FEASIBILITY STUDIES ON FORMATION AND COOLING OF *MALAI LACHHA*

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NATIONAL DAIRY RESEARCH INSTITUTE, KARNAL
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IN PARTIAL FULFILMENT OF THE REQUIREMENT
FOR THE DEGREE OF

MASTER OF TECHNOLOGY
IN
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(DAIRY ENGINEERING)

BY
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B.Tech. (Dairy Technology)

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(Dairy Engineering)

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CERTIFICATE

This is to certify that the thesis entitled **"FEASIBILITY STUDIES ON FORMATION AND COOLING OF *MALAI LACCHA*" submitted** by **Mr. RAJUNAIK. B** 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 him under my supervision and guidance and no part of the thesis has been submitted for any other degree or diploma.

Dated: **(Dr. R.K. Kohli)**

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Dedicated

to my

Family

&

Dear friends

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Date: *(Rajunaik. B)*

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LIST OF ABBREVIATIONS AND SYMBOLS

AOAC	….	Association of Official Analytical Chemists
BIS	….	Bieuro of Indian Standards
cm	….	Centimeter
dt	….	The mean temperature difference
dw/dθ	….	Moisture evaporation rate from drum surface
FPHE	….	Flat Plate Heat Exchanger
H_c	….	Convection coefficient
H_e	….	Evaporation film coefficient
H_p	….	Film coefficient of the product
H_r	….	Radiation coefficient
H_s	….	Film coefficient of steam, kcal/hm^2 °C
k	….	Thermal conductivity of metal, kcal/hm°C
K	….	Kelvin
LDPE	….	Low Density Poly Ethylene
kg	….	Kilogram
mm	….	Mili meter
PFA	….	Prevention of Food adulteration Act
rpm	….	Rotations Per Minutes
SNF	….	Solid Not Fat
SS	….	Stainless Steel
cm^2	….	Square centimeter
TMS	….	Total Milk Solids
TPI	….	Threads per inches
ts	….	Surface temperature in degree Celsius
U	….	Overall heat transfer coefficient
VLSD	….	Variable Lip Slot Die
W	….	Watt
x	….	Thickness of metal, m
%	….	Percentage

ABSTRACT

Dairy industry in India at present is passing through a transition phase as major emphasis is being laid on manufacture of indigenous dairy products. *Malai Lachha* is an important Indian indigenous milk product. *Malai Lachha* is a heat desiccated clotted cream shredded thin firm layers, pale yellow to light caramel in colour and delicious in taste. *Malai Lachha* is used as a finishing material on top of the sweets by garnishing especially on the Bengali sweets. It also adds delicious taste and nutritive value to the final products. Most of the sweets manufacturers are producing *Malai Lachha* traditionally. This method is laborious, time consuming and unhygienic. Owing to the rapid increase of traditional milk products demand, the industry faces the challenge of producing indigenous products in a hygienic manner and with machines. An attempt has been made to mechanize the production of *Malai Lachha* by developing cooling system with flat plate heat exchanger. Three sets of concentration of milk (30, 35, 40% TMS), steam pressure (0.3, 0.4, 0.5 kg/cm^2), opening of lip slot variable die (1.0, 1.5, 2.0 mm) and cooling rate (2500, 3000, 3500 W) were used in this study. On the basis of preliminary trials, 1.5 and 2.0 mm opening of lip slot variable die were unsuitable for formation of layers in mechanized production of *Malai Lachha*. *Malai Lachha* layer was formed at 1 mm opening of lip slot variable die at all concentrations, steam pressures and cooling rates. Based on the sensory evaluation a combination of variable parameters having concentration of milk at 35% TMS, 1mm opening of lip slot die, 0.4 kg/cm^2 steam pressure and 3500 W cooling rate with 55 minutes of total processing time (heating and cooling) were selected for the production of best quality *Malai Lachha.*

सारांश

वर्तमान में भारतीय डेयरी उद्योग एक परिवर्तन चरण से गुजर रहा है। प्रमुख रूप से स्वदेशी डेयरी उत्पादों के निर्माण को बल दिया जा रहा है। मलाई लच्छा एक महत्वपूर्ण भारतीय स्वदेशी दूध का उत्पाद है। मलाई लच्छा एक गर्मी शोषित कटा मलाई दृढ़ पतली परत, पका पीले से दीप शुष्कशर्करा- रंग और स्वाद में स्वादिष्ट होता है। मलाई लच्छा विशेष रूप से बंगाली मिठाई के ऊपर एक सजावट सामग्री के रूप में प्रयोग किया जाता है और यह स्वाद एवं उत्पादों के पोषक मूल्यौ को बढाता हैं। अधिकांश मिठाई निर्माता मलाई लच्छा पारंपरिक विधि से उत्पादन कर रहे हैं। यह पारंपरिक विधि समय लेने वाली श्रमसाध्य और अस्वास्थ्यकर है। परंपरागत दूध उत्पादों की मांग में तेजी से वृद्धि , इस उद्योग में एक स्वच्छ तरीके से स्वदेशी उत्पादों का उत्पादन और मशीनों के साथ चुनौती का सामना के कारण, स्वदेशी उत्पादों के लिए एक प्रसार तंत्र विकास द्वारा मशीनीकरण करने का प्रयास किया गया है। मलाई लच्छा के यांत्रिक विधि से उत्पादन के लिए शीतलन प्रणाली के साथ समतल प्लेट ऊष्म विनिमयक का निर्माण किया गया | इस अध्ययन में दूध की सांद्रता के तीन समुच्चय (30, 35 और 40%), भाप दबाव (0.3, 0.4 और 0.5 किगा/सेमी^{2}), परिवर्तनीय होंठ खांचा विवर (1.0, 1.5 और 2.0 मिमी) और शीतलन दर (2500, 3000 और 3500 वाट)का प्रयोग किया गया। प्रारंभिक परीक्षण में 1.5 और 2.0 मिमी परिवर्तनीय होंठ खांचा खोलने के आधार पर मलाई लच्छा के यंत्रीकृत उत्पादन में परतों के गठन के लिए अनुपयुक्त थे। मलाई लच्छा की परत परिवर्तनीय होंठ खांचा 1 मिमी खोल कर सभी सांद्रता, भाप दबाव और शीतलन दरो में बनाई गई थी। सर्वोत्तम गुणवत्ता का मलाई लच्छा के उत्पादन के लिये संवेदन मूल्यांकन के आधार पर एक चर प्राचल का संयोजन, दूध की सांद्रता 35% TMS, 1 मिमी होठ खांचा का खोल, 0.4 किगा/सेमी^{2} भाप का दबाव और 3500 वाट का शीतलन दर; 55 मिनट के कुल संसाधन समय (गर्म और ठंडा करने के लिये) का चयन किया गया|

CHAPTER – 1

INTRODUCTION

INTRODUCTION

Traditional dairy products have significant role in the economic, social, religious and nutritional well being of our people since time immemorial. Deep-rooted tradition offers a considerable scope for organizing and channeling the amount of milk being used for conversion into traditional dairy products. The major strength of the traditional dairy products sector is the mass appeal enjoyed by such a wide variety of products. It is estimated that about 50 – 55 percent of milk produced till now is converted by manufacturers into variety of Indigenous dairy products using processes such a heat and acid coagulation, heat desiccation and fermentation. This fact underlines the significance of traditional dairy products in our national economy. In spite of such great importance of traditional dairy products in our country these products are still manufactured at the small scale (cottage industry) with variable quality depending on the skill of the manufacturer. There has been hardly any quality control and hence the shelf life of the products is poor. The current production methods of these products are primitive and based on techniques that essentially remain unchanged. The rural scale operations are associated with inefficient use of energy, poor hygiene and sanitation and non-uniform product quality. Most of the preparations are labor intensive and rely on local inputs.

There is rapid expansion of dairy industry in our country. The indigenous products are becoming very popular and tend to commercialization. Most of indigenous dairy products are still manufactured by using batch processes. The unit operations used for manufacture of these products include heating, evaporation and boiling. Due to the growth of dairy industry, there is a need to design and develop equipments for manufacture of these dairy products. The technology and design of process equipment is also undergoing continuous changes. Therefore, it is necessary to give priority to the work on design and development of mechanized systems for manufacture of indigenous dairy products.

Malai Lachha is a heat desiccated clotted cream shredded thin firm layers, pale yellow to light caramel in color and delicious in taste. *Malai Lachha* is being used as a finishing material on top of the sweets for garnishing especially on the Bengali sweets. It also adds delicious taste and nutritive value to final products.

Still most of the sweets manufacturers are producing *Malai Lachha* traditionally. This method is laborious, time consuming and unhygienic. The heat losses during the production are also high. Thus there is a need to design and develop energy efficient equipments for manufacture of *Malai Lachha* and other indigenous dairy products. These equipments should adopt heat exchangers of proven better thermal efficiency which will reduce the processing cost of these products. To deep the processing cost to a minimum possible extent, we must adopt inbuilt mechanisms and arrangements for energy conservation in mechanized processing systems for *Malai Lachha.*

Efforts contributing to the hygienic design of food processing equipment are essentially aiming at optimizing manufacturing economics i.e., material selection for dairy equipment, improvement of the hygienic quality of products efficient cooling of product after processing, reduction of production costs etc.

Food cooling is the most important step in food refrigeration and has been of great interest in food preservation during the past few decades. The phenomena involved in food processing and preservation comprise heat and mass transport, reaction kinetics, and the principles of thermodynamics and chemical science. For practical food cooling application, the factors that influence the temperature change and cooling rate are the following:

- Temperature and flow rate of cooling medium (coolant)
- Thermal properties and physical dimensions of food product.

Regardless of the type of cooling technique, knowledge and determination of the cooling process parameters are essential to provide efficient and effective food cooling at the micro and macro scales. Some major design process factors for food cooling process are cooling process conditions in terms of temperature, flow rate, relative humidity, arrangement of individual products and/or product batches, depth of the product load in cooling medium and initial and final temperatures of products.

An attempt has been made to develop *Malai Lachha* formation system with cooling mechanism in Dairy Engineering Workshop, NDRI, Karnal. This mechanism was used for improving the hygienic quality, homogeneous product and avoiding grainy texture in the product, increasing shelf life, producing value added products and reducing man power and manufacturing time during production of *Malai Lachha.*

In order to achieve the above facts, the specific objectives of this study are,

1. To develop *Malai Lachha* formation system with cooling mechanism.
2. Optimization of process parameters.

CHAPTER – 2

REVIEW OF LITERATURE

REVIEW OF LITERATURE

Malai Lachha production in India is characterized by an unorganized nature of business mainly a cottage industry. In response to the changing life style and emerging consumers demand for food safety and extended shelf life of product, mechanization of *Malai Lachha* based sweets is a necessity today for improving their hygienic quality and reducing man power and manufacturing time during production. *Malai Lachha* based sweets have not received the attention which it richly deserved from research workers. Till date only one literature is available on layer formation of *Malai Lachha* and no information is reviewed with regard to the cooling mechanism of *Malai Lachha* for the mechanized production. This chapter therefore deals with the literature pertaining to similar mechanism for the layer formation of *Malai Lachha* and method of manufacture. The available information related to proposed study has been classified and reviewed under the following sub-headings:

2.1 *Malai Lachha*

2.2 Types and Composition of *Malai Lachha*

2.3 Layer formation systems

2.4 Cooling of dairy and food products

2.1. *MALAI LACHHA*

Malai: According to PFA rules (1976), "*Malai* refers to the product rich in butter fat prepared by boiling and cooling cow or buffalo milk or a combination thereof. It shall contain not less than 25 percent milk fat".

Malai Lachha is a heat desiccated clotted cream shredded thin firm layers, pale yellow to light caramel in colour and delicious in taste. It is used as a finishing material on top of the sweets with a purpose of making it more attractive, especially on the Bengali sweets. It also adds delicious taste and nutritive value to the final products.

2.1.1. Technology of *Malai Lachha*:

Still most of the sweets manufacturers are producing *Malai Lachha* by traditional method. This method is laborious, time consuming and unhygienic. *Malai Lachha* production is a highly skilled technique and requires considerable experience and constant attention. *Malai Lachha* is normally prepared from 3 – 4 litres of milk in ratios of 3:1 or 1:1 of cow and buffalo milk taking into shallow pan (76.2 cm diameter, 12.7 cm deep, 5 cm thickness). First 10 – 12 minutes vigorous heating is done with continuous stirring up to 2 – 3 fold concentration of milk. After cooling of milk up to 90ºC for 3 minutes, it is subjected to continuous gentle heating at 85-90ºC for 30 – 40 minutes. During this process in each 30 – 35 seconds there is formation of a thin layer on surface of the milk. This layer is taken up by a bamboo stick inserted into middle of the circular layer divided in half circle and spreaded over bottom to periphery of the remaining cooled surface of shallow pan up to 30 – 40 minutes with continuous rotating shallow pan. After this, remaining quantity of milk (1.5 litre approximately) is drained. The layers sticking on periphery of shallow pan are heated for evaporation of moisture of clotted milk/cream layers up to desired level. Then the shallow pan is cooled down and put on a revolving stand. Finally firm clotted milk layers are cut in to desired width depending on application according to different types of *Malai Lachha* based products.

(Courtesy: Haldiram Industry).

2.1.2. *Malai Lachha* Process

(Courtesy: Haldiram Industry)

Receiving raw milk in Shallow pan

(Cow and Buffalo Milk, 3:1) at 5°C & 3 – 4 litres

↓

Vigorous heating with continuous stirring at 97 – 100°C

(10 – 12 minutes)

↓

Cooling of milk (90°C for 3 minutes)

↓

Formation of layer on air- concentrated milk interface at 85 – 90ºC

(each batch 50 – 55 layers in 30 – 35 minutes (SIMMERING PROCESS)

↓

Removal of (Clotted Cream) layer surface from concentrated milk by bamboo stick for spreading to periphery of shallow pan

↓

Drainage of milk (1.5 litre)

↓

Cool to room temperature for 10 – 15 minutes

↓

Cutting of strips and scrapping from periphery

↓

Transfer strips into aluminium tray on LDPE (layer)

↓

Stored at 4°C

2.2. TYPES AND COMPOSITION OF *MALAI LACHHA*

Table 2.1. Types of *Malai Lachha*

Type of *Malai Lachha*	**Thickness (cm)**	**Width of Layer (cm)**
Milk Crown Lachha	0.10	3 – 5
Ras Malai Lachha	0.15	3 – 4
Malai Roll Lachha	0.20	5 – 6

Courtesy: Haldiram Industry

Table 2.2. Composition of *Malai Lachha*

Types of *Malai Lachha*	**Moisture content (wb) (%)**	**Fat content (%)**	**Total Milk Solids content (%)**
Milk Crown Lachha	21	35	79
Ras Malai Lachha	23	34	77
Malai Roll Lachha	25	33	75

Courtesy: Haldiram Industry

2.2.1. Application of *Malai Lachha*

2.2.1.1. ***Milk Crown Lachha:*** This is used in the following products such as *Milk crown, Anorodh, Anarkali, Chines Rasogulla, Badam (Almond) Milk, Mutka kulfi, Indrani cup and Fruit cup*.

2.2.1.2. ***Ras Malai Lachha:*** Used in *Ras Malai.*

2.2.1.3. ***Malai Roll Lachha:*** Used in *Malai Roll*.

2.2.2. Flow diagram of *Milk Crown Lachha*

Panwar and Kohli, (2007) have adopted the following procedure.

Receiving cow and buffalo milk
(3:1 ratio, 5% fat and 8.5% SNF)

↓

Heating in steam jacketed kettle (20 litre capacity)
at 0.5 – 0.7 kg/cm^2 steam pressure for 45 – 55 minutes
(Upto 30 – 45% total solids)

↓

Transferring concentrated milk into bucket

↓

Pouring concentrate through perforated trays on FPHE

↓

Formation of *Malai Lachha* layers over Flat Plate Heat Exchanger at
(0.3 – 0.5 kg/cm^2) steam pressure in 15 – 25 min.

