. and Raju N. (2007) Indian traditional dairy products: an overview. In: International Conference on Traditional Dairy Foods. Souvenier, 2007, pp: 2-5

Pantulu PC, Sebastian J, Unnikrishnan V, Bhiwasena Rao M (1976) Colorimetric estimation of sucrose in ice-cream. J Food Sci Technol 13:176-185

Patel H.G. and Upadhayay K.G. (2001) Characterization of *Basundi* sold in selected cities of Gujarat. *Indian Journal of Dairy Science*, **54**(6): 344-348

Patel H.G. and Upadhayay K.G. (2003) Physico-chemical changes in milk system during manufacture of basundi. *Indian Journal Dairy Science*, **56**(5): 285.

Punjarath, J.S. 1991. Indigenous Milk Products of India- The Related Research and Technology Requirements in Process Equipments. Indian Dairyman, 43(2):75-87.

Punjrath J.S. and Veeranjaneyullu B. 1990. Inclined scraped surface heat exchangers for continuous khoa making. Indian Journal of Dairy Science 43(2):225-30.

Ranjeet Kumar.2003. 'Studies on the manufacture of Basundi using conical process vat.' M.Sc. Thesis, NDRI, Karnal.

Shah B.P. and Solanki M.J.2004. Mechanization of Basundi making. Progress Report on Network Project 2003-2004.

Appendices

APPENDIX-I

EVALUATION CARD for sensory evaluation of Basundi

Parameter	Undesirable characters/ defects	Intensity of undesirable characters / defects			Your Deduction
		Slight	Definite	Pronounced	
Flavour(45)	Salty	5	10	15	
	Cooked	5	10	15	
	Highly heated	7	12	20	
	Burnt	5	7	10	
	Unclean	5	7	10	
	Stale/Rancid	8	14	22	
	Sour	7	12	20	
	Harsh(excess)	7	11	16	
	Less/more sweet	5	7	10	
	Unpleasant	7	12	20	
Body and texture (35)	More thin/viscous	5	10	15	
	Sticky/pasty	5	8	12	
	Lumpy	5	8	12	
	Chalky	5	7	10	
	Flaky	5	10	15	
	Uneven flakes	3	5	8	
	Not uniform texture	5	7	10	
	Flour-like	5	7	10	
	Grainy/course	3	6	10	
	Gritty	3	6	10	
Colour and appearance (15)	COLOUR Creamy/white	1	1.5	2.5	
	Dull/Dark Brown	1	2	3	
	Unclean	1	1.5	2.5	
	Unnatural	1	2	3.5	
	APPEARANCE More thin/viscous	2.5	3.5	5	
	Fat separation/oozing	1	1.5	2	
	Burnt particles	1.5	2.5	4	
	Flaky/bigger flakes	2.5	3.5	5	
	Unclean/dirty	1	2	3	

Package/Container (05)	Not attractive	1	1.5	2	
	Dirty/soiled	1	1.5	2	
	Damaged/leaky	1.5	2.5	3.5	

Range of score deduction for each parameter of Basundi at different

S.No.	**Parameter**	**Intensity of defects**		
		Slight	**Definite**	**Pronounced**
1	Flavour	5 to 8	7 to 14	10 to 22
2	Body and texture	3 to 5	5 to 10	8 to 15
3	Colour and appearance	1 to 2.5	1.5 to 3.5	2 to 5
4	Package/container	1 to 1.5	1.5 to 2.5	2 to 3.5

S.No.	**Parameter**	**Maximum Score**	**Score**
1	Flavour	**45**	
2	Body and texture	**35**	
3	Colour and appearance	**15**	
4	Package or container	**05**	
Total score		**100**	

Remarks:

Signature

Date:

APPENDIX-II

DATA RECORDED DURING STUDY (based on Sensory Evaluation, Proximate composition analysis and physico-chemical analysis)

