

ENGINEERING INTERVENTION IN MECHANIZATION OF MOZZARELLA CHEESE MANUFACTURE

Thesis

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in partial fulfillment of the requirements for the degree of**

**MASTER OF TECHNOLOGY
in
DAIRY ENGINEERING
(Minor Subject: Dairy Technology)**

By

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CERTIFICATE – I

This is to certify that the thesis entitled, “**ENGINEERING INTERVENTION IN MECHANIZATION OF MOZZARELLA CHEESE MANUFACTURE**” submitted for the degree of **M.Tech.**, in the subject of **Dairy Engineering** (Minor Subject: **Dairy Technology**) of the Guru Angad Dev Veterinary and Animal Sciences University, Ludhiana, is a bonafide research work carried out by **Charanjit Singh (L-2017-D-01-M)** under my supervision and that no part of this thesis has been submitted for any other degree.

The assistance and help received during the course of investigation have been fully acknowledged.

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ABSTRACT

Cheese is the fresh or matured product obtained by the drainage of whey after coagulation of milk through use of rennet and starter. There are more than 2000 individual varieties of cheeses out of which Mozzarella cheese is one of the most popular variety worldwide and accounts for nearly one-third of total cheese consumption. It belongs to the member of pasta-filata group of cheese, which was originated in southern region of Italy. In India, buffalo milk contributes approximately 51% to total milk production of the country; whereas in Punjab the share of buffalo milk is as high as 71% (Anon 2016). There is high potential of making mozzarella cheese from buffalo milk as technological knowhow is well documented for this product. Despite the increase in production of cheese by 15% per year, in response to growing demand in India and availability of ample buffalo milk in Punjab, dairy processors are not able to tap the market potential. The reason for this is lack of indigenous mechanization in mozzarella cheese at small scale. To bridge this gap, two existing mechanisms i.e. planetary mixer (two attachments) and screw mixer were tested for kneading and stretching. Out of two mechanism screw mixer was found to be suitable which gave yield of 76.91%. After some modifications the new design of screw mixer was fabricated. For power transmission system V-belt was employed along with 1.0HP (a.c.) motor. For lowering the speed, reduction unit was used with a speed ratio of 1/25 to increase the torque value. In fabricated unit, rpm was varied as 10, 15 and 20 rpm along with water used for kneading as 0.5L, 1.0L and 1.5L. Efficiency of unit (on the basis of curd) decreased with increase in both rpm and amount of kneading amount from 80.954% to 78.99%. The values of Stretchability, meltability, moisture content and free oil formation increased with increase in the rpm as well as water used for kneading. These values were compared with mozzarella cheese made by conventional method. On comparison of the values generated from conventional method and mechanized method it was concluded that the results from conventional method were closer to the values generated in case with highest speed (rpm-20) and highest kneading water amount.

Keywords: Mechanization, Mozzarella cheese, kneader, screw mixer

Signature of Major Advisor

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ABBREVIATIONS

°C	:	Degree centigrade
AC	:	Alternating current
cm	:	Centimeter
g/cm ²	:	gram per centimeter square
gm	:	gram
h	:	Hour
hp	:	Horse Power
Hz	:	Hertz
KCl	:	Potassium Chloride
kg	:	Kilogram
kg/min	:	Kilogram per minute
KW	:	Kilowatt
L	:	Litres
m	:	Meter
m/s	:	Meter per second
m ²	:	Meter square
mg	:	Milligram
min.	:	Minutes
ml	:	Milliliter
mm	:	Millimeter
mm ²	:	Millimeter square
mW	:	Milliwatt
pH	:	Potential of Hydrogen
PLC	:	Programmable logic controller
ppm	:	Parts per million
rpm	:	Revolution per minute
Sec	:	Second
T	:	Temperature
V	:	Volt
w/w	:	Weight by weight

CHAPTER I

INTRODUCTION

Mozzarella cheese is a soft, unripened cheese variety of the Pasta-filata family which had its origin in its Battipaglia region of Italy. Conventionally, Mozzarella cheese was made from buffalo milk. However, these days it is being manufacture in European countries. Cheese is the ripened or unripened soft, semi-hard, hard, or extra-hard product obtained by coagulation of the milk protein with the help of rennet or starter addition.

There are more than 2000 individual varieties of cheeses which are being manufactured around the world (Waltra *et al* 2006).Mozzarella cheese is one of the most popular cheese worldwide which has around 30% consumption out of total cheese consumption. In countries like Italy and Bulgaria buffalos are herded for the production of Mozzarella cheese by traditional method. Mozzarella is eaten fresh because it is not aged like other cheeses. It is used in salads, seafood, meats, vegetables and many food recipes as a seasoning ingredient.

The Mozzarella cheese which is prepared from the milk of buffalo is known as *Mozzarella di Bufala*, and other varieties of this cheese which is made from pasteurised or unpasteurised cow milk is known as *Mozzarella Fior di*. There is also a smoked variety of Mozzarella cheese named *Mozzarella Affumicata*.

Mozzarella cheese owes a unique property of stretchability with a very smooth and shiny surface. Mostly it is used as a topping on pizza pie owing to its inherent stretching qualities at high temperature after melting. The popularity of pizza parlour, especially amongst youngsters has increased the demand of Mozzarella cheese. In Italy Mozzarella cheese accounts for 78% of the total Italian cheeses (Merrill *et al* 1994).

Pure white colour is the basic requirement of Mozzarella cheese which is lacking in cow milk cheese due to presence of carotene. So buffalo milk is observed to be more suitable and beneficial than cow milk for Mozzarella cheese (Jana and Mandal 2011)

India accounts 56% (38.638 million) of world's total buffalo population (Anon 2014). The contribution of buffalo milk to total milk production of the India is

approximately 51% (81.266 million tonnes); whereas in Punjab the share of buffalo milk is as high as 71% (8.03 million tonnes) (Anon 2019a). So there is high potential of making Mozzarella cheese from buffalo milk as technological knowhow is well documented for this product.

The global market value of mozzarella cheese is worth US\$ 10100 million dollars (Anon 2019b) but the Indian cheese market is presently worth around US\$ 237 million which is 2.4 per cent of the global market value (Anon 2019c). Despite the increase in production of cheese by 15% per year, in response to growing demand in India and availability of ample buffalo milk in Punjab, dairy processors are not able to tap the market potential (Zicarelli 2004). The reason for this is lack of indigenous mechanization in Mozzarella cheese at small scale. The large capacity mechanized units are available with two Italian companies Comat and Almac SRL and these units are highly priced and needs to be imported.