↓

Cutting by multi-blade roller cutter and scrapping by scraper blade

↓

Put in aluminium trays (testing and judging)

According to Panwar and Kohli, (2007) perforated trays having rectangular slots of 5 cm length, 0.3 cm width and 0.5 cm pitch for 40% total milk solids concentrated milk was best suitable for uniform spreading. At 35% TMS and 0.4 kg/cm^2 steam pressure *Malai Lachha* was soft, homogeneous and thin shredded layers. He has also stated that increasing the concentration of milk (% TMS) at constant steam pressures, process time decreases. Also quicker evaporation at higher temperature yields a whiter khurchan, while slower evaporation at lower temperatures makes the khurchan somewhat brownish in colour.

2.3. LAYER FORMATION SYSTEMS

Malai Lachha is a multilayered (two or three layered) indigenous dairy product. Due to the growth of dairy industry, it requires mechanical formation of layers for their mechanized production. For effective layer formation, first milk is concentrated upto 30 – 40% TMS in Thin Film Scrapped Surface Heat Exchanger without any clots or grains in the concentrated milk then followed by layer formation over Flat Plate Heat Exchanger.

Antonijevic and Voronjec, (2000) studied a model of variable coefficients for heat and mass transfer in contact drying. Layers of the material were placed on the heated surface of constant temperature, while over the opposite free surface of the material the air of certain temperature, relative humidity and velocity was blown. Heat was supplied to the moist material layer primarily by conduction and removed by convection. The system of equations describing combined heat and mass transfer in the layer of moist material as well as the corresponding equations for the initial and boundary conditions at contact and free surface are derived in the assumption that all thermo-physical coefficients were fully dependent on the temperature and moisture content inside the material during the process. The proposed model was solved numerically. The mathematical model was confirmed through a comparison of the numerical results to the results obtained experimentally.

Kornyukhin and Zhmakin, (2000) developed a system of the equations for heat and mass transfer in drying of porous bodies by averaging the fundamental conservation and heat transfer laws with three characteristic scales. The system included the equations of motion, continuity and mass transfer for liquid and gaseous phases and also the equation of energy. The convective transfer in the phases was described using the model of motion of non-mixing liquids in unsaturated porous materials. The system was closed using the equation of phase equilibrium i.e., the equation of desorption isotherm. Phase transitions (moisture evaporation) were considered without any special assumption about the form of source terms. The equation of liquid motion was simplified by estimating the magnitudes of its terms. The system obtained was suitable for the description of high-rate drying processes.

Smeding *et al.* (2006) designed a sandwich flat plate heat exchanger for application in a high temperature solid sorption heat pump. The heat exchanger consists of two metal sheets that are brazed together with a metal wire mesh in between. This results in a lightweight construction with favourable heat transfer properties and sufficient mechanical strength to resist cyclic pressure variations. The flow distribution in a circular sandwich plate heat exchanger was determined experimentally as well as the average internal heat transfer rate. The results of these experiments were in good agreement with results of simulations that determined the local and average flow, temperature and heat transfer. Finite element calculations were done to select plate thickness and wire mesh dimensions of a sandwich plate heat exchanger to be applied in solid sorption heat pump where it should resist up to hundred thousand load cycles.

Raghavarao, (2007) designed and developed a device for various operations involved in *dosa* preparations such as batter spreading, cooking / baking, oiling, curry dispensing etc. Geometrical shapes obtained were of uniform dimension and obtained in a continuous / intermittent manner on the concept of spreading on a revolving hot plate. The machine has a capacity to produce 400 *dosa*/hr. This machine will help in reducing manual labour and drudgery, improving hygiene and enhancing uniformity in quality and quantity. All the parts of the machine (except hot plate) are made of stainless steel of different grades.

2.3.1. Variable Lip Slot Die

Patterning methods are used extensively by manufacturers for dispensing a range of viscous liquid materials such as adhesives and uncured liquid polymers onto stationary or moving surfaces of various shapes, sizes, and textures in a controlled manner. Materials include digital technologies standard printing techniques and more conventional techniques (rolling, spraying, syringe deposition). Because of issues such as high viscosity, high reactivity with surfaces, time and temperature varying physical properties and the tendency to cure, viscous liquid materials are difficult to deposit onto substrates or surfaces in a controlled manner. Furthermore, special precautions and cleaning techniques must be followed to avoid damage to patterning equipment. Other limitations of some patterning methods include excessive material waste, lack of equipment versatility, deposition repeatability and accuracy, and slow dispensing speeds. A new technology that allows accurate and controlled two-dimensional patterning of a wide range of viscous liquid materials with either uniform or variable thickness and in a rapid, cost-effective, and flexible manner would be well received by the industries.

The basic idea behind the VLSD concept is to move a substrate beneath the die or move the die above the substrate while portions of its extrusion slot are temporarily constricted (i.e., reduced in width or completely closed-off), thereby forcing material out of open slot sections.

Hilleringmann, (1984) stated that when the die block was mounted in the die assembly, the residual stress caused the total indicated run-out of the slot to be larger than anticipated and distorted. Consequently, layer uniformity was degraded.

According to Mukherjee, (2002) A VLSD was essentially a standard slot die with a pin actuated variable lip that allows real-time control over the pattern and thickness of viscous liquids deposited on substrata.

2.3.2. Coat Hanger Die

The coat-hanger dies are widely used in the polymer processing for the production of sheets and films. Both the geometrical and material quality of the products is governed by the uniformity of flow rate and residence time distributions. The designs of T-die and coat-hanger die were mainly carried out by analytic method under the assumptions that both the flows in the manifold and the slot are fully-developed in the machine direction and have no interactions, using power-law fluid for the polymer melts. The slot thickness shows negligible effect on the flow rate distribution while the manifold angle is found to be the important factor for maximizing the uniformity of flow rate. Optimum manifold angle can be determined for each power-law index. The optimum manifold angle increases from 10^0 to 20^0 as the power-law index is decreased from 1.0 to 0.4. The flows tend to move to the die centre when the manifold angle is greater than the optimum.

Su Yeon, (1994) stated that in a Coat Hanger Die, as slot thickness increases, the region of uniform flow rate decreases proportional to slot thickness.

Su Lion, (1998) developed a three dimensional design which was successfully accomplished in the various process conditions. The manifold profile rapidly covered the optimum profile that generated uniform pressure gradient and flow rate distribution. The manifold profile increased in the whole range as power law decreased and was found very sensitive to the slot thickness. The effect of slot thickness and manifold angle on manifold profile increased from die side end to die centre.

Sun and Gupta, (2008) studied coat hanger die, in which the Carreau model was used to capture the shear-rate (λ) dependence of shear (η_s) and elongational viscosity (η_e) of the LDPE resign.

$$\eta_s = \eta_o \, (1 + (\lambda e_\pi)^2)^{\frac{n-1}{2}}$$

An Arrhenius type model is used for temperature dependence of the zero-shear viscosity (η_o)

$$\eta_o = A \, exp({}^{T_a}/_{T})$$

Where,

e_π = λ	=	shear-rate
η_o	=	zero shear viscosity
λ, n, A, T_a	=	material parameter
T	=	temperature of polymer

2.3.3. Patch Slot Coating

Slot coating process, in continuous and patch (or intermittent) modes, has been applied for the many precise coating products, manufacturing uniform coating products is not a trivial task at high-speed operations because various flow instabilities or defects such as leaking, bubbles, ribbing, and rivulets are frequently observed in this process. It was concluded that optimal die internal design has been developed guaranteeing uniform velocity distribution of both Newtonian and shear thinning liquids at the die exit. And also optimal die lip design has been established, providing the longer uniform coating layer thickness in coating patterns.

Steven J, (2004) employed narrow channels to form a liquid layer and control its thickness which was comparable to the minimum gap and consequently tight mechanical tolerances were required to create a thin film.

2.3.4. Coating Flows

According to Weinstein and Ruschak, (2004) coating is the process by which thin liquid layers are formed and applied to a solid surface. Coating flows are the flows utilized in coating processes and also include the incidental flows that occur after coating and before immobilization. The continuous coating of wide web's, which gives rise to ideally two-dimensional, steady laminar flows, coating processes may be broadly classified as self-metered and pre-metered. In self-metered flow, the liquid properties, web speed, and geometry combine to determine the thickness of the coated film. Self-metered methods include dip, roll, and blade coating. In pre-metered coating processes, direct setting of the flow rate determines the thickness of the coated film independently of these parameters. Pre-metered methods require a precision liquid delivery system and a die for width wise distribution. These methods include slot coating, slide coating, and curtain coating. A genuinely predictive analysis of a realistic coating process is generally not possible, and the number of coating methods is extensive. It is therefore advantageous to examine the fluid mechanical components (flow elements) comprises.

2.3.5. The Flow of a Thin Film

The flow of thin films adjacent to walls is common to several flow elements, and so it is being addressed separately. In regions of a coating process, it is often the case that film thickness changes gradually. Inertia may be neglected for small values of the modified Reynolds number, the product of the usual Reynolds number and the aspect ratio. Thus, when a small aspect ratio is imposed by walls, such as rollers and doctoring blades, classical lubrication theory applies. By contrast, the aspect ratio is not always anticipated in a free-surface flow, and often the modified Reynolds number is not small. As a result, inertia must be included, and a boundary-layer form of the momentum equation is required.

2.3.6. Dispenser

Lazar, (2007) claimed that a sheet material dispenser for dispensing portions of sheet material has been invented to which a composition has been applied. The dispenser comprises: a) a feed mechanism for holding and advancing the sheet material, b) a drive mechanism including a carriage, said drive mechanism being configured to displace said carriage along a path of motion; c) an applicator assembly deployed on said carriage so as to be carried along said path of motion, said applicator assembly including at least one container containing a composition to be applied to the sheet material and at least one applicator for directing a quantity of the composition towards a surface of the sheet material; and d) a controller associated with said feed mechanism, said drive mechanism and said applicator assembly, said controller being configured to actuate said applicator assembly to apply a quantity of the composition to the surface of the sheet material while said drive mechanism carries said applicator assembly along said path of motion.

Holden, (1964) stated that variations in concentrate viscosity were caused by temperature changes and intrinsic batch differences ranging from 70 to 800 centipoises. Foam stability was well correlated with concentrate viscosity. Foaming ability of each batch was correlated with temperature and minima were 70^{o}F. A complex correlation of viscosity and temperature described foaming ability for all batches. This depected the importance of viscosity and temperature as control parameters in the vacuum foam-drying process and also showed that final foam structure was established early in the drying operation.

2.3.7. Non Oriented Film Production Lines

A polymer, which was uniformly melted in the extruder, is extruded from the die. The extruded molten polymer film is stuck to the casting (cooling roll) and cooled to solidification, then it is winded by the winder via the take-off unit that carries out surface treatment and other processing. In a non oriented film production line, the flow rate distribution in the die width direction significantly affects the thickness distribution in the film width direction. Consequently, uniformization of the flow rate distribution in the die width direction is important for widening film.

2.3.8. Spreading of Non-Newtonian Fluids

Cramer, (1984) developed a slot shaped dispensing aperture on the lower side of the dispenser which was automatically opened and closed progressively by movable closer in such a manner that the open portion of slot matches the corresponding dimension of the area to be dispensed upon as they moved beneath the dispenser. This enabled complete coverage of these areas with the sauce, without dispensing it upon other portion of other areas where it was not desired.

Rafaı, (2005) have reported that the spreading of non-Newtonian liquids a shear thinning fluid, the contact line singularity was removed, at least in the theory, due to the viscosity decrease. On the other hand, normal stresses provided an additional driving force that has overcome the viscous resistance near the contact line. One would thus imagine that both shear thinning and normal stress effects should accelerate the motion of the contact line. In contrast with this naive expectation, in both experiments the spreading was slowed down.

2.4. COOLING OF DAIRY AND FOOD PRODUCTS

Thermal processing is widely used in the food industry, and the design of equipment for such processing, for example, cooling operations, depends strongly on the knowledge of the cooling heat transfer parameters of the food to be cooled. It is also important especially for economic reasons, that the energy balances be considered in the design of cooling equipment. It is essential that the design engineer should know the quantity of heat to be released and time taken to remove it. Consequently, cooling heat loads are calculated based on the effect of rate of cooling on the product quality.

Dincer, (1995) carried cooling experiments of figs and methodology was presented to determine the cooling data, such as cooling coefficient, lay factor, half cooling time and seven-eighths cooling time, as well as the heat transfer coefficient for the individual figs cooled in air medium at the flow velocities of 1.0, 1.5, 2.0 and 2.5 m/s. The half time cooling times and seven-eighths cooling times decreased, and the heat transfer coefficient increased with increasing the flow velocity in air cooling. It can be concluded that the present methodology is a simple and useful tool to determine the thermal cooling data in the practical cooling applications.

Dincer, (1997) exposed 5 kg package of cylindrical shape produce to cold air stream and reported that surface boundary condition can be better solved by sum of convective and radiative heat transfer coefficient than by pure convective heat transfer coefficient.

Landfeld and Houska, (2006) studied the vacuum cooling process and found that it enables porous, just cooked products to be chilled within several minutes instead of hours. On the other hand, water evaporated from cooked food represents the undesirable mass loss especially for high value meal components such as beef or pork meats.

Reddy, (2000) cooled 1 kg, 2 kg and 3 kg *Paneer* blocks in cubical and cuboidal shapes in chilled water at 5 and 10^{o}C. The cooling was done for 3 hours and 30 minutes the temperatures at two layers were noted down at 5 min intervals. The time temperature distribution curves for *Paneer* were drawn and the regression equations were developed. The film heat transfer coefficient of chilled water for 3kg cuboidal *Paneer* block varies from 224.96 to 467.468 $W/m^{2}\,^{o}C$ when chilled water temperature varied from 5 to 10^{o}C. The surface heat transfer coefficient of cuboidal *Paneer* blocks were found to be 35.8, 35.6 and 34.2 $W/m^{2}\,^{o}C$ for 1, 2 and 3kg blocks respectively, when cooled by chilled water at 5^{o}C.

Khodwe and Bikram, (2002) subjected the *Burfi* to 3 cooling rates i.e. ambient temperature cooling rate (18 to 20^{o}C), domestic refrigeration cooling (0.1 to 2^{o}C) and refrigeration tunnel cooling (-4 to -5.5^{o}C) and found that in all types of cooling coefficient decreases with increase in thickness of *Burfi*. It was also concluded that when *Burfi* was subjected to cooling under refrigerated tunnel temp. quality of *Burfi* from sensory point of view, mainly suffers from hardness.

Ghuman and Dhatt, (2002) developed batch type hydro cooler for mangoes and other horticulture produce. Here water is cooled by vapour compression refrigeration system and then this water is sprayed over mangoes.

Selection of VLSD for dispensing and spreading the layers of viscous concentrated product is based on its ability to allow the accurate and controlled two dimensional patterning of a wide range of viscous materials. It will provide rapid, uniform or variable thickness, cost effectiveness and flexibility in operation.

Cooling process using FPHE is innovative and would result in uniform thickness and quality of *Malai Lachha*. Horizontal FPHE is not found in review of literature. A new system needs to be investigated for feasibility studies.

Interference drawn from the review of literature lead to formulation of following objectives:

1. To develop *Malai Lachha* formation system with cooling mechanism.
2. Optimization of process parameters.

CHAPTER – 3

MATERIALS AND METHODS

MATERIALS AND METHODS

Experimentation of the proposed study has been envisaged under following sub-headings:

3.1. Development of experimental set-up

3.2. Performance Parameters

3.3. Materials required

3.4. Experimental procedure

3.5. Chemical Analysis

3.6. Sensory Evaluation of *Malai Lachha*

3.1. DEVELOPMENT OF EXPERIMENTAL SET-UP

The experimental set-up was developed for mechanized production of *Malai Lachha.* The basic requirements of the experimental apparatus were to spread a regulated and measured quantity of concentrated milk on hot surface for layer formation and cool the *Malai Lachha* to maintain the final quality.

The unit operations used for manufacture of *Malai Lachha* includes spreading, heating, evaporation and cooling. The equipments for production of *Malai Lachha* has been developed for small capacities, only the necessary design data required for *Malai Lachha* is not available in the literature and, therefore, it becomes a very difficult task to design thermally efficient heat exchanger and equipment for mechanized production of *Malai Lachha*.