SUGAR TYPE	SSHE1 rpm	SSHE2 rpm	FLV	BT	CA	OA	FAT	SNF	SUCROSE	TS	FAT:SNF ratio	ACIDITY	PH	SPCGRAVT	VISCOSITY
WCS	100	100	35.25	27.12	10.5	77.87	14.13	23.55	12.45	50.13	0.6	0.45	6.52	1.124	80.49
WCS	100	125	35.1	27.5	10.25	77.85	13.98	23.3	12.97	50.25	0.6	0.47	6.5	1.123	88.2
WCS	100	150	33.2	27.1	10.75	76.05	13.64	22.36	14.05	50.05	0.61	0.45	6.51	1.125	106.23
WCS	100	175	32.5	23.15	10.8	71	13.7	22.46	13.84	50	0.61	0.48	6.48	1.13	217
WCS	125	100	35.5	28.25	11.5	79.25	13.62	21.97	13.41	49	0.62	0.44	6.52	1.112	90.6
WCS	125	125	35.7	28.5	11.75	79.95	13.82	23.03	13.4	50.25	0.6	0.46	6.5	1.116	91.57
WCS	125	150	35.2	28.1	12	80.03	13.92	22.82	13.76	50.5	0.61	0.47	6.49	1.121	99.84
WCS	125	175	32.25	23	11.25	71.5	13.65	22.75	13.14	49.54	0.6	0.45	6.51	1.115	226
WCS	150	100	35.2	27.5	12	79.7	13.81	22.27	14.12	50.2	0.62	0.45	6.5	1.121	99.17
WCS	150	125	35.5	27.53	12	80.03	13.63	22.34	13.53	49.5	0.61	0.47	6.46	1.115	101.12
WCS	150	150	35	26.5	11.75	78.25	13.94	22.85	13.71	50.5	0.61	0.47	6.45	1.123	101.14
WCS	150	175	32.1	22.7	11.5	71.3	13.9	23.17	12.93	50	0.6	0.46	6.49	1.12	229
WCS	175	100	34.5	24.2	10.75	74.45	13.78	22.59	13.13	49.5	0.61	0.45	6.5	1.11	220.13
WCS	175	125	34.25	24	10.73	73.98	13.85	23.08	13.07	50	0.6	0.45	6.51	1.121	224.16
WCS	175	150	34.52	23.75	10.62	72.89	13.92	23.2	13.9	50.9	0.6	0.47	6.46	1.122	250.28
WCS	175	175	32.12	22.79	10.57	70.59	13.69	22.08	13.33	49.1	0.62	0.46	6.47	1.123	305.26
CSSS	100	100	42	29	13.5	87.5	13.98	22.55	13.66	50.19	0.62	0.48	6.39	1.131	83.41
CSSS	100	125	42.5	30.5	13.5	89.5	13.65	22.75	13.1	49.5	0.6	0.47	6.44	1.123	90.24

APPENDIX-II

DATA RECORDED DURING STUDY (based on Sensory Evaluation, Proximate composition analysis and physico-chemical analysis)

CSSS	100	150	41	28	14	86	13.73	22.51	13.89	50.13	0.61	0.47	6.43	1.125	112.06
CSSS	100	175	39	24	13	79	13.82	22.66	13.79	50.27	0.61	0.46	6.45	1.122	207
CSSS	125	100	43.4	32	14	93.4	13.94	23.23	13.12	50.29	0.6	0.46	6.48	1.111	88.61
CSSS	125	125	43.9	33	14	94.9	13.98	23.3	13.45	50.73	0.6	0.45	6.5	1.121	91.31
CSSS	125	150	42.1	31	14	91.1	13.82	22.66	13.87	50.35	0.61	0.46	6.47	1.12	101.34
CSSS	125	175	38.1	23	14	79.5	13.79	22.98	13.46	50.23	0.6	0.46	6.47	1.125	210
CSSS	150	100	42	30.2	14	90.2	13.68	22.8	13.65	50.13	0.6	0.45	6.51	1.112	101.3
CSSS	150	125	42.5	30.5	13.5	90.5	13.74	22.52	13.03	49.29	0.61	0.47	6.45	1.115	101.34
CSSS	150	150	41.2	28.1	13.5	86.8	13.85	23.08	13.32	50.25	0.6	0.46	6.48	1.119	110.15
CSSS	150	175	38	23.6	14	78.6	13.91	22.44	13.14	49.49	0.62	0.47	6.44	1.115	214
CSSS	175	100	40.5	24.5	14	82	13.98	22.92	13.31	50.21	0.61	0.46	6.42	1.121	188
CSSS	175	125	39.7	24.2	13.5	80.4	13.68	22.06	13.99	49.73	0.62	0.46	6.44	1.129	192.27
CSSS	175	150	39.2	23.5	13.5	79.2	13.79	22.24	13.48	49.51	0.62	0.47	6.41	1.127	221.32
CSSS	175	175	37	23	13	76	13.88	23.13	13.18	50.19	0.6	0.46	6.45	1.116	281