Traditionally Mozzarella cheese is manufactured using starter culture technique but this technique consumes a lot of time. Now a days Mozzarella cheese is manufactured using direct acidification method. In this method, manufacture of Mozzarella cheese involves proper acidification of milk followed by coagulation using commercially available enzyme called rennet. After the curd is set, it is cut and cooked in whey at 36-40°C to get proper consistency. Then the whey is drained and the curd is stretched and moulded in hot water to get desired stretchability and melting characteristics in cheese (Ingaldi and Jagusiak-Kocik 2007). Stretching and moulding the Mozzarella curd in different shapes give different names to the product. In addition to the characteristic spherical shape of buffalo Mozzarella cheese, other shapes can be “created”, for example bite-sized portions called bocconcini (little snacks), perline (little pearls), ciliegine (little cherries), as well as trecce (braids) and nodini (small knots). In the specific case of buffalo Mozzarella cheese, the yield may vary in the range 12-15%. In refrigerated condition Mozzarella can be stored for 30 days. Also, Mozzarella cheese should contain not more than 60% moisture and not less than 35% milk fat on dry matter basis

Unit operations like, heating the curd in hot water and transforming into plastic and workable consistency are involved in kneading of curd. Stretching of the curd means the working of curd into unidirectional fibrous ribbon of plastic curd.

Labour requirement is quite high in this process and also leads to drudgery as the labour has to do the process with hands dipped in high temperature water (80°C) which leads to the problem of undesirable contamination in the product by the labours' hands. So the mechanization is must in the kneading and stretching process for the reduction of drudgery and establishing a better control over moisture and fat content of the cheese obtained. Keeping in view the above facts present study is planned with the objective is:

1. To study and evaluate the existing kneading and stretching mechanisms.
2. To standardize the operational parameters for selected mechanism for preparation of Mozzarella cheese.

CHAPTER – II

REVIEW OF LITERATURE

Traditionally, Mozzarella cheese manufacturing uses standardized, pasteurized milk that is cultured, coagulated, cut and cooked. After whey drainage, the curd is subjected to kneading and stretching in hot water. The hot cheese is immediately molded into desired shape and salted chilled brine water.

With regards to mechanization of Mozzarella cheese manufacturing process, the most labour intensive operation is kneading and stretching in hot water (80°C). It is important to mechanize this unit operation so that Mozzarella cheese manufacture is prompted in the state. This chapter contains literature on different types of kneaders and mixer used in Food/Dairy Industry. It also contains different parameter of Mozzarella cheese as affected by different operational parameter of machine used for it.

2.1 Dough Kneaders

Dough kneaders are designed for heavy duty mixing and kneading in the commercial kitchens. The dough kneader is manufactured using stainless steel with rotating arms and bowls. Dough kneader takes lesser time and gives better water absorption and also folds and stretches the dough for aeration and fermentation. It features a stainless steel bowl which either moves at a slow speed or it is stable. The dough kneader makes mixing of the dough easier for preparing chapattis, breads, puris, namkeens, Mozzarella production etc.

2.1.1 Types of Kneaders

In practice, some other four mixing and kneading systems have been widely used namely: planetary mixers, impeller kneaders, helical ribbon impellers and more recently twin-screw extruders. In the present work, one fairly common mixer is considered, the Double Planetary Mixer. (Shehzad *et al* 2012)

2.1.1.1 Planetary mixers

These are used to perform both mixing and kneading having major use of any kitchen. These multipurpose mixers allow users to make a variety of mixes from pastry to whisks. In various dimensions these are available and with various specifications.

Planetary mixers can come in either a gear driven variety or a belt driven assembly, with a tilt-able bowl or not and in various capacities and powers. The first thing that must be understood is that it is not a dough (or spiral) mixer. Although all planetary mixers can mix dough, they cannot mix large amounts of dough as they are generally not designed to be as tough.

Attachments- Most if not all planetary mixers come with attachments for mixing dough (dough hook), whipping (whisk) and mixing (beater). Changing the attachments is often a straightforward process and a safety guard ensures that this procedure cannot be carried out whilst the machine is running.

Because these mixers are batch type so these do not have much preference to industrial processing. It causes the requirement of huge labour. (Mansvelt *et al* 1979)

2.1.1.2 Impeller Kneaders

There are two possible ways of classifying an impeller in kneaders, according to the discharge flow it produces, or according to its size with respect to the vessel. In the first category, there are radial discharge impellers (flat turbine), axial discharge impellers (propellers) and tangential flow impellers (anchors). If the diameter of an impeller is significantly smaller than the diameter of the vessel, this impeller is an open impeller. On the contrary, if the impeller exerts a scraping action at the vessel wall, it is called a close clearance impeller. In viscous and non-Newtonian mixing, close-clearance impellers are by far the best choice due to their superior top-to-bottom pumping capacity and wall scraping action as compared with open impellers. If the medium is a paste, multiple impellers comprising high speed tools for intense shearing in the bulk (emulsification head, dispersing disk) and low speed wall scraping blades may be advantageously used (Tanguy *et al* 1999)

2.1.1.3 Helical Ribbon Impellers

Among the close-clearance impellers, the helical ribbon impellers are recognized to be the most efficient system. In order to compare the performance of helical ribbon agitators, two criteria of macro-mixing are used: mixing and circulation times. It is equipped with an anchor at the bottom in

order to avoid the formation of a stagnant zone; secondly the size of the pitch ratio is greater than with a typical double helical ribbon mixer. The axial pumping capacity of the mixing system is greatly reduced with single helical ribbon agitators compared to double helical ribbon impellers. There different effects of geometrical parameters (clearance, pitch ratio, blade width ratio) of the mixing systems on the effectiveness of the mixing process in this type of kneader (Delaplace *et al* 2000)

2.1.1.4 Twin-Screw Extruders

Single screw extruders are no longer adequate because of increase in requirement for new and higher quality products. So for meeting these more demanding processing requirements this type of extruder must be used. (Riaz 2000)

Types:

1. Counter rotating twin-screw extruders
2. Co rotating twin-screw extruders

Tomatis (1986) developed a machine with a continuous process of pasta filata cheese production in which there is stretching mechanism. When hot water is added while kneading and moulding process then pasta filata is obtained into cheese such as Mozzarella. Machine comprises nozzles, twin augers, a channel into a vertical, substantially cylindrical stretching chamber where a rotating stretching swift having radially projecting, arched paddles which stretches the curds into pasta filata against the reaction of a stationary, wall-mounted paddle.