A careful study of work environment such as temperature, pressure, aeration, humidity, impurities, surface conditions, etc. of a process plant during design of dairy equipment can reduce the total cost of the equipment. Taking all necessary requirements for the mechanized production of *Malai Lachha* an experimental set-up was proposed as shown in Plate No 3.1.

The experimental set-up consisted of:

- FPHE
- Cooling System
- Thin Film Scrapped Surface Heat Exchanger
- Steam control Valve (manual)/ steam control mechanism
- Water flow regulating valve
- Compound Pressure Gauge (-1 to 7 kg/cm^2)
- Spring loaded safety valve (0.7 kg/cm^2)
- Steam trap
- Air vent
- Digital thermometers

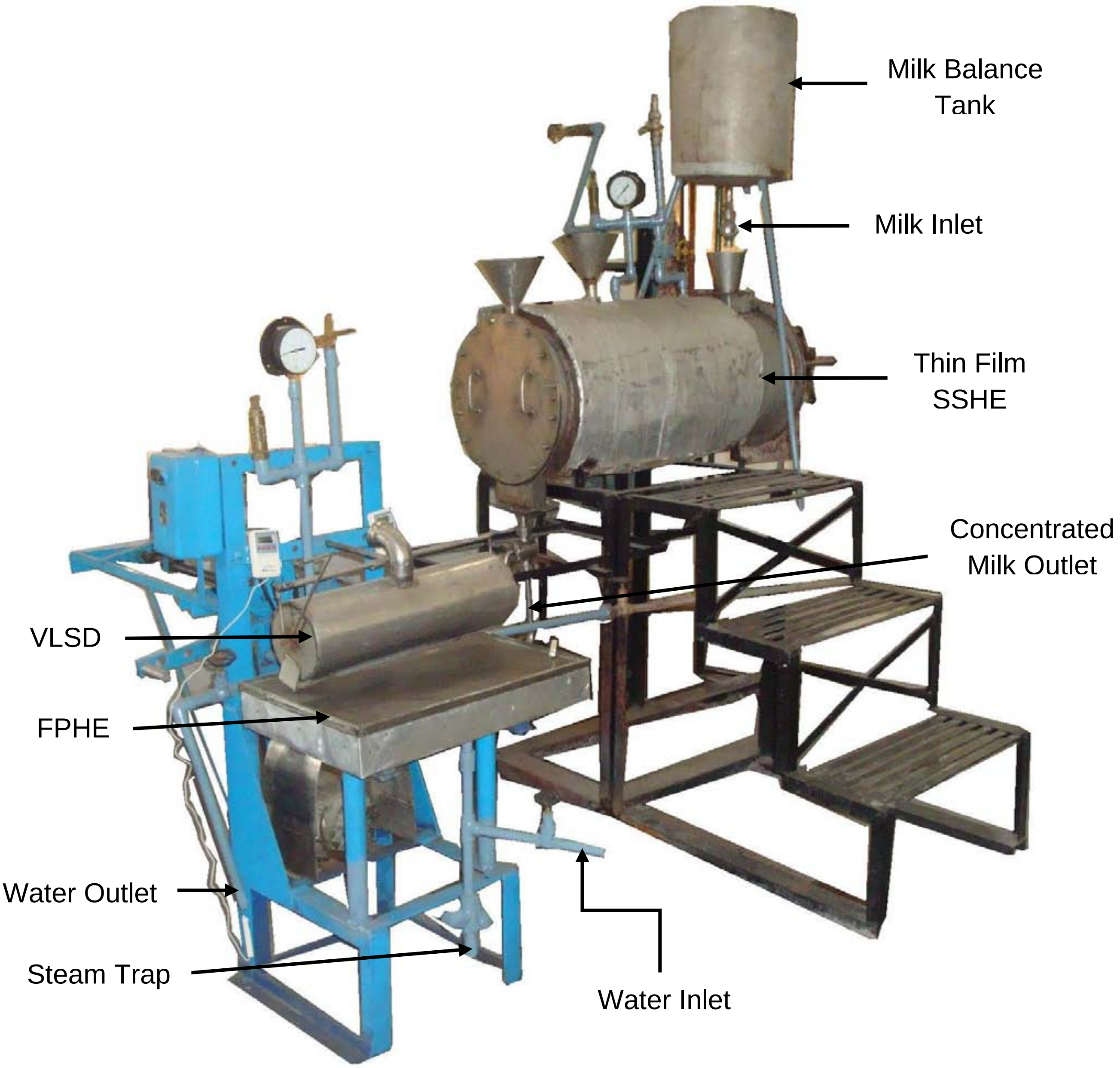

Plate 3.1 Experimental Set-up for *Malai Lachha*

3.1.1. Cooling System

A flat plate heat exchanger (FPHE) made of 304 stainless steel, having top plate of 0.5 cm sheet thickness; other five bounding plates were made of Mild Steel of 0.8 cm thickness, was used. The dimension of flat plate heat exchanger was 60 cm long, 38 cm width and 5 cm height. Three baffles were attached to inner side of top plate of FPHE at equal partitions that increases thermal efficiency of heat exchanger and avoids the bulging of heat exchanger. The FPHE has three ports, one for steam inlet and cooling water outlet, one for steam trap and cooling water inlet and, one for spring-loaded safety valve, an air vent and compound pressure gauge. The two digital thermometers were also attached on experimental set-up to note down the temperatures of cooling water outlet and *Malai Lachha* as shown in Figure 3.1 and Plate No 3.2.

The cooling load was calculated by as follows:

1. Heat to be removed from *Malai Lachha*

$$Q_{(M.L)} = m_{(M.L)} \times C_{p(M.L)} \times dt_{(M.L)} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

2. Heat to be removed from FPHE

$$Q_{(FPHE)} = m_{(FPHE)} \times C_{p(FPHE)} \times dt_{(FPHE)} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

$$m_{(FPHE)} = (\text{Area} \times \text{Thickness} \times \text{Density of FPHE})$$

3. Total cooling load

$$Q_{(CL)} = Q_{(M.L)} + Q_{(FPHE)} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

4. Quantity of water required

$$m_{(W)} = Q_{(CL)}/(C_{p(W)} \times dt_{(W)}) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (4)$$

Where,

$Q_{(M.L)}$, $Q_{(FPHE)}$ = Quantity of heat to be removed from *Malai Lachha* and FPHE in KJ

$Q_{(CL)}$ = Total cooling load in KJ

$m_{(M.L)}$, $m_{(FPHE)}$, = Mass of *Malai Lachha* and FPHE in kg

$m_{(W)}$ = Quantity of cooling water required in kg

$C_{p(M.L)}$, $C_{p(FPHE)}$, $C_{p(W)}$ = Specific heat of *Malai Lachha* (3.2), FPHE (0.48) and Water (4.2) in KJ/kg K

$dt_{(M.L)}$, $dt_{(FPHE)}$, $dt_{(W)}$ = Temperature difference of *Malai Lachha,* FPHE and Water in K

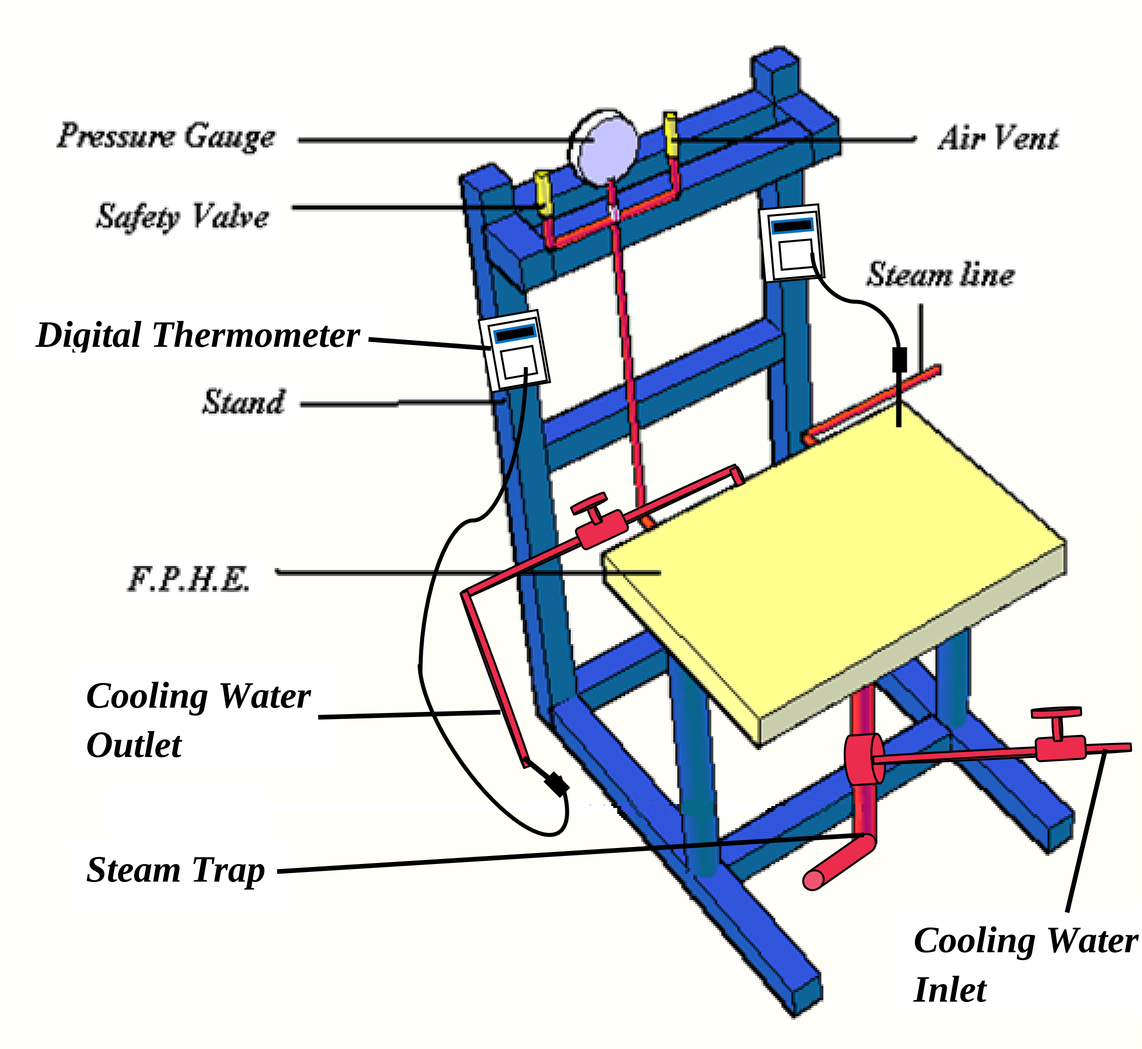

Fig. 3.1 Model of Cooling System with Flat Plate Heat Exchanger

Plate 3.2 Realization of Cooling System

3.1.2. Thin Film Scrapped Surface Heat Exchanger

The horizontal thin film scrapped surface heat exchanger (TFSSHE) of 304 stainless steel, having 40 cm I.D., 0.3 cm wall thickness and 100 cm overall length, was used (Plate No 3.3). Mild steel jacket of 45 cm I.D. with 0.3 cm wall thickness was provided. The heated length was 65 cm. For insulation the heat exchanger was provided with glass wool of 5 cm thickness. The end covers of heat exchanger were of 0.6 cm thickness and of 45 cm diameter. The rectangular outlet from heat exchanger of 15x7.5 cm^2 for the finished product had been provided with a rectangular slit to control the flow of finished product. The machine was provided with regulating and steam control. The machine component had been assembled and fitted on an angle iron frame with an inclination of 20 mm. The rotor assembly of stainless steel (SS) shaft of 2.5 cm diameter with 100 cm length was used. The SS blades of length 53 cm with 2.2 cm width had been hinged. The thickness of blade was 0.16 cm.

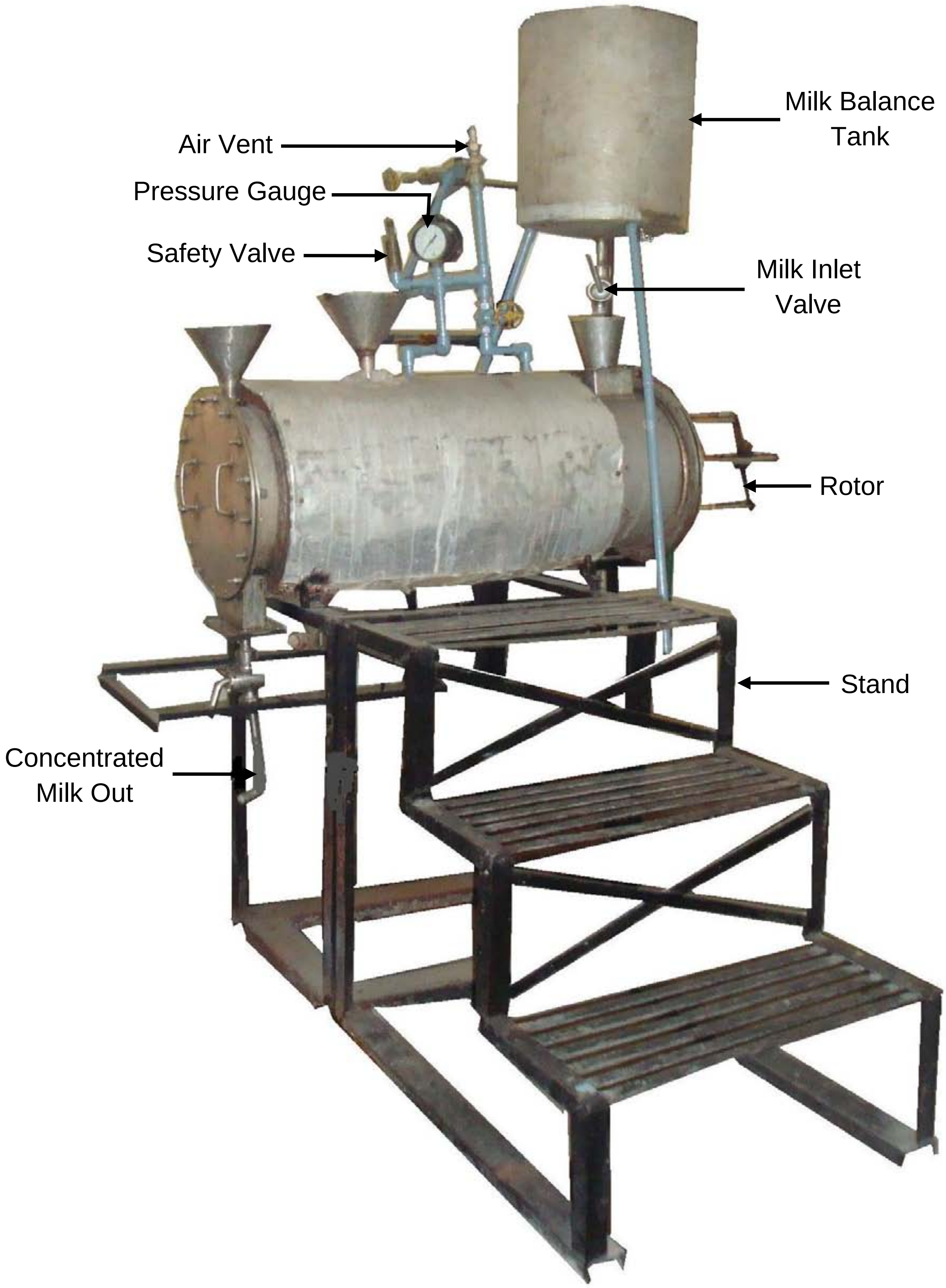

Plate 3.3 Thin Film Scrapped Surface Heat Exchanger

3.2. PERFORMANCE PARAMETERS

3.2.1. Constant parameters

Milk composition (5% Fat and 8.5% SNF)

3.2.1.1. Cow and buffalo milk in ratio of 3:1 respectively

3.2.1.2. Thickness of layers 0.1 cm for *Milk Crown Lachha*

3.2.1.3. Initial temperature of *Malai Lachha* for cooling: 85^{o}C

3.2.1.4. Final temperature of *Malai Lachha* for cooling: 45^{o}C

3.2.2. Variable parameters

3.2.2.1. Variable lip slot opening: 1, 1.5 and 2 mm

3.2.2.2. Concentration of milk: 30, 35 and 40 % total milk solids

3.2.2.3. Steam pressure: 0.3, 0.4 and 0.5 kg/cm^2

3.2.2.4. Flow rate of cooling water: 4, 5 and 6 kg/min

3.3. MATERIAL REQUIRED

Milk, Beaker, Oven/Desiccator, Thin Film Scrapped Surface Heat Exchanger (TFSSHE), Steam, Cutter, Scrapper, Potable water, Caustic soda, Refractometer, Digital thermometer and Stopwatch, etc.

3.3.1. Milk

Cow and buffalo milk was used in present study obtained from the experimental dairy of NDRI.

3.3.2. Beaker

A 200ml capacity glass beaker was used to collect the sample of milk for chemical analysis.

3.3.3. Oven/Desiccator

The Oven/Desiccator was used for chemical analysis of *Malai Lachha* sample.

3.3.4. Thin Film Scrapped Surface Heat Exchanger (TFSSHE)

The thin film SSHE with rotor speed of 115 rpm and steam pressure of 1.5 to 1.7 kg/cm^2 provided with steam control valve was used for concentration of milk.

3.3.5. Steam

The steam used for present investigation of research was obtained from the experimental dairy of NDRI.

3.3.6. Cutter

A stainless steel multi blade roller cutter was used for (1.8 cm) cutting *Malai Lachha* layers in uniform width.

3.3.7. Scrapper

A stainless steel scrapper blade was used for scrapping of *Malai Lachha* layer.

3.3.8. Water

Potable water available at the Dairy Engineering Division, NDRI, Karnal was used in this study.

3.3.9. Caustic soda

The Caustic soda was used for cleaning of SSHE and *Malai Lachha* machine effectively.

3.3.10. Refractometer

A Refractometer was used to check the concentration of milk. Two refractometers were used with the ranges of 0 to 30 and 28 to 62.

3.3.11. Stopwatch

A Stopwatch was used to record the time taken during *Malai Lachha* formation and cooling of *Malai Lachha.*

3.3.12. Digital thermometer

A thermometer with digital display was used to record the temperature of milk, concentrated milk, *Malai Lachha* layers and cooling water.

3.4. EXPERIMENTAL PROCEDURE

3.4.1. The Preparation of test samples:

The cow and buffalo milk (20 liters) was taken into a storage tank in the ratio of 3:1 (5.0 % Fat and 8.5 % SNF) and mixed thoroughly. The milk was fed into the thin film SSHE at a pressure of 1.5 – 1.7 kg/cm^2 for 25 – 30 minutes with rotor speed of 115 rpm and required mass flow rate to get the final desired level of concentration of milk.

3.4.2. Spreading on Flat Plate Heat Exchanger (FPHE):

The concentrated milk was fed into the feed cylinder and spreaded through the variable lip slot die, on FPHE. To and fro motion to the feed cylinder was given by the hand lever and at the same time feed was given to die by tilting of feed cylinder with the help of tilting lever for uniformly spreading over flat plate heat exchanger.

3.4.3. Formation of *Malai Lachha* layer:

A uniform concentrated milk layer was formed and heated for production of *Malai Lachha* over flat plate heat exchanger at low steam pressure of 0.3 – 0.5 kg/cm^2 for 40 – 50 minutes by evaporating moisture.

3.4.4. Cooling of *Malai Lachha* layer:

Cool the *Malai Lachha* layers immediately after drying on flat plate heat exchanger with a cooling water flow rate of 4 – 6 kg/min for 8 – 12 minutes.

3.4.5. Cutting of *Malai Lachha* layers:

A stainless steel multi blade roller cutter was used for uniform width (1.8cm) cutting of *Malai Lachha* layers on flat plate heat exchanger.

3.4.6. Scrapping of *Malai Lachha* layers:

A stainless steel scrapper blade was used for scrapping of *Malai Lachha* layer, after desired level of moisture has been removed. The *Malai Lachha* layer was put into aluminum trays for chemical analysis and sensory evaluation of the product.

3.4.5. Experimental procedure flow diagram of *Milk Crown Lachha*

Receiving Cow and Buffalo milk
(3:1 ratio, 5% Fat and 8.5% SNF)

↓

Mix thoroughly and collect sample
for chemical analysis

↓

Transfer into storage tank and concentrate in TFSSHE
(1.5 – 1.7 kg/cm^2 steam pressure, 115 rpm of rotor speed, upto 30 – 40% total solids)

↓

Spreading of concentrated milk through
the Variable Lip Slot Die on FPHE

↓

Formation of *Malai Lachha* layers over FPHE
(0.3 – 0.5kg/cm^2 steam pressure in 35 – 40 min)

↓

Cooling of *Malai Lachha* by circulating water after immediate drying (4 – 6kg/min in 8 – 12 min)

↓

Cutting by multiblade roller cutter and scrapping
by scrapper blade

↓

Collected in aluminium trays (testing and judging)

3.5. CHEMICAL ANALYSIS

3.5.1. Analysis of milk

The raw milk was tested for fat, SNF and total solids (TS) by using standard methodologies. Total solids (%) = SNF + fat

The fat content was determined by Gerber method (IS: 1224, 1977) and the SNF content was ascertained by lactometer.

3.5.2. Determination of Moisture content of *Malai Lachha*

Moisture content of *Malai Lachha* layers was determined by gravimetric method used for *Khoa* as suggested by BIS-2001.

Metal dishes were heated containing about 20 gm of prepared sand with a stirring rod in the oven for 1 hour. It was cooled in desiccators for 30 to 40 minutes. 2 gm of *Malai Lachha* was weighed into pre-weighed and pre-dried dishes. Sand was saturated by the careful addition of few drops of distilled water. It was thoroughly mixed with the *Malai Lachha*. Dishes were placed on the boiling water bath for 20 to 30 minutes and then transferred to the oven at 102 ± 1^{o}C for 4 hours. Dishes were cooled in desiccators and then weighed. This process of heating was repeated after every 30 minutes until the difference between two consecutive weighing were less than 0.1mg. Lowest weight was recorded.

$$\text{Moisture (\%)} = \frac{(W_1 - W_2)}{(W_1 - W_3)} \times 100$$

Where,

W_1 = weight in gm of dish with *Malai Lachha* before drying.

W_2 = weight in gm of dish with *Malai Lachha* after drying

W_3 = weight in gm of empty dish

3.5.3. Determination of Fat content of *Malai Lachha*

Fat content of *Malai Lachha* was determined by Mojonnier fat extraction tube. 1 to 1.5 gm of *Malai Lachha* was weighed into extraction tube. 10 ml of concentrated Hydrochloric acid was added and boiled gently. The tube was cooled under running water. 10 ml of alcohol was added and mixed well. 25 ml of solvent ether was added. Cork was closed and shakes vigorously for one minute. Open the tube was opened and 25 ml of light petroleum ether was added. Again close the tube and shake vigorously for 1 minute. The tube was allowed to stand until the ethereal layer was clear and completely separated from the aqueous layer usually not less than 30 minutes. Supernatant layer was decanted as such as possible into suitable flask by carefully bringing the cylinder bulb in to horizontal position. Experiment was repeated two more times by using 15 ml of solvent ether and petroleum ether each. Distil carefully the solvents and transferred to a pre-weighed dish. Dish was transferred in oven maintained at 98 to 100^{o}C for 1 hour and make sure that all volatile solvent traces are removed.

$$\text{Fat}\ (\%) = \frac{(W_2 - W_1)}{(W)} \times 100$$

Where,

W_2 = weight in gm of dish after drying

W_1 = weight in gm of empty dish

W = weight of sample

3.6. SENSORY EVALUATION OF *MALAI LACHHA*

A selected panel of judges performed sensory evaluation of different samples of *Malai Lachha* at different variable parameters. They are using 100 point score card, which comprised of flavour (50), body and texture (35) and colour and appearance (15) as suggested by Rajorhia *et al.* (1990).

CHAPTER – 4

RESULTS AND DISCUSSION

RESULTS AND DISCUSSION

In the present investigation systematic attempt has been made to mechanize the process of *Malai Lachha* production with desirable quality using Flat Plate Heat Exchanger. The preconditioning of the milk at three different levels of concentrations (i.e. 30%, 35% and 40% TMS), steam pressures (i.e. 0.3, 0.4 and 0.5 kg/cm^2) and cooling rates (i.e. 2500, 3000 and 3500 W) has been adopted in the present dissertation work. Product obtained was subjected to sensory evaluation using selected panel of judges. Based on the trials, the operating parameter for formation of desired quality of the product has been optimized. The results obtained during present investigation are discussed in the proceeding text here as mentioned below:

4.1. Optimisation of variable parameters

4.2. Process heating time as affected by Steam pressure and Initial concentration of milk

4.3. Variations in Cooling time as affected by Cooling rate and Initial concentration of milk

4.4. The chemical analysis of *Milk Crown Malai Lachha* layers

4.4.1. Effect of Initial concentrated milk and Steam pressure on fat and moisture content of *Malai Lachha* layers

4.5. The sensory evaluation of *Milk Crown Malai Lachha* layers

4.5.1. Flavour score as affected by Cooling rate

4.5.2. Body and Texture score as affected by Cooling rate

4.5.3. Colour and Appearance score as affected by Cooling rate

4.5.4. Overall Acceptability score as affected by Cooling rate

4.6. Selection of best combination of variable parameters

4.1. OPTIMISATION OF VARIABLE PARAMETERS

Experiments were conducted with four variables as concentration of milk, steam pressure, opening of lip slot variable die and cooling water flow rate at three levels each. Three sets of concentration of milk (30, 35, 40%), steam pressure (0.3, 0.4, 0.5 kg/cm^2), opening of lip slot variable die (1.0, 1.5, 2.0 mm) and cooling water flow rate (4, 5, 6 kg/min) were used in this study. On the basis of preliminary trials, 1.5 and 2.0 mm opening of lip slot variable die were unsuitable for formation of layers in mechanized production of *Malai Lachha*. Therefore *Malai Lachha* layer was formed at 1 mm opening of lip slot variable die at all concentrations, steam pressures and cooling water flow rates.

4.2. PROCESS HEATING TIME AS AFFECTED BY STEAM PRESSURE AND INITIAL CONCENTRATION OF MILK

Figure 4.1 and Table 4.1 shows the effect of concentrated milk (%TMS) and steam pressure on the heating time of 3:1 cow & buffalo milk for 0.1 cm thickness of *Malai Lachha* layers. The heating time of *Malai Lachha* was varied from 35 to 57 minutes. It can be inferred from the graph that, an increase in the concentration of milk (% TMS) at constant steam pressure increases the heating time. It can also be inferred from graph that an increase in the steam pressure at constant concentration of milk (% TMS) decreases the heating time. It is due to higher concentration and viscosity of concentrated milk which leads to more time during drying for diffusion of moisture from the upper layer (i.e. 3rd layer).

Table 4.1 Process heating time as affected by the Steam pressure and Initial concentration of milk									
Concentrated Milk	30% TMS			35% TMS			40% TMS		
Pressure (kg/sq.cm)	0.3	0.4	0.5	0.3	0.4	0.5	0.3	0.4	0.5
Heating Time (min.)	47	42	35	53	47	40	57	52	46

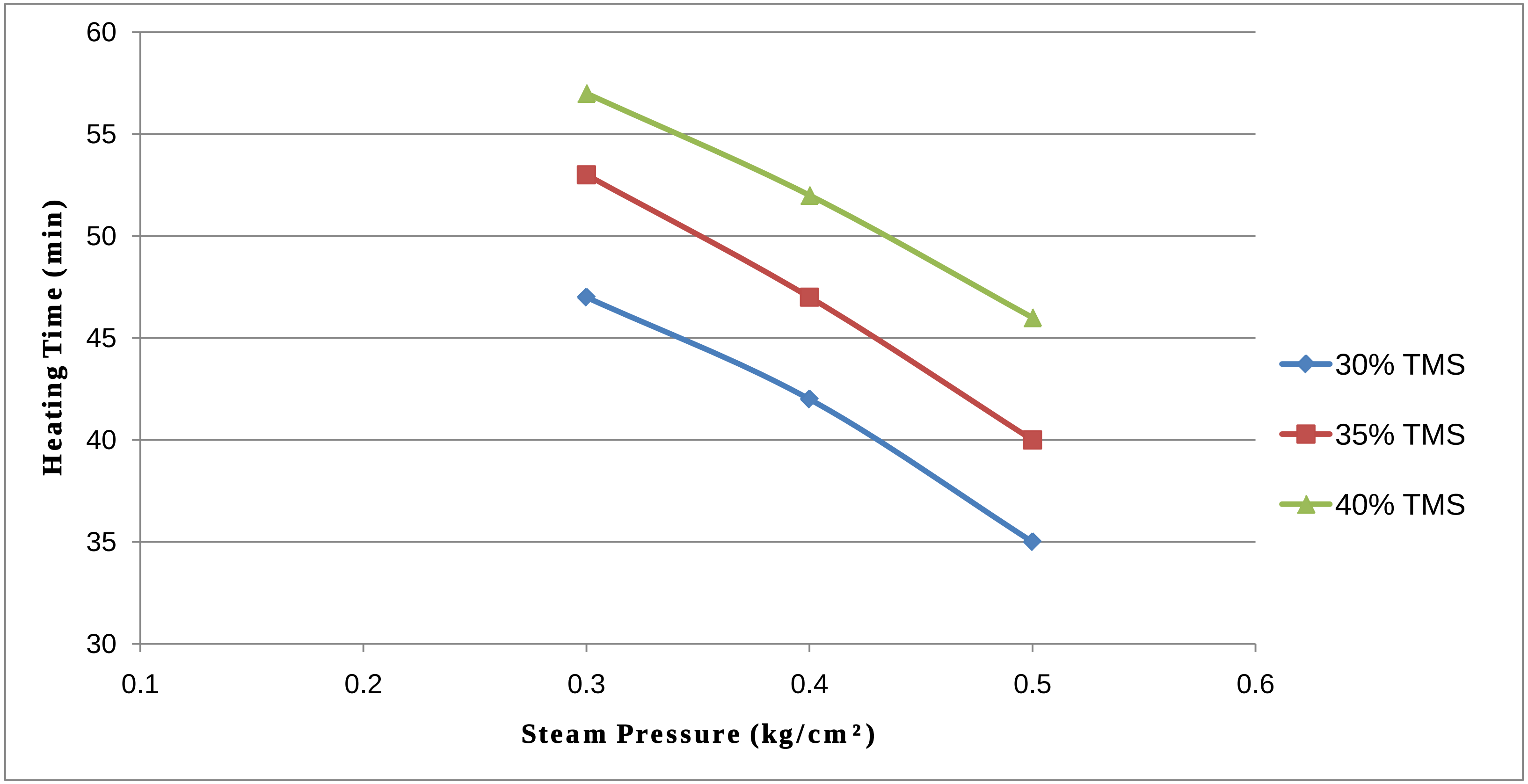

Fig. 4.1 **Process heating time as affected by the Steam pressure and Initial concentration of milk**

4.3. VARIATIONS IN COOLING TIME AS AFFECTED BY COOLING RATE AND INITIAL CONCENTRATION OF MILK

Figure 4.2 and Table 4.2 shows the effects of concentrated milk (%TMS) and cooling rate on the cooling time of 3:1 cow & buffalo milk for 0.1 cm thickness of *Malai Lachha* layers. The cooling time of *Malai Lachha* was varied from 7.0 to 13.5 minutes. In Table 4.2, the cooling rate of *Malai Lachha* was calculated by equation as shown under and specific heat of water is taken as 4.2 KJ/kg K.

$$Q = \frac{m * C_p * (T_{out} - T_{in})}{(t)}$$

Where,

Q = Cooling rate in Watt (W)

m = Mass of cooling water in kg

C_p = Specific heat of water in J/kg K

T_{out} = Temperature of water outlet in K

T_{in} = Temperature of water inlet in K

t = Time taken for cooling in Seconds (S)

It can be inferred from the graph that, as the concentration of milk (% TMS) increases at constant cooling rate, the cooling time increases.