Xie and Friend (1998) conducted an experiment on a dough hook and the bowl in a planetary mixer and observed that in dough development process there is a major role of clearance between the dough hook of the mixer apparatus and the bowl. It was investigated that longer time will occur in kneading for incorporation and development of dough if the clearance is high but if there is too little clearance; the hook pinches the dough very hard against the bowl. Then there will be high requirement of horse power from the motor which will cause very high load to all of the parts of the mixer, and energy will get wasted due to the pinching of the dough instead of the desired kneading action.

Tanguy *et al* (1999) conducted an experiment on observation of a double planetary mixer in which the mixing hydrodynamics were observed over the course of a cross-linking reaction with varying speed of rotations and investigated numerically and experimentally that this mixer provides good radial dispersion capabilities but poor axial (top-to-bottom) pumping, irrespective of the viscosity level but fail to predict the power consumption.

Wade *et al* (1999) he used a Strain gauge in a mixer to sense the amount of force exerted on the dough arms by the mixing machine and a signal processor during kneading operation. Strain gauge for processing the Sensing Signals was coupled with the personal computer which generated graphical mix display on the computer monitor illustrating the amount of force versus time. This graph was used to determine the optimum value of torque value needed for the dough development. Monitoring of dough development was also a purpose of using a strain gauge assembly.

Jongen *et al* (2003) investigated and characterized the type of deformations taking place during kneading of dough in a quantitative and systematic manner and observed the influence of mixer configurations and operating conditions. Using relevant kinematic flow classification parameters the characterization was done for determination of the type of deformation taking place in the mixers based on the time-dependent velocity fields obtained.

Loiselet (2003) invented the sourdough fermenter for the production and preservation of sourdough which included a vessel, temperature regulators for selectively cooling and heating the vessel a rotating tool for agitating products in the vessel and for exchanging heat with the products, a non-rotating tool for the injection of thermostatically controlled gaseous products into the dough mass in the vessel and a controller with display. The invention enables precise regulation of temperature of the products in a Scalable production process.

Thymi *et al* (2005) conducted an experiment for a continuous extrusion process by using a combination of batch type kneader and twin screw

elements to utilize a twin-screw extruder which is practically and economically feasible for production on large scale as well as has various advantages due to having features like excellent temperature control, highly efficient pulverization by application a high shearing force, high throughputs, and adaptability to different processes such as high-pressure applications and explosion treatments.

Ktenioudaki *et al* (2010) proposed the study that was to observe whether extensional rheological and baking properties of the dough were affected from different mixers and energy inputs during mixing and observed that in uniaxial and biaxial extension the extensional properties were impacted by the mixing equipment.

Chesterton *et al* (2011) conducted an experiment on observation of shear rate in planetary mixer when fluid was agitated in the bowl by a wire whisk by using two different mixers Kenwood KM250 and a Hobart N50 which are widely used in domestic as well as in laboratories. Observations were noted that the shear rate is shown to be a maximum at the bowl wall and the shear rate profile is sensitive to the vertical positioning of the agitator within the bowl.

Domanskii *et al* (2011) studied and tested the design of large size Agitator with Precession Impeller for ore Slurries. In this experiment a one dimensional mathematical model addressing the field of tangential velocities, agitation power and other hydrodynamic features necessary for designing large-size unbaffled agitators with a precession impeller studied. After testing it was observed that the adequacy of the model was confirmed and lengthy positive operational results for industrial agitators with a volume of up to 1000 m³ was found which was designed for leaching of ore slurries.

Jirout and Rieger (2011) studied the effect of impeller type on off-bottom particle suspension. On the basis of numerous suspension measurements correlations are proposed for calculation just suspended impeller speed for eleven impeller types and geometries in the wide range of concentrations and particle diameters. In this experiment the suspension efficiency of tested impellers compared in terms of the power consumption required for off-bottom suspension of solid particles.

Kitta (2011) developed a mixer having a cabinet a bowl supported within the cabinet. There is an opening in bowl body through which dough is inserted into the

bowl for a mixing operation. For kneading and mixing purpose an agitator is mounted in the bowl for rotation and there is a refrigeration jacket is mounted to an exterior of the bowl body. On the periphery of the bowl body there are some channel members those include unitary plate member having an elongated centre panel extending along a periphery of the bowl body. The centre panel is spaced from and facing the bowl body. A first leg is connected to the centre panel by a first bend. The first leg extends toward the bowl body. A second leg is connected to the centre panel by a second bend. The second leg extends away from the bowl body.

Andre *et al* (2012) investigated the feasibility and mixing efficiency in the process of homogenization of free flowing granular materials with planetary mixer by studying the effects of various parameters like the ratio of impeller rotational speeds, mixing time, power consumption and dimensional analysis. It was well suited for the stated process of homogenization with the use planetary mixer.

Asiri (2012) designed and implemented a differential agitator with motive of maximizing the agitating performance. This unit comprised electromechanic set having two shafts, agitating group, fixing group. The agitating group was fabricated inside the cylindrical container equipped for purpose of containment of square directors for liquid entrance. The square directors with liquid exit called fixing group was installed for containing the agitating group. Shape optimization was carried out for improving efficiency, parametric study and shape. For the designing and implementation of the unit a numerical analysis, manufacturing and laboratory experiments were conducted. So, in conclusion this experiment was about designing, manufacturing, implementation of the differential agitator for maximizing the agitator performance.

Wang *et al* (2012) studied the power consumption required to suspend water–solid slurries in a mechanically agitated tank over a wide range of design and solids conditions with the motive of improving the agitation energy

efficiency. In this experiment Axial-flow impellers in baffled tanks were found more energy efficient to suspend solids.

Brischiani (2013) developed an electronic manager for bread dough mixers and operating method with a motive to provide automatic equipment suitable for products of pizza manufacturers and bakers and that will allow products of constant quality to be obtained quickly and simply. This Instrument is well suited to the obtaining of pizza dough starting from a special mixture which simply requires the addition of water and mixing by means of the inventive equipment. It comprises integral module having a programmable logic controller (PLC) which, by means of relays, controls a low-speed contact, a high-speed contact and an electro valve in order to operate a mixer. In addition, the PLC controls a temperature sensor, a flowmeter and a visual and audible indicator.

Canja (2014) observed the effect of kneading time on bread dough quality and concluded that many factors like flour quality, production process, mixing and kneading time affects the quality of bread. In this experiment the influence of kneading time on the sensorial qualities and on the other basic properties was observed. Kneading time was varied from 2 to 20 minutes. Wheat and rye type bread flour was used in this experiment. In terms of kneading time best results were obtained for the bread that was mixed for 8 minutes and on comparing white bread and rye bread, we see major differences in terms of quality characteristics.

Pastukhov and Dogan (2014) investigated effect of mixing speed and temperature on thermomechanical properties of wheat flours having breadmaking quality. Experiment was conducted at the constant water absorption with variable mixing speeds (60–120 rpm). Observation regarding the impact of temperature at 80 rpm, 100 rpm, 120 rpm, and effect of mixing speed at 30°C, 40°C, and 50°C were also studied. Relationship between parameters like dough consistency during mixing, mixing stability, protein weakening, starch gelatinization, amylase activity and starch gelling with mixing speed (rpm) was observed.

Wenxiong (2017) proposed the study of providing of a kneading dough hook assembly to overcome the deficiencies of the conventional kneading dough hook with good kneading dough effect and to provide ideal kneading dough results with

reduction in vibration and in shaking. This assembly comprises a mounting frame, a first kneading dough hook, a second kneading dough hook, a first fool - proof mechanism and a second fool - proof mechanism. The first fool - proof mechanism is provided between the first kneading dough hook and its corresponding first mounting rod. The second fool - proof mechanism is provided between the second kneading dough hook and its corresponding second mounting rod.

2.2 Use of Kneaders and Mixers in Dairy Industry

Kieffaber (1975) developed a dough mixer with continuous feed mechanism having a long trough like body with an discharge outlet. This unit comprises a pair of shafts, paddels having ribs, baffle wall and a conveyor. Bearings and its housings were used along with the belt and pulley type transmission in this unit. Two parallel shafts rotate in the same direction and paddels having ribs jointed on the shaft rotates for mixing.

Yun *et al* (1993) invented the effect of milling pH on initial chemical composition and proteolytic changes in Mozzarella cheese during refrigerated storage. Three milling pH (5.10, 5.25, and 5.40) were used to make three vats of cheese and then curd formed from them was used for stretching. For stretching of salted curd a pilot-scale, twin-screw Mozzarella mixer having water jacket and separate thermostatic temperature control of the circulating salt brine in the mixer was used with a feed rate of 3 kg/min. During process electrically heated jacket was kept at 57°C and the screw speed was constant (12 rpm) throughout the process. The salt content of circulating brine solution decreased from 10% to 7.5%.The study showed change in titratable acidity, cheese ph and the amount of residual intact α -casein.

Chaves *and* Grosso (1999) reported a study shows the effect of refrigerated storage on the proteolysis, free oil content and meltability. In this study Mozzarella was prepared by using a curd sample at 58°C in a twin-screw Mozzarella mixer for stretching and kneading in the stretching water temperature of 75°C. After extrusion into plastic boxes cheese sample was treated with cold bath at 3-5°C then it was transferred in 23% brine solution at

12°C for 24 hours. Then after treating one batch with slow freezing for 15 days and the other under refrigeration both were tempered for 1 month. After experiment the observation found decrease in proteolysis levels which was the reason for decrease in meltability. But there was increase in free oil content majorly in tempered samples.

Joshi and Mahajani (2001) and McCabe *et al* (2001) stated that for effective mixing of highly viscous liquids helical type agitator is widely used. Such mixers drive the liquid from bottom to top or vice versa depending upon its design and direction of rotation.

Yu and Gunasekaran (2004) developed a mathematical model for the observation of viscous flow inside a deep-channel single-screw stretcher, mentioning both the flight and curvature effects on the sample. This study investigated screw characteristic curves with velocity distributions testing and also concluded that in terms of overall volumetric flow rate the flight effect was more important than the curvature effect. Single-screw stretcher was used for trial on Newtonian fluid feed rpm above 150 and found that volumetric flow rate was within 0.5% of the experimental data comparing other models.

Yu and Gunasekaran (2005) invented a mathematical model to investigate the viscous flow inside a deep-channel twin-screw stretcher, considering both the flight and curvature effects by studying the stretcher-cooker geometry and operating condition for the optimization of pasta filata making process.

Karunanithy *et al* (2007) attempted to develop a kneader suitable for channa in process of making rasogulla. The kneader thus developed was evaluated in terms of degree of mixing, uniformity of mixing index with respect to temperature rise of kneader.

El-Bakry *et al* (2010) compared the farinograph cheese with batch size of 800 gm at 50 rpm having moisture levels of 48, 50 and 52 g/100 g sample with the cheese sample made from a twin-screw cooker named blentech a traditionally used pilot-scale cooker. In study of comparison no significant differences were observed in compositional analyses, water activities, relaxation times, and cohesiveness and melting temperatures. Flowability of both cheese samples were the same but

farinograph cheeses contained lower hardness. Overall conclusion was that farinograph was better choice small-scale manufacture of imitation cheese.

Annis and Wolters (2013) developed a mixing beater for a small scale which comprises a metallic frame having an arm, a rigid plastic shell extending over the arm, and only one scraper. The scraper extends over the rigid plastic shell and also has a flexible blade configured to contact an inner surface of a mixing bowl.

Anjos *et al* (2014) inspected the effect of addition of modified starch and stabilizers on the physical-chemical of cheese bread by measuring moisture, pH and acidity, volume, density, coefficient of expansion, and compression resistance and found that the addition of stabilizers improve these characteristics in the cheese bread and shows better physicochemical characteristics. In this study dough was prepared using planetary mixer by addition of sweet and sour starch with modified starch and heating with a mixture containing half milk, salt, margarine, egg and cheese one by one with some intervals of time.