Table 4.2 Variations in Cooling time as affected by Cooling rate and Initial concentration of milk

Concentrated Milk	30% TMS			35% TMS			40% TMS		
Water Flow Rate (kg/hr)	250	300	350	250	300	350	250	300	350
Cooling Time (min.)	11	9	7	12.5	10.5	8.5	13.5	11.5	9.5
Cooling Rate (W)	2504	3005	3507	2504	3005	3507	2504	3005	3507

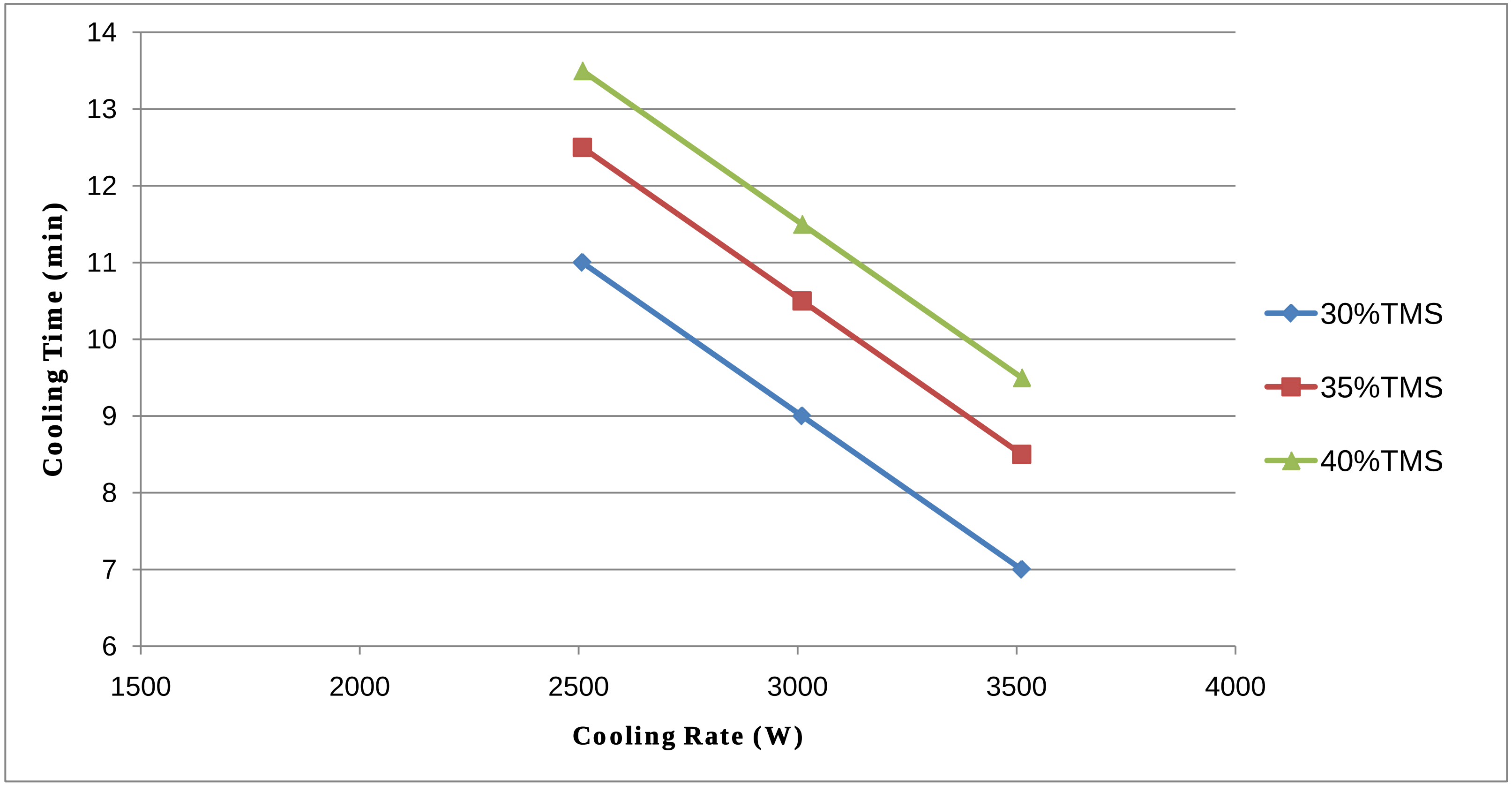

Fig. 4.2 **Variation in Cooling time as affected by Cooling rate and Initial concentration of milk**

4.4. THE CHEMICAL ANALYSIS OF *MILK CROWN MALAI LACHHA* LAYERS

The *Milk Crown Malai Lachha* layer so produced was analysed for fat and moisture contents. The average fat and moisture content of *Milk Crown Malai Lachha* layers produced at different operating conditions given in Table 4.3.

4.4.1. Effect of concentrated milk and steam pressure on fat and moisture content of *Malai Lachha* layers

Table 4.3 shows the effect of concentration of milk (%TMS) and steam pressure on fat and moisture content of 3:1 cow & buffalo milk for 1 mm thickness of *Malai Lachha* layers. The fat content in *Malai Lachha* was varied from 35.1 to 35.5 percent and moisture content in *Malai Lachha* was varied from 20.5 to 20.9 percent. It can be inferred from the table, the fat and moisture content of *Malai Lachha* did not vary significantly with the increase in the initial concentration of milk (%TMS) and steam pressure.

Table 4.3 Chemical Composition of *Milk crown Malai Lachha*									
Concentrated Milk	30% TMS			35% TMS			40% TMS		
Steam Pressure (kg/sq.cm)	0.3	0.4	0.5	0.3	0.4	0.5	0.3	0.4	0.5
Fat (%)	35.1	35.3	35.2	35.3	35.2	35.4	35.2	35.5	35.3
Moisture (%)	20.8	20.9	20.7	20.9	20.6	20.7	20.8	20.5	20.6

4.5. THE SENSORY EVALUATION OF *MILK CROWN MALAI LACHHA* LAYERS

The *Milk Crown Malai Lachha* layers so produced were sensory evaluated. The average sensory score of *Milk Crown Malai Lachha* layers produced at different operating conditions given in Table 4.4.

4.5.1. Flavour score as affected by Cooling rate

Table 4.4 and Figure 4.3, 4.4, 4.5 shows the effects of steam pressure and cooling rate on flavour of 3:1 cow & buffalo milk for 1 mm thickness of *Malai Lachha* layers at three different concentrations (30, 35 and 40%) of milk. The flavour score of *Malai Lachha* was varied from 37.5 to 41.5. It can be inferred from the graphs that 35% TMS, 0.4 kg/cm^2 steam pressure and 3500 W cooling rate carry highest flavour score of 41.5. These values of %TMS, steam pressure and cooling rate are best suitable for *Malai Lachha* preparation (due to caramelized rich flavour). At 30% and 40% TMS, and 0.3 and 0.5 kg/cm^2 steam pressure, *Malai Lachha* layer carries lower flavour score of 39.5 and 40 (due to flat and slight bitter flavour) respectively. It can also be inferred from the graphs' that, with the increase in the cooling rate at constant steam pressure, the flavour score increases at all concentrations of milk (% TMS) because cooling minimizes the browning occurs after drying of *Malai Lachha* layers.

Table 4.4 Sensory Evaluation of *Malai Lachha*

Concentrated Milk (% TMS)	Steam Pressure (kg/cm^2)	Cooling Rate (W)	Flavour (50)	Body and Texture (35)	Colour and Appearance (15)	Overall Acceptability (100)
30%	0.3	2500	38	28.5	10.8	77.3
		3000	38.5	28.8	11.2	78.5
		3500	39.2	29.2	11.5	79.9
	0.4	2500	38.4	29	11.3	78.7
		3000	39	29.4	11.6	80
		3500	39.5	29.7	11.8	81
	0.5	2500	37.5	28.2	10.3	76
		3000	38.2	28.4	10.7	77.3
		3500	38.8	28.7	11	78.5
35%	0.3	2500	39.5	29.8	10.7	80
		3000	40.2	30.3	11.1	81.6
		3500	40.7	30.8	11.5	83
	0.4	2500	40	30.2	11.2	81.4
		3000	40.7	30.7	11.6	83
		3500	41.5	31	12	84.5
	0.5	2500	39	29.3	10.1	78.4
		3000	39.6	29.8	10.5	79.9
		3500	40.3	30.3	10.9	81.5
40%	0.3	2500	39	29.8	11.2	80
		3000	39.6	30.2	11.5	81.3
		3500	40	30.5	11.7	82.2
	0.4	2500	38.4	29.3	10.8	78.5
		3000	39.1	29.6	11.1	79.8
		3500	39.8	30.1	11.5	81.4
	0.5	2500	37.8	28.8	10.3	76.9
		3000	38.5	29.2	10.7	78.4
		3500	39.2	29.7	11	79.9