Rajasekaran and Kumar (2014) stated that agitator system selection depends upon the nature of liquid, the detailed design of a dynamic mixer (agitator) system, operation condition and intensity of circulation and shear. Inducing motion of materials in a specific way depends upon effective agitation and mixing fluid to a great extent.

Rezende *et al* (2015) used a planetary mixer first time for mixing a combination of milk powder, sucrose, maltitol + edulcorant, inulin and β -glucan concentrate butter in a planetary mixer with $2/3$ of the corresponding cocoa at 40°C for 10 min and then second time it was used for the conching process at 60°C for 14 h for proper cocoa butter incorporation. These two process were made for the chocolate production to invent sucrose-free chocolate formulations employing a mixture design to add fibres as partial substitutes for cocoa butter and for observing the change in casson plastic viscosity, casson shear stress and the sensory characteristics of chocolate

under the effect of combination of different contents of inulin, β -glucan concentrate and cocoa butter.

Chong *et al* (2017) proposed a study to observe the mechanical properties cheese cracker dough at different baking stages. At a few baking conditions changes in microstructure was recorded using cryo-SEM as well as changes in change in mechanical properties during baking were reported. In this study for the dough production a mixer having four planetary rotating pins and two stationary pins was used for stretching and mixing wheat flour, parmesan cheese, unsalted butter, cream and salt at 118 rpm.

2.3 Evaluation of different parameters of Mozzarella cheese from kneaders and mixers

Kindstedt and Rippe (1990) conducted a test for free oil formation in melted Mozzarella cheese by using standard Babcock equipment. In this experiment 64 samples of Mozzarella cheese samples were taken from super market and 2 samples were taken from cheese plants. Free oil as a percentage of total cheese fat varied from 8.8 to 84.9%. This experiment concluded that, if the value of fat content on dry basis increases than the value of free oil also increases.

Barbano *et al* (1994) proposed the study of increasing the moisture content of low moisture, part-skim Mozzarella cheese by using a stirred curd and following of cheese no brine Mozzarella cheese-making process. The aim of this study was to increase the moisture content to a range between 45 to 52% while having normal salt, pH, and fat content on a dry weight basis and study showed a similar case of changes in proteolysis and functional properties during the refrigerated storage that was common in commercial cheeses. In the experiment for stretching and kneading of curd a twin-screw, pilot-scale Mozzarella mixer (model 640; Stainless Steel Fabricating, Columbus, WI) was used with a feeding rate of 2 kg/min in 57°C hot water. Hot maintained water at 57°C water was poured about 3 min. prior to addition of curd to the mixer and the stretching and kneading process was conducted for 10 min. at 12 rpm.

Mulvaney *et al* (1997) studied the impact of mixer screw speed and barrel temperature on the length of the filled section in the mixer, melt exit temperature,

specific mechanical energy, and viscoelastic properties. A twin-screw, counter-rotating Mozzarella stretcher-cooker was used for stretching three batches of cheese with varying (19, 12, and 5) rpm of 12 at different water temperatures (57, 66, and 74°C). For each screw speed (at constant barrel temperature), the horsepower increased almost linearly as the length of the filled section increased. The study also observed that a decrease in barrel temperature causes decrease in linearity of the relationship between horsepower and filled length.

Renda *et al* (1997) observed the impact of screw speeds of the mixer on chemical composition, proteolysis, and functional properties of low moisture part-skim Mozzarella cheese during storage. Three samples prepared with different screw speeds at 5, 12, and 19 rpm were taken. This experiment concluded that Screw speed of the mixer influenced fat, moisture and free oil formation. Variation in screw speed also affected both the cheese temperature attained and the residence time of the cheese in the mixer during stretching.

Gupta (2003) developed a mixing and blending mechanism in conical process vat for preparation of viscous dairy products. Three designs of standard mixing agitators anchor type; helical type and turbine type for this vat were selected, designed and fabricated. For performance evaluation of mixing these agitators were installed on the driving shaft of the unit. The performance was studied in terms of parameters like design of agitator, mixing time and initial moisture content in khoa. In case of trial with turbine type maximum mixing was observed followed by anchor type and then helical type. There was an observation of significant effect of all the selected operational parameters on mixing time and mixing index. For effective mixing of ingredients 30% of initial moisture content was found as a optimum value for all type of agitator types. Mixing time for the turbine type was 15 minutes and the mixing index was 40.62. Minimal difference was observed manufactured from three types of agitators in sensory evaluation in terms of body, flavour, texture, colour and appearance of the product.

Noronha *et al* (2008) compared two mechanisms of cheese manufacturing units and studied the effect of unit design and blade or auger speed on the functional properties of imitation cheese. Cheeses with same compositions were produced using blentech twin-screw or a stephan single-blade cooker. Single-blade cooker was operated at high (750, 1,125 or 1,500) rpm but in case of twin-screw cooker the rpm was low (100 and 200). This study proved that cheese can be possibly be made by single-blade cooker having some sort of similar properties to the cheese which is made by twin-screw. But the cheese produced from single-blade cooker had a high firmness issues which could be resolved by increasing the moisture content of cheese curd. This study also noted the effect of agitation speed of both units on physicochemical properties of imitation cheese.

Bahler *et al* (2016) used a batch type instrument for pasta filata cheese production named ‘Thermomix’. The observation was noted that there is the effect of kneading time (180, 420 and 600 seconds) and temperature (55, 60 and 70°C) on the chemical composition of the pasta filata cheese. This research also concluded that there is a reduction in the cheese yield of the pasta filata cheese production from 88.0% to 59.0%, compared to initial curd weight which also established the correlation between process temperature and the water-holding properties of protein (casein micelles).

Bahler *et al* (2016) proposed a study in which a bench top scalding-kneader was used to kneading of pasta filata cheese at 60°C with various batches of varying stretch water containing 1.0, 2.0 and 2.8 g.100 g⁻¹ sodium chloride at different kneading durations of 180, 420, and 600 seconds for observing improvement in the cheese yield and water holding capacity of pasta filata cheese. After the experiment it was found that there was an increase in values like moisture content, protein water-holding capacity but decrease in moisture-to-protein ratio, dry mass and hardness with increase in sodium chloride content.

2.4 Methods used to measure stretchability of Mozzarella cheese

Kosikowski (1982) studied that by the operation of stretching the curd is converted into cheese with sheen surface and property of elasticity due to formation

of mono calcium para caseinate from the action of lactic acid on dicalcium paracaseinate at pH of between 5.2 and 5.4.

Ghosh and Kulkarni (1996) studied that titratable acidity for cheese stretching was 0.8% lactic acid. With increase in curd acidity from 0.5 to 0.8% lactic acid there was increase in sensory score of cheese. Increase in curd acidity led to a decrease in cheese moisture and total solid loss during stretching, while quality improved.

Timothy *et al* (1997) used a simple empirical method for measuring the stretchability of cheese on cooked pizza pies. Grated cheese was distributed on pre-cut pizza pie with a fixed loading of 0.25g/cm² and cooked at 280°C. One side of pie was clamped and the other side was stretched by rolling element until breakage of last string connecting the two halves of pie. The Observation made this experiment was that the stretch values obtained for low-moisture Mozzarella of different ages were influenced by cheese load and holding time before stretching of the cooked pizza pie, but were independent of stretching speed in the range 0.033-0.100 m/s. The stretchability of 2-17 weeks old low-moisture Mozzarella cheese was greater than that of 2-25 weeks old Cheddar cheese.

Hicsasmaz *et al* (2004) used Ring-and-Ball method to measure the stretchability of Mozzarella cheese. In this technique temperature and moisture loss was controlled properly. In results the average stretch length varied between 4 to 9 cm between the youngest and the oldest cheese samples. This method was sensitive enough to discriminate between cheeses of different ages. The results showed that the technique is reproducible and gives reliable stretch length.

Ma *et al* (2012) conducted a temperature-controlled 3-prong hook test for evaluation of Stretchability of Mozzarella cheese by using 3-prong hook with Instron tensile tester. Stretching of melted cheese was done with hook probe and the load and extension data were recorded by the Instron tensile tester. Observation in this experiment was that the sample load of the sample prepared from high screw speed was low and sample load was high in case

low screw speed. Low fat Mozzarella had 3 times higher load than high fat Mozzarella sample.

CHAPTER III

MATERIALS AND METHOD

The study was planned to intervene in mechanization of Mozzarella cheese manufacture. Two mechanisms were tested for kneading and stretching mechanism. After that the selected mechanism was modified and tested. This chapter contains various materials used for the study along with methods applied.

3.1 Material

3.1.1 Milk

The mixed pasteurized and standardized milk (Fat – 4.5) milk for manufacture of Mozzarella cheese was procured from Experimental Dairy plant, College of Dairy Science and Technology, Guru Angad Dev Veterinary and Animal Sciences University, Ludhiana.

3.1.2 Rennet

Microbial Rennet was procured from Essdee Marketing, Pune.

3.1.3 Acidulant

Citric Acid anhydrous food grade was procured from local market in powder form for lowering the pH value of milk to 5.2-5.4.

3.1.4 Potassium Chloride

Potassium Chloride was procured from HiMedia laboratories Pvt. Ltd. to make the 3M KCl solution for the calibration of the pH meter.

3.1.5 Muslin Cloth

A two meter muslin cloth was procured from local market for whey separation.

3.1.6 Distilled Water

Distilled water was required for kneading and stretching of curd.

3.1.7 Buffer Solutions

Two Buffer solutions of pH 4 and 7 were used for the calibration of the pH meter.

3.1.8 Common Salt

It was procured from local market for brining.

3.2 Instruments/Equipments used for Mozzarella cheese manufacture

3.2.1 Induction Plate

Electronic digital induction plate (Fig. 3.1) was used for heating milk at the various temperatures during Mozzarella cheese manufacturing. It was also used for heating the water which was used in kneading operation.

Table 3.1: Specifications of Induction Plate

Make	Prestige
Model	PIC 20.0
Power	1200 watts
Voltage	230 V AC, 50 Hz
Product Depth	8.89 cm
Product Height	30.48 cm
Product Width	25.40 cm
Product Weight	1900 gm



Fig. 3.1: Induction Plate

3.2.2 pH meter

During acidification pH meter was used to determine the pH value of milk.

Table 3.2: Specifications of pH Meter

Make	Cole Parmer
Model	PH-200
Temperature Range	0-55 °C; 32-130 °F
Resolution	0.01 pH
Temperature resolution	0.1 °C/F
Accuracy	+/- 0.1 pH
Temperature accuracy	+/-1%
Minimum EC/TDS	5 uS/10 ppm
Electrode	Replaceable glass sensor and reference tube electrodes
Housing	IP-67 Waterproof (submersible; floats)
Power source	2 x Triple A (AAA)
Dimensions	18.5 x 3.4 x 3.4 cm
Weight	96.4 g

3.2.3 Tachometer

To measure the revolutions per minute of hook assembly in planetary mixer and revolving screw in the screw mechanism Tachometer of Lutron make was used (Table 3.3 and Fig. 3.2).

Table 3.3: Specifications of Tachometer

Make	Lutron
Model	DT-2234C
Measuring Range	5-99,999 rpm
Measuring Distance	Max. 2.0 meters
Measuring Angle	at less than 120°angle
Accuracy	±0.05%
Laser output	≤1mW
Dimensions	190x72x37 mm
Weight	approx. 200 gm



Fig. 3.2: Tachometer

3.2.4 Weighing Balance

Electronic digital weighing balance of Cole Parmer (ED2000) make having maximum weighing capacity of 2.0kg (Fig. 3.3) with least count of 0.1 mg was used for weight determination of samples like rennet and citric acid. It was also used for weighing curd and Mozzarella cheese.