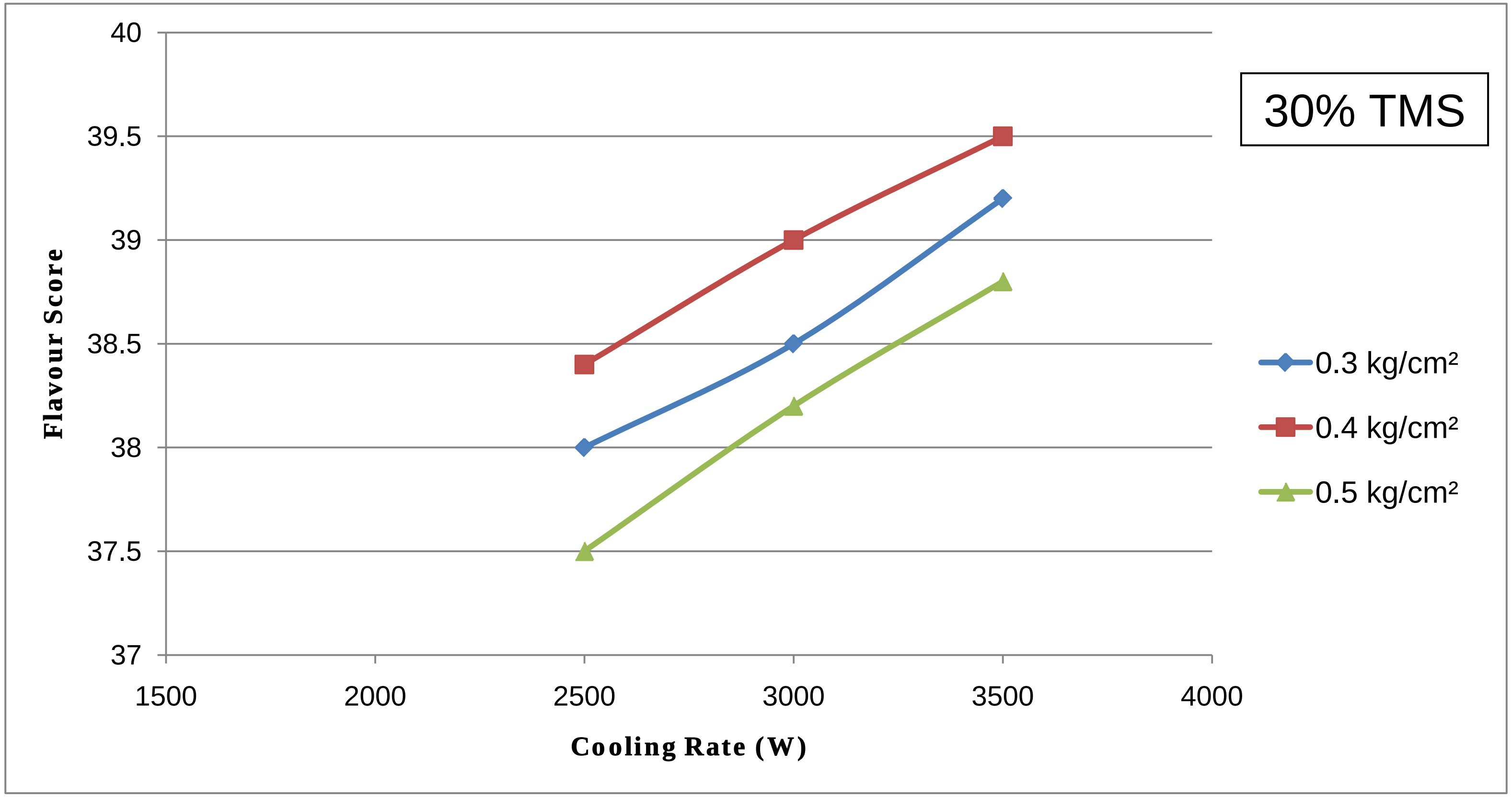

Fig. 4.3 Flavour score as affected by Cooling rate

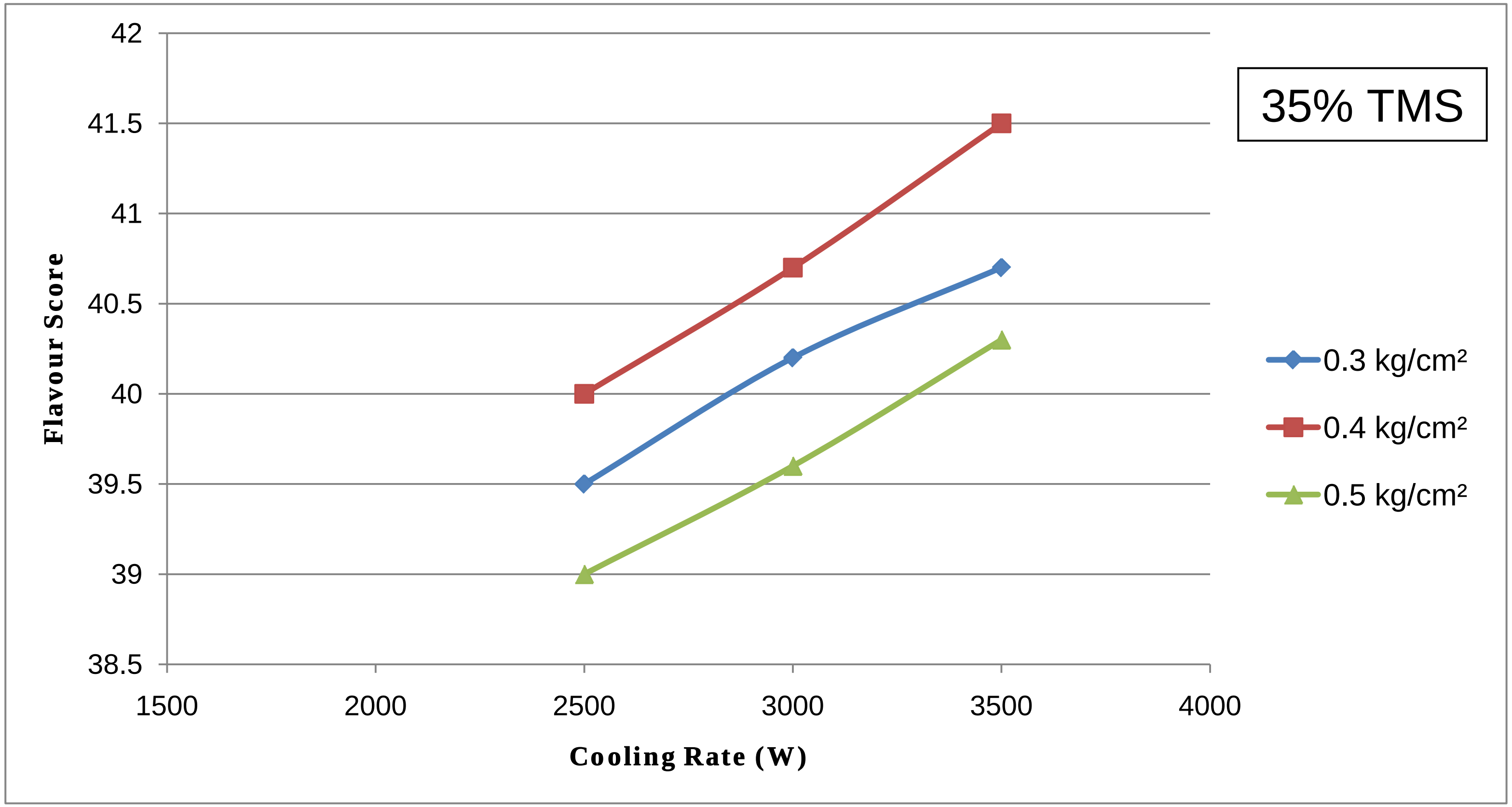

Fig. 4.4 Flavour score as affected by Cooling rate

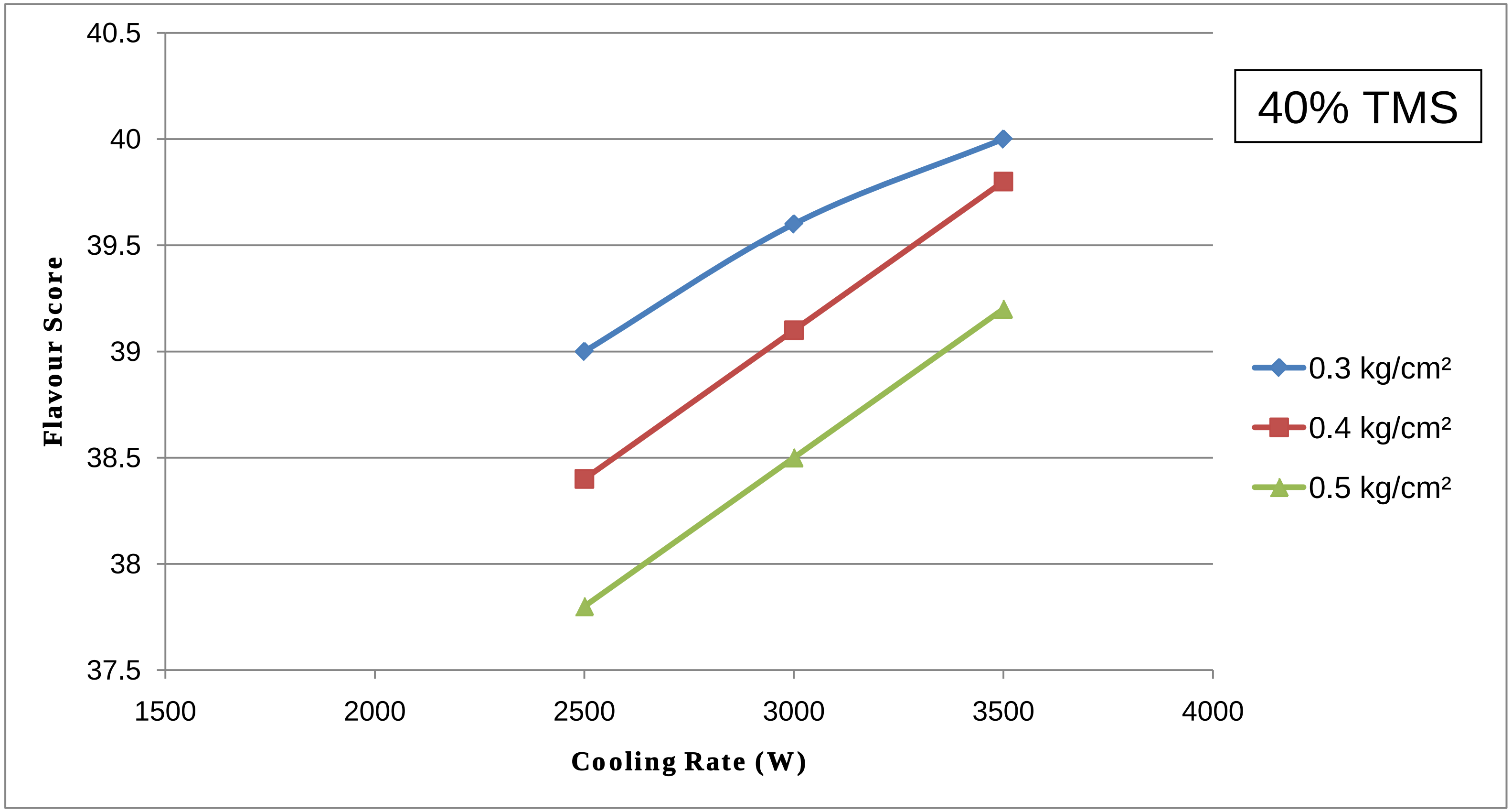

Fig. 4.5 Flavour score as affected by Cooling rate

4.5.2. Body and Texture score as affected by Cooling rate

Table 4.4 and Figure 4.6, 4.7, 4.8 shows the effects of steam pressure and cooling rate on body and texture of 3:1 cow & buffalo milk for 1 mm thickness of *Malai Lachha* layers at three different concentrations (30, 35 and 40%) of milk. The body and texture score of *Malai Lachha* was varied from 28.2 to 31. It can be inferred from the graphs that 35% TMS, 0.4 kg/cm^2 steam pressure and 3500 W cooling rate carry highest body and texture score of 31. These values of %TMS, steam pressure and cooling rate are best suitable for *Malai Lachha* preparation (due to soft homogeneous and thin shredded layers). At 30% and 40% TMS, and 0.3 and 0.5 kg/cm^2 steam pressure, *Malai Lachha* layers carry lower body and texture score of 29.7 and 29.8 (due to very soft and dryness, brittle body and texture) respectively. It can also be inferred from the graphs that with the increase in the cooling rate at constant steam pressure, the body and texture score increases at all concentrations of milk (% TMS) because cooling immediately after drying minimizes the dryness in *Malai Lachha* layers.

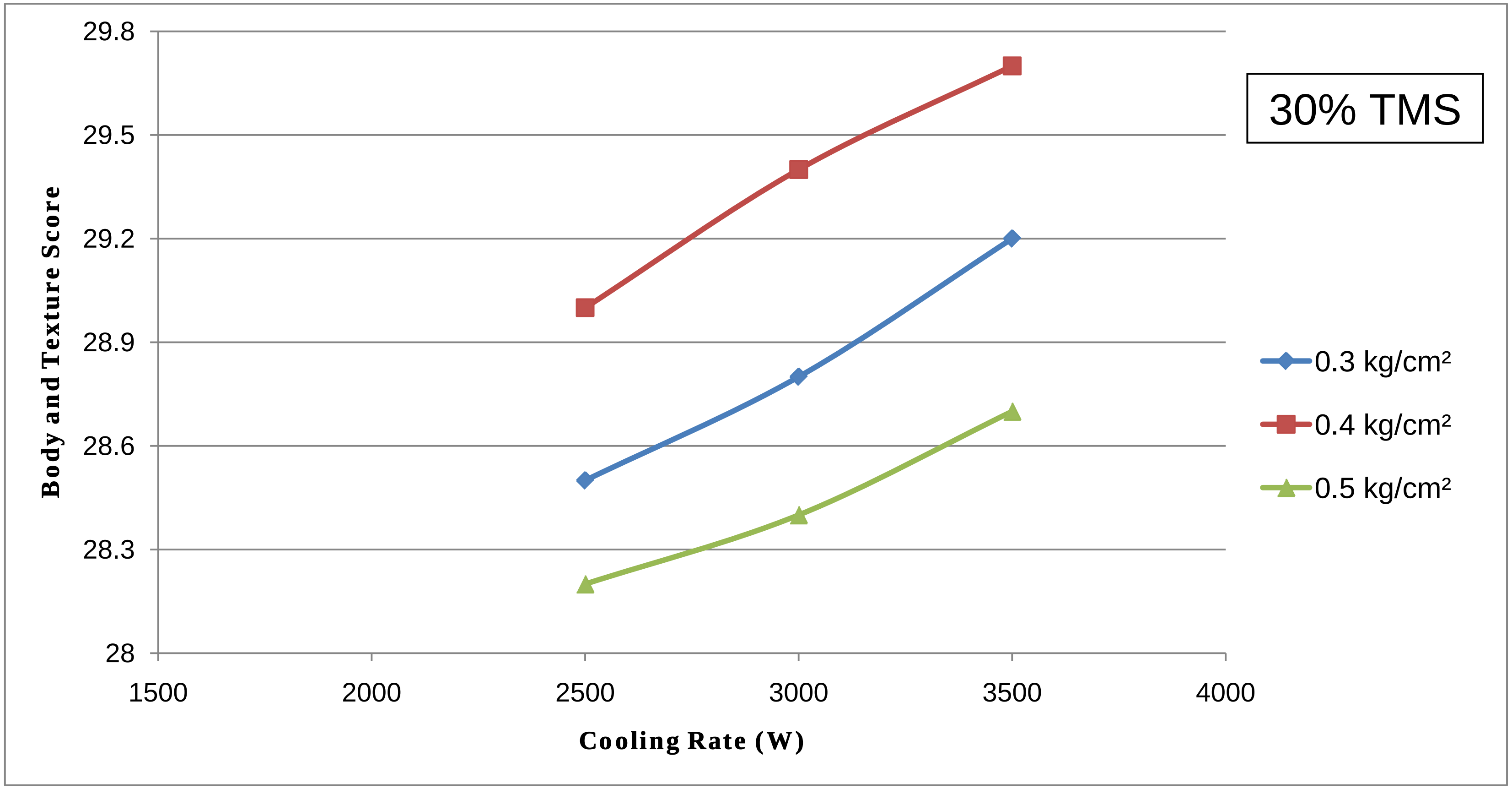

Fig. 4.6 Body and Texture score as affected by Cooling rate

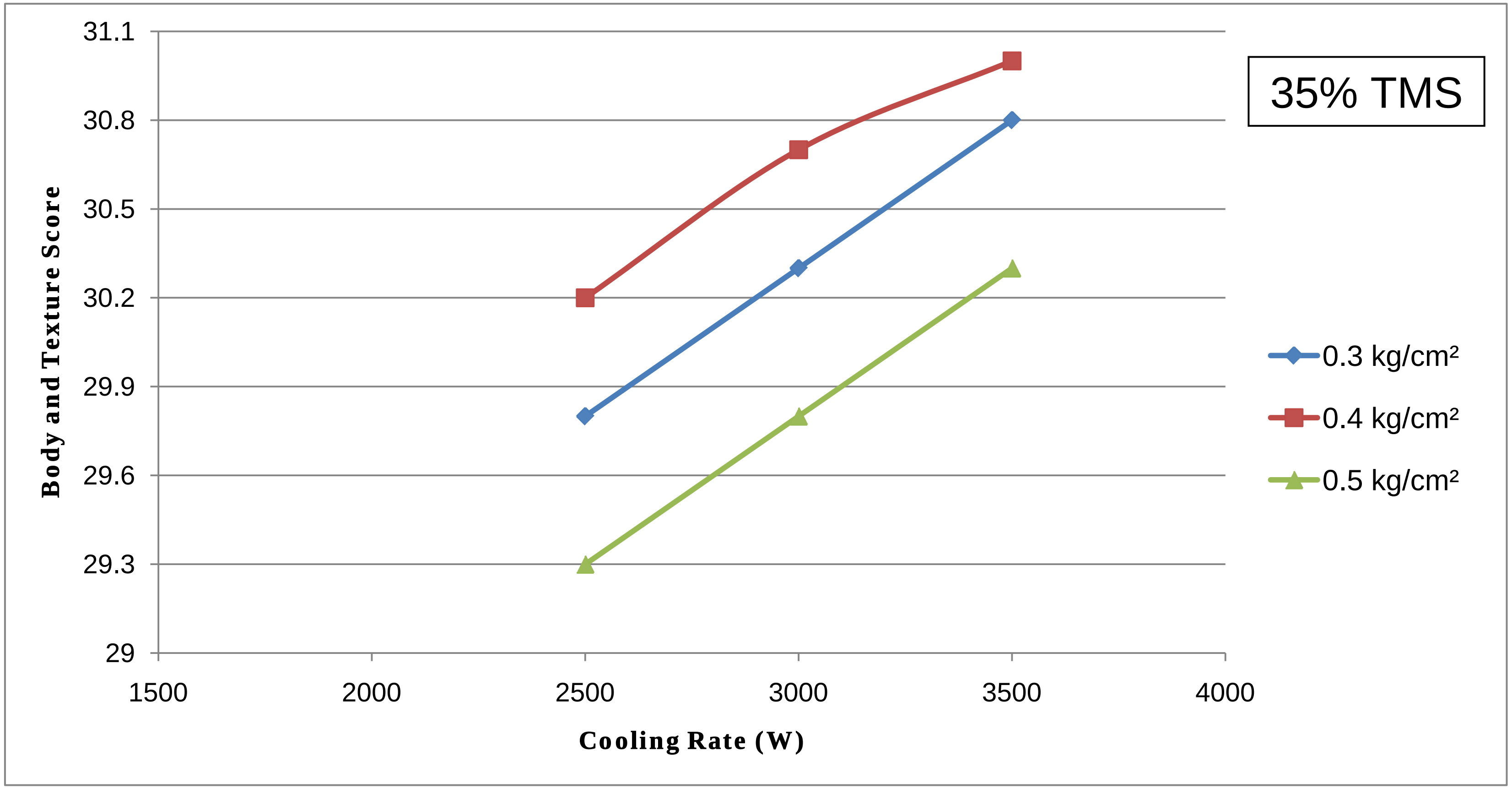

Fig. 4.7 Body and Texture score as affected by Cooling rate

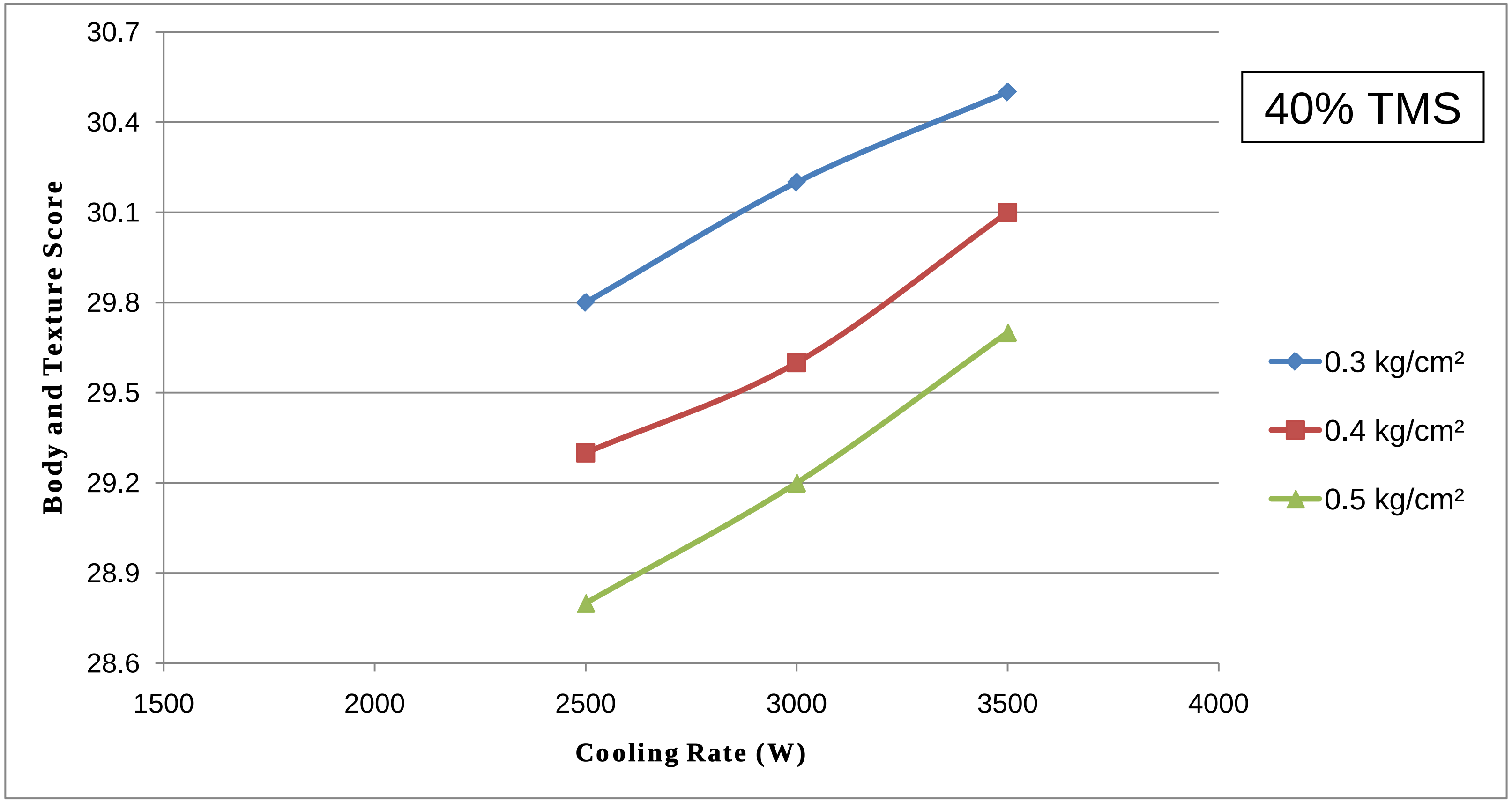

Fig. 4.8 Body and Texture score as affected by Cooling rate

4.5.3. Colour and Appearance score as affected by Cooling rate

Table 4.4 and Figure 4.9, 4.10, 4.11 shows the effects of steam pressure and cooling rate on colour and appearance of 3:1 cow & buffalo milk for 1 mm thickness of *Malai Lachha* layers at three different concentrations (30, 35 and 40%) of milk. The colour and appearance score of *Malai Lachha* was varied from 10.1 to 12. It can be inferred from the graphs that 35% TMS, 0.4 kg/cm^2 steam pressure and 3500 W cooling rate carry highest colour and appearance score of 12. These values of %TMS, steam pressure and cooling rate are best suitable for *Malai Lachha* preparation (due to light caramel colour). At 30% and 40% TMS, and 0.3 and 0.5 kg/cm^2 steam pressure, *Malai Lachha* layers carries lower colour and appearance score of 11.8 and 11.7 (due to whitish and more brownish colour) respectively. It can also be inferred from the graphs that as the cooling rate increases at constant steam pressure, the colour and appearance score increases at all concentrations of milk (% TMS) because cooling immediately after drying reduces the browning in *Malai Lachha* layers.

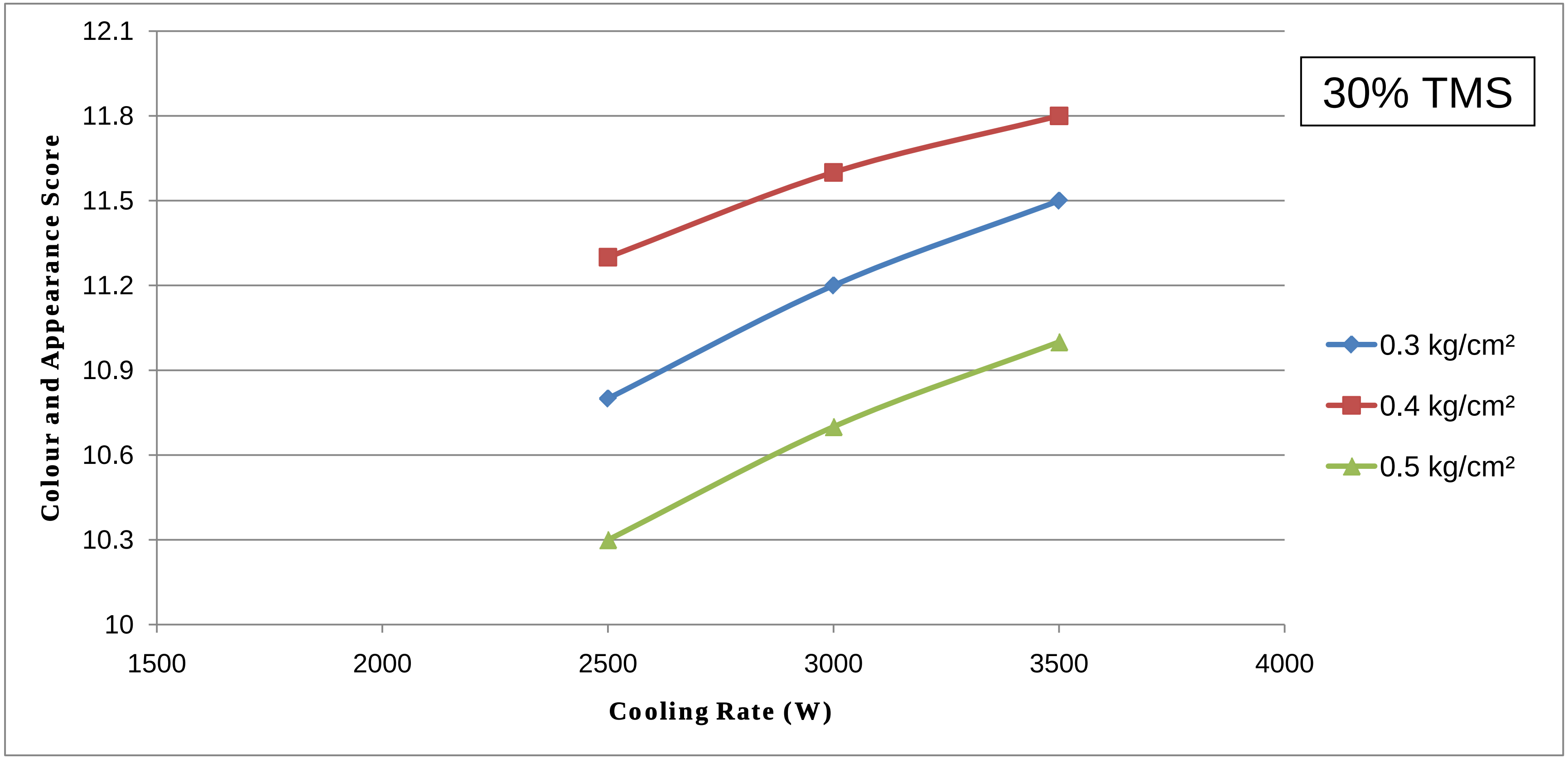

Fig. 4.9 Colour and Appearance score as affected by Cooling rate

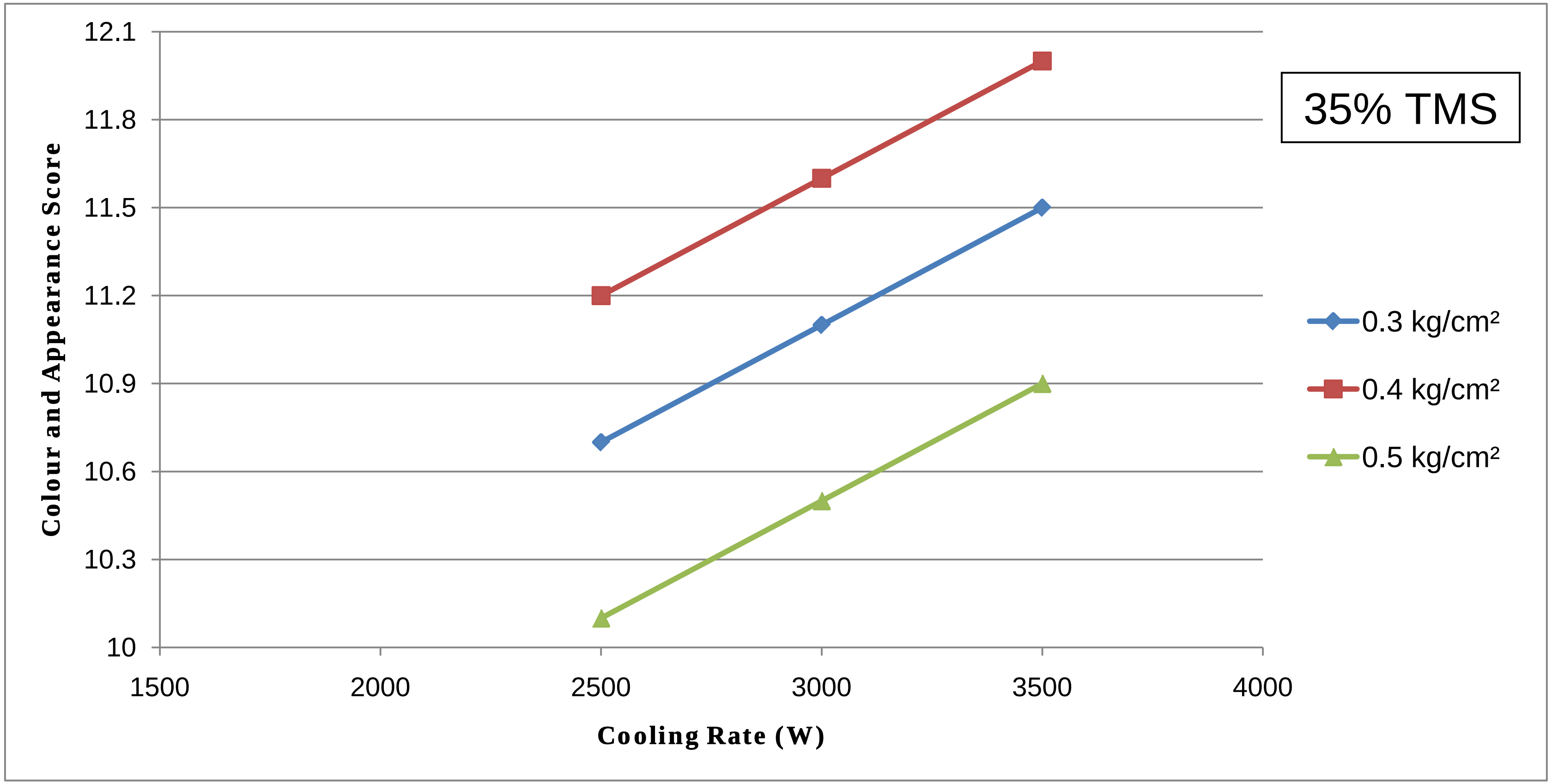

Fig. 4.10 Colour and Appearance score as affected by Cooling rate

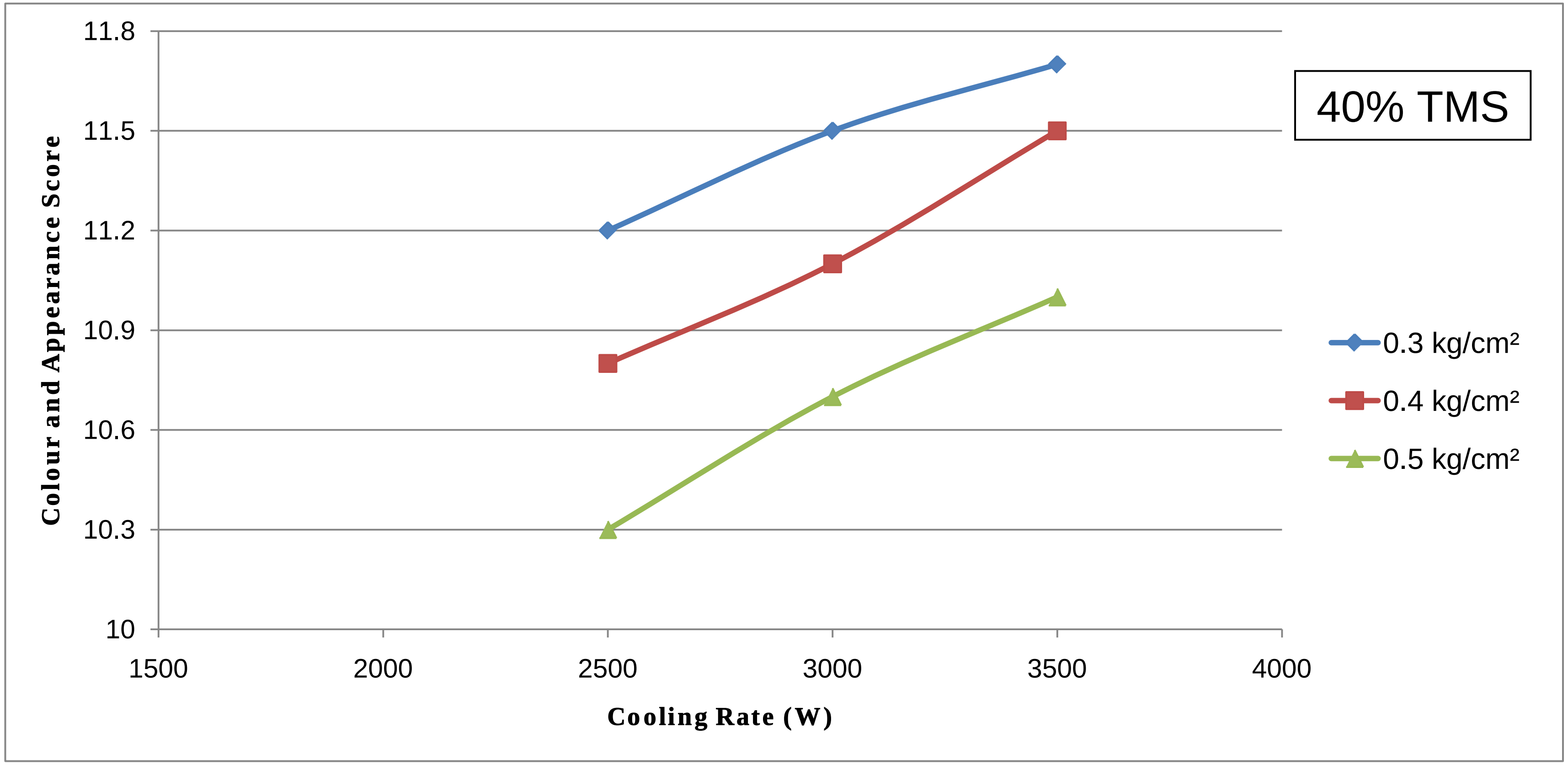

Fig. 4.11 Colour and Appearance score as affected by Cooling rate

4.5.4. Overall Acceptability score as affected by Cooling rate

Table 4.4 and Figure 4.12, 4.13, 4.14 shows the effects of steam pressure and cooling rate on overall acceptability of 3:1 cow & buffalo milk for 1 mm thickness of *Malai Lachha* layers at three different concentrations (30, 35 and 40%) of milk. The overall acceptability score of *Malai Lachha* was varied from 76 to 84.5. It can be inferred from the graphs that 35% TMS, 0.4 kg/cm^2 steam pressure and 3500 W cooling rate carries highest overall acceptability score of 84.5. These values of %TMS, steam pressure and cooling rate are best suitable for *Malai Lachha* preparation (due to caramelized rich flavour, soft homogeneous, thin shredded layers and pale yellow colour). At 30% and 40% TMS, and 0.3 and 0.5 kg/cm^2 steam pressure, *Malai Lachha* layer carries lower overall acceptability score of 81 and 82.2 (due to flat and slight bitter flavour, very soft, dryness and more brown colour) respectively. It can also be inferred from the graphs that as the cooling rate increases at constant steam pressure, the overall acceptability score increases at all concentrations of milk (% TMS) because cooling immediately after drying minimizes the changes in flavour, body and texture and colour and appearance in *Malai Lachha* layers.