Fig. 3.3: Weighing Balance

3.2.5 Thermometer

Thermometer with a range of -10°C to 150°C was used for temperature determination of milk during Mozzarella manufacturing at various instants, at the time of acidification, at the time of rennet addition and at the time of cooking operation and it was also used for temperature determination of water during heating to 85°C which was used in kneading operation (Fig. 3.4)

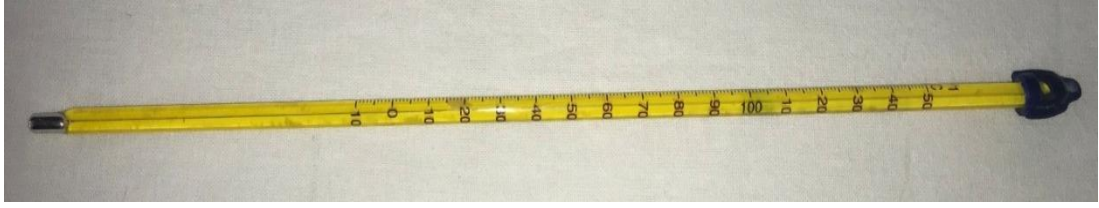


Fig. 3.4: Thermometer

3.2.6 Induction cooktops

Two utensils of 7.5 litres and 5 litres capacities were used for storing and heating milk using induction plate and heating of water at 85°C for kneading operation.

3.2.7 Ladle

Ladle was used to thoroughly mix the starter culture, additives and rennet in milk and also to achieve uniform heating of the cheese curd / whey mixture (Fig. 3.5).



Fig. 3.5: Ladle

3.3 Method for Mozzarella cheese manufacture

The method employed for Mozzarella cheese manufacture was standardized by College of Dairy Science and Technology, Guru Angad Dev Veterinary and Animal Sciences University (Ludhiana). The method (Fig. 3.6) is direct acidification which is time saving and there is less cost of production. This method was also applied due to ease in mechanization. In this method the various operations of containment, cooking, stretching and kneading was done with hot water jacketed vat with both inlet and exit port. But this experiment was done with some modifications. In this experiment for containment purpose utensil was used and for heating operation induction plate was used. After preparation of curd the stretching and kneading was done in existing mechanisms as discussed below.

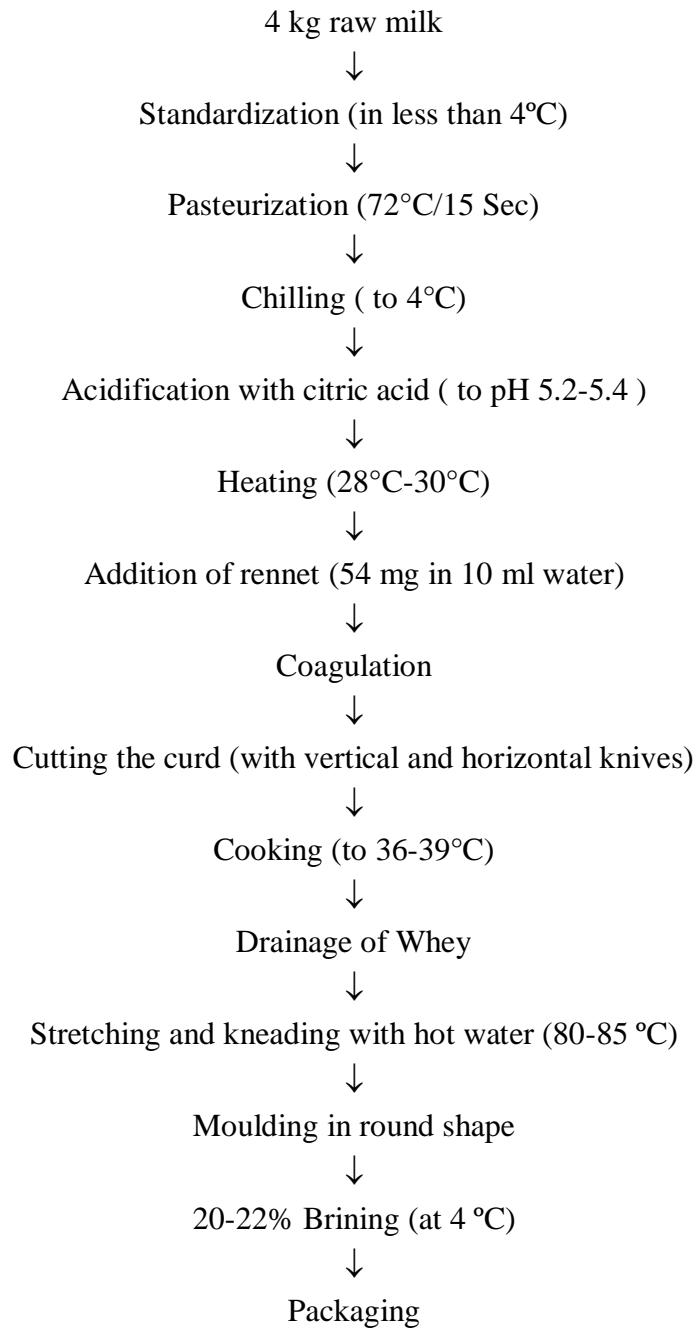


Fig. 3.6: Flow Diagram for the manufacture of Mozzarella cheese using direct acidification method. (Bansal *et al* 2018)

3.4 Method for selection of appropriate mechanism

Two existing kneading and stretching mechanisms were selected for Mozzarella manufacture preliminary trials.

- Screw mixer
- Planetary Mixer

3.4.1 Screw mixer

Screw mixers are those systems which are based on operating principle behind Archimedes' screw. These units are used to perform operations like mixing, dewatering, and compression along with conveying process of materials in bulk. Screw inside the stationary tube or barrel is in helix form which rotates and conveys material in axial direction. Screw in the barrel can be set up horizontally, diagonally, and vertically to convey bulky material. These units are used with a limited length of conveying process. In these units high power supply is required due to friction between screw trough and material. If the feeding rate is high than conveying process will stop due to perpendicularly rotating material getting stuck at the end. So the feed rate is kept low for better conveying operation at low screw speed. The delivery rate of system depends upon screw's speed, the inner and outer diameters, the degree of inclination, the level of filling, and the friction between the material and the screw. Friction on trough wall should be more than the friction on screw for maximum delivery rate.

Screw mixers comprises following elements:

- Screw barrel or screw trough
- Screw consists of helical flighting
- Feed inlet and exit outlet
- Screw shaft with drive shaft and seals
- Drive unit
- Drive mechanism
- Bearings for screw setup

3.4.2 Setup of Screw mixer section for preliminary trial

Screw mixer mechanism was developed in Department of Dairy Engineering, College of Dairy Science and Technology, Guru Angad Dev Veterinary and Animal Sciences University, Ludhiana. This section was used in the experiment of kneading and stretching operation of curd along with hot water for observing the feasibility of manufacturing of Mozzarella cheese.