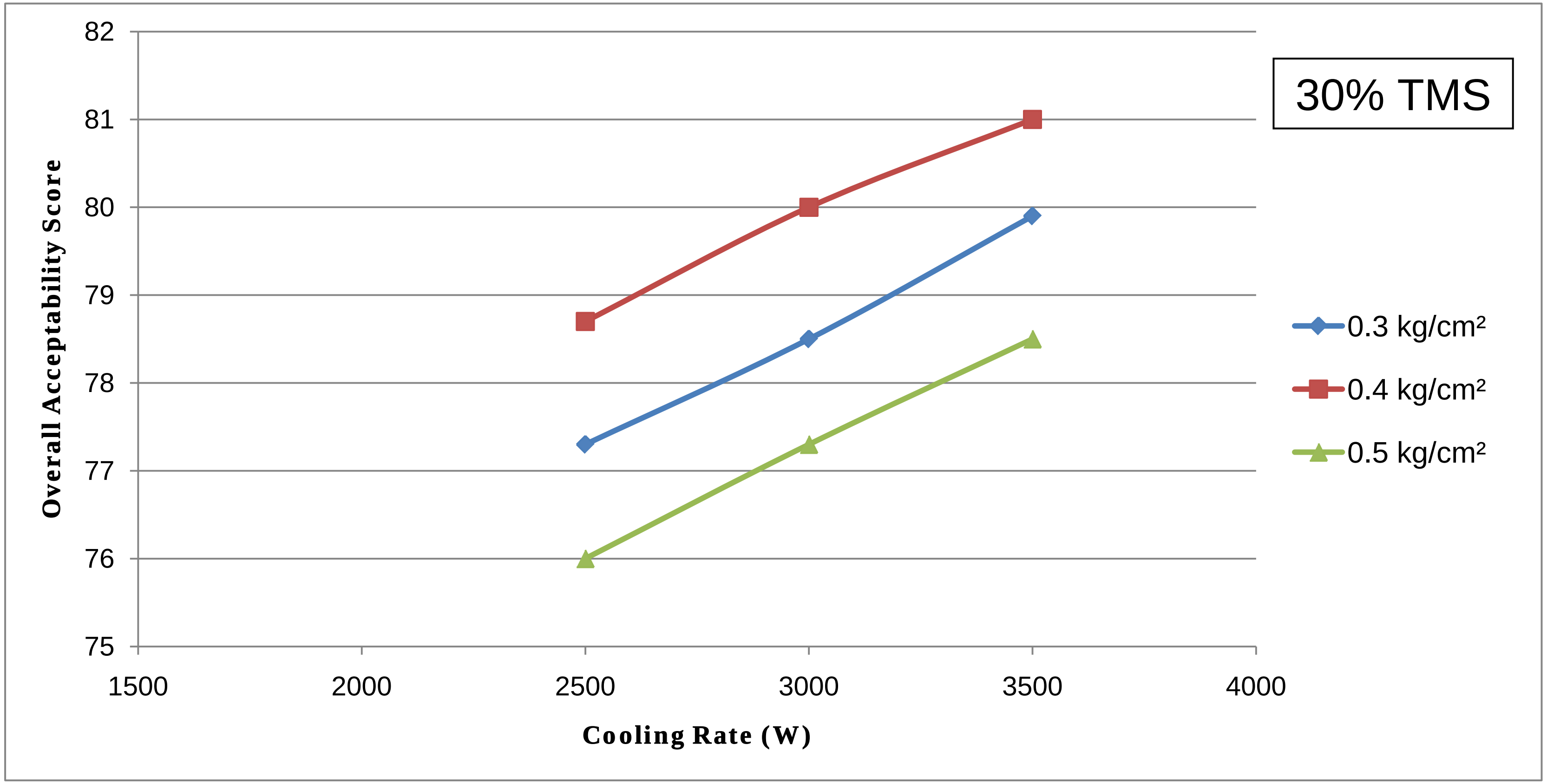

Fig. 4.12 Overall Acceptability score as affected by Cooling rate

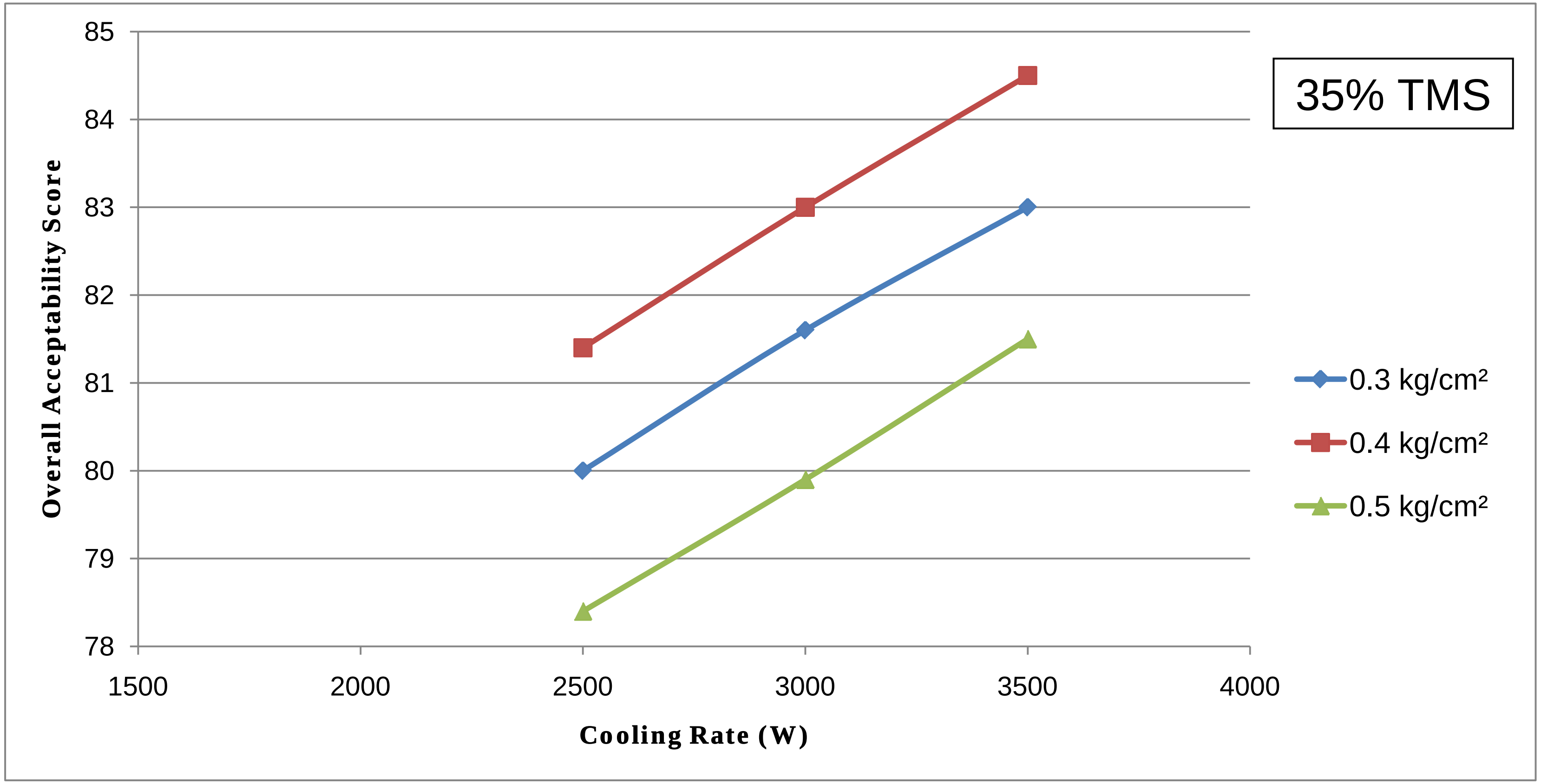

Fig. 4.13 Overall Acceptability score as affected by Cooling rate

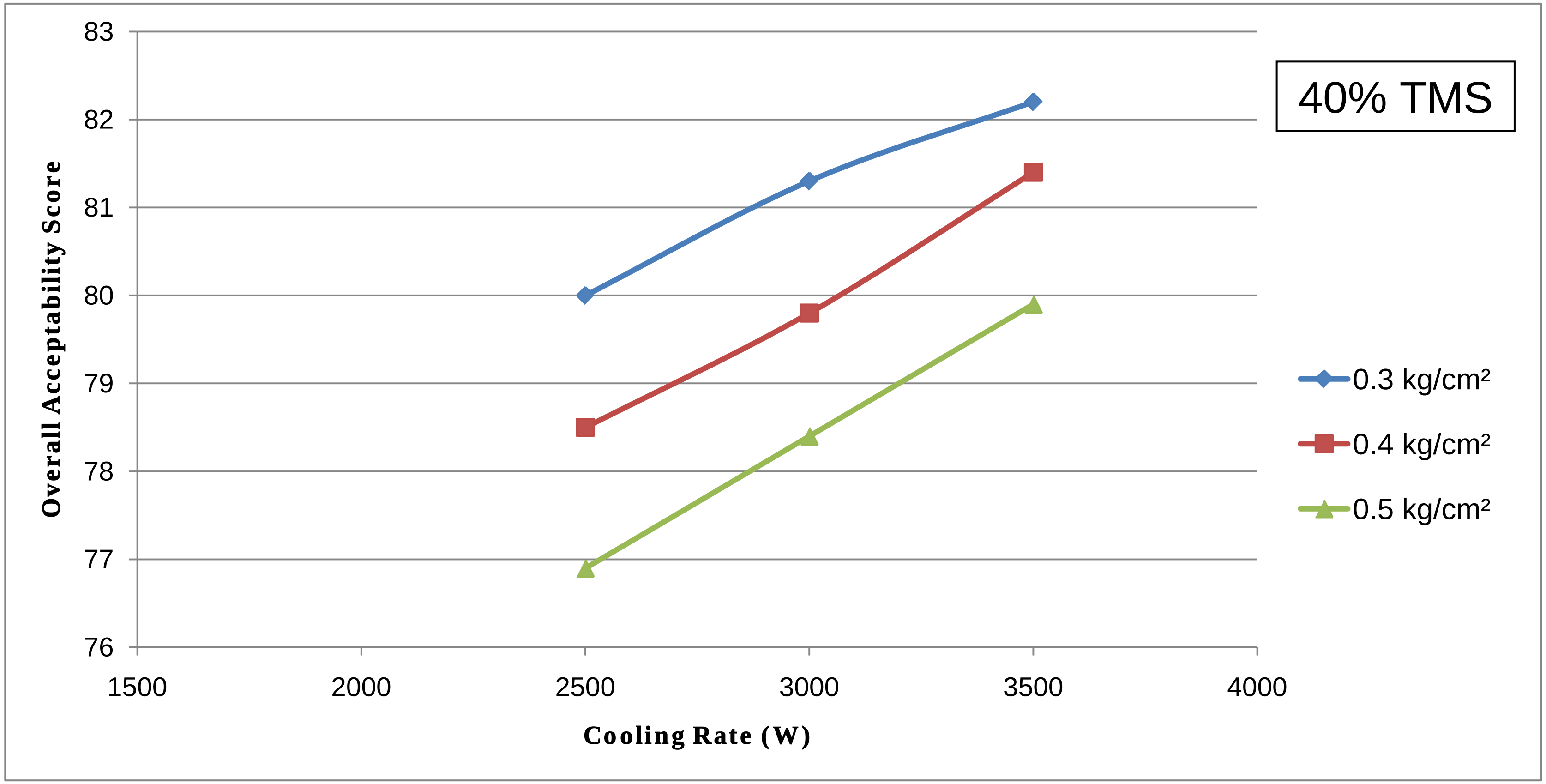

Fig. 4.14 Overall Acceptability score as affected by Cooling rate

4.6. SELECTION OF BEST COMBINATION OF VARIABLE PARAMETERS

The best combination of concentration of milk (% TMS), steam pressure and cooling rate has been selected on the basis of sensory score and least time elapsed in production of satisfactory quality *Malai Lachha.* The opening of lip slot die was set as 1mm. The product obtained met the standards with 35.1% fat and 21% moisture content. The sensory evaluated *Malai Lachha* of concentrated milk at 30% and 40% TMS with all three steam pressures (0.3, 0.4 and 0.5 kg/cm^2) and cooling rates (2500, 3000 and 3500 W) were found less score than the *Malai Lachha* of concentrated milk at 35% TMS with 0.4kg/cm^2 steam pressure and 3500 W cooling rate. Hence a combination of variable parameters, concentration of milk at 35% TMS, 1mm opening of lip slot die, 0.4 kg/cm^2 steam pressure and 3500W cooling rate with 55 minutes of total processing time (heating time 47 minutes and cooling time 8 minutes) was selected for the production of best quality *Malai Lachha.*

CHAPTER – 5

SUMMARY AND CONCLUSION

SUMMARY AND CONCLUSIONS

Indigenous dairy products, apart from being an integral part of Indian heritage, have great social, religious, cultural, medicinal and economic importance. Dairy industry in India at present is passing through a transition phase as major emphasis is being laid on manufacture of indigenous dairy products. Heat treatments and concentrations are the major unit operations involved in preparation of many indigenous dairy products. Most of indigenous dairy products are still manufactured by using traditional batch processes. Due the growth of dairy industry, there is a need to develop equipments for manufacture of these dairy products.

Malai Lachha is a heat desiccated clotted cream shredded thin firm layers, pale yellow to light caramel in color and delicious in tastes. *Malai Lachha* is used as a finishing material on top of the sweets to make it more attractive by garnishing especially on the Bengali sweets. It also adds delicious taste and nutritive value to final products. Still most of the sweets manufacturers are producing *Malai Lachha* traditionally. This method is laborious, time consuming and unhygienic process.

Owing to the rapid increase in traditional milk products demand, the industry faces the challenge of producing indigenous products in a hygienic manner and with machines. An attempt has been made to develop cooling system with flat plate heat exchanger for mechanized production of *Malai Lachha* layers. Present study included variable parameters of three different concentrated milk (% TMS), steam pressures and cooling rates. Studies were also conducted to see the influence of the concentrated milk (% TMS), steam pressure and cooling rate on chemical composition and sensory characteristics of *Malai Lachha* layers.

The present study led to the following conclusions:

1. The cooling system was developed with flat plate heat exchanger and necessary instruments for mechanized production of *Malai Lachha.*

2. The scrapped surface heat exchanger was used to concentrate the milk for different concentration levels (% TMS) to get smooth and soft body and to avoid grainy texture in the final product of *Malai Lachha.*
3. On the basis of preliminary trials, 1.5 and 2.0 mm opening of lip slot variable die were unsuitable for formation of layers in mechanized production of *Malai Lachha* for all three concentrations, steam pressures and cooling rates.
4. The fat and moisture content of *Malai Lachha* did not vary significantly with the increase in the initial concentration of milk (%TMS) and steam pressure.
5. The sensory characteristics of final *Milk Crown Malai Lachha* product was found to be best in case of 35% TMS concentrated milk (3:1 ratio of cow and buffalo milk), 0.4 kg/cm^2 steam pressure and 3500 W cooling rate with 55 minutes of process time (heating and cooling) among all the combinations resulting in the sensory score of flavour 41.5, body and texture 31, colour and appearance 12 and overall acceptability 84.5.

The problems and suggestions in production of *Malai Lachha* are mentioned below:

1. For more uniform heating, the flat plate heat exchanger should require baffle plates.
2. A steam control valve of higher accuracy should be used to control the steam pressure.
3. Pool boiling of concentrated milk was observed at 0.5 kg/cm^2 steam pressure. Two fluid nozzles can be used for spreading of concentrated milk for finer thin layer to avoid the boiling.
4. Extruder die can be used for higher concentration of milk with low positive pressure.
5. Enclosed flat plate heat exchanger with vacuum can be used for drying of layers to reduce the process time and browning in *Malai Lachha.*
6. Studies can be initiated for other two types of *Malai Lachha* layers.
7. New product with dry fruits ingredients can be developed as *Malai* layers (Pappad).

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APPENDICES

Appendix No:- 1

Score card for Sensory evaluation sample of ***Milk Crown Malai Lachha.***

Name of judge:……………………………………………

Date:

Score of Samples:-

Characteristics	Control Sample	Samples		
		1	2	3
Flavour (50)				
Body &Texture (35)				
Colour &Appearance (15)				
Overall Acceptability (100)				

a) Remarks, if any

Signature

Appendix No:- 2

Variations in Cooling time as affected by Cooling rate and Initial concentration of milk

Concentrated Milk	30% TMS			35% TMS			40% TMS		
Water Flow Rate (kg/hr)	250	300	350	250	300	350	250	300	350
Cooling Time (min.)	11	9	7	12.5	10.5	8.5	13.5	11.5	9.5
Cooling Water Inlet (°C)	22.8	23.4	23.8	24	24.7	25.4	26	26.2	26.5
Cooling Water Outlet (°C)	31.4	32	32.4	32.6	33.3	34	34.6	34.8	35.1
Cooling Rate (W)	2504	3005	3507	2504	3005	3507	2504	3005	3507
Water Quantity (kg)	46.5	45	40.5	53.8	52.5	49.5	58.3	57.5	55.4