The main components of this section were detachable hopper, screw, screw drive shaft and exit die with plate type structure. From top the hopper was connected

to the barrel feed opening. The barrel was connected to the exit die with plate type structure at the exit point. There was a screw in the barrel connected to the shaft of a gear with a chain drive setup. The chain drive setup connected with a gear reduction box was used for power transmission. The gear reduction box was further connected to the alternating current motor again by the chain drive. Feeding was done through the hopper. Then the material was conveyed by rotating screw through the barrel to the exit die.

The design of kneading section having different components was evaluated. For this evaluation the dimensions of all the components of this section was noted down and are given follows in Table 3.4 and 3.5. The picture of Screw with hopper is shown in Fig. 3.7.

Table 3.4: Dimensions of the Screw mixer section

Name of Component	Dimension (cm)
Hopper Width at the top	30
Hopper Width at the base	10
Hopper length at the top	32
Hopper length at the base	13
Barrel length	27.5
Diameter of screw	8.7
Length of screw	26

To observe the optimum value of power consumption for the development of the better power unit in the modified Screw mixer setup the following data was collected:

Table 3.5: Specifications of Power Unit and Driving Mechanism

Motor	1.0 HP
Motor type	A.C
Transmission Assembly	Chain and Gear
Gear Reduction Box	1:25 (Reduction ratio)



Fig. 3.7: Existing Screw mixer with Hopper (left) and Exit Section (right)

3.4.2.1 Procedure for Preliminary trial on Screw mixer

The following preliminary trial procedure was adopted for performance evaluation of existing Screw mixer mechanism:

Setting up of detachable hopper in its place was done (on the top of barrel opening or feeding point) for proper feeding operation of curd along with hot water and for avoiding the spillage of water from the barrel. The barrel exit was closed with cloth for retaining the hot water for some time in the barrel for proper kneading operation. After whey drainage Mozzarella curd was collected and weighed on digital weighing balance. Before using this mechanism value of rpm of screw was set to 12 which were used as the constant value throughout the preliminary trials. It was a mechanism of continuous process so the curd was divided into three parts for proper slow feeding and kneading operation. Water sample of 2 litres was taken and heated to 85°C for using in feeding along with the curd in the bowl. After cross checking of blockage in barrel exit by cloth the operation of feeding started in which at first one part of curd out of three was put in the barrel and then water was being continuously fed at 85°C. Kneading operation started as the screw starting rotating. After 2 minutes of kneading operation the blockage made by the cloth was removed and the cheese began to come through the barrel exit. Time taken for the kneading operation for all the trials was 10 minutes. After switching off the power supply the cheese was

collected and weighed. After checking the feasibility of the operation of proper kneading and stretching using this mechanism the above procedure was repeated for two more trials.

Limitations in this mechanism:

- This mechanism is bulky but there are more losses in the operation.
- This mechanism is well suited for continuous production with high production rate but due to low rpm, requirement for the duration of kneading operation is 5 times more than planetary mixer.
- Kneaded Mozzarella got stuck in the barrel in which the screw rotates and screw is not detachable from barrel so some notable part of kneaded cheese gets stuck inside the barrel.
- Hopper is detachable so there is some clearance between barrel feed opening and hopper base which also makes some losses because in this clearance space kneaded Mozzarella gets stuck and is difficult to remove with time.

3.4.3 Planetary Mixer

Planetary mixers are based on the principle of two types of ongoing motions of auger or blade inside the bowl in which first type rotation is of blade on its own axis and the second type rotation of blade covering round distance around the centre. These units are used for mixing of pastes, adhesives, dough, powders and granulations with high shear rate and at high rpm. Different types of attachments like whisk, hook, flat beater etc are used for kneading and mixing of different types of material. Whisk type of auger is generally used in cake making and cream preparation. Hook type auger is used for kneading and mixing of dough while flat beater used to aerate mixtures.

Types of planetary mixers:

- a. Single Blade Planetary Mixer: These types of mixers are generally used for light and medium viscous sticky products in food industry. The mixer contains single auger which rotates around the centre of the bowl.
- b. Double Blade Planetary Mixer: This type is also known as twin shaft mixer in which two augers are attached 90° from each other. This type is used to mix

medium to high viscosity non-flowing products with shear effect. The torque value is high but the speed is low for mixing viscous ingredients and preparing homogenous product.

3.4.4 Procedure for Preliminary trial on Planetary Mixer

In preliminary trials, initially wire mesh was used for observing the feasibility of kneading operation in planetary mixer (Fig. 3.8) and then hook type attachment was used. After comparing the results from both attachments (Fig. 3.9) it was concluded that better kneading operation was done with hook type. So hook type attachment was used for the whole session of preliminary trials. Before using planetary mixer rpm of hook assembly was set to 52 which were used as the constant value throughout the preliminary trials. After placing bowl in its place the dough hook probe was fitted for the stretching and kneading operation by opening the mouth of using lock adjustment. After whey drainage Mozzarella curd was collected and weighed on digital weighing balance. The weighed curd values were varying for different trials so the efficiency values on the basis of curd noted were also varying. Water sample of 2 litres was taken and heated to 85°C for using in feeding along with the curd in the bowl. This mechanism was for batch process so at first the whole part of curd was put in the bowl then the water was added at the 85°C temperature and on that instant machine was switched ON. Time taken for the kneading operation for the first trial was 3 minutes for the first trial and for the rest of trials it was 2 minutes. After kneading the water temperature was observed (varied between 60-65°C). After switching OFF the power supply and opening the mixer with lock adjustment the cheese was collected and weighed using digital weighing balance. After checking the feasibility of the operation of proper kneading and stretching using this mechanism the above procedure was repeated for two more trials.

Limitations in this mechanism:

- This mechanism is not for handling curd more than 2 kg.
- This is a batch type mechanism so there will be more time consumption for same production value of cheese.
- This mechanism cannot be used in continuous production line.
- Least rpm of the hook of the mechanism also resulted in losses.



Fig. 3.8: Bowl (left) and Planetary Mixer (right)



Fig. 3.9: Hook type (left) and Wire mesh type Attachment (right)

3.5 Testing Procedure of Mozzarella cheese using existing mechanisms

3.5.1 Stretchability

Pizza base was cut equally in two halves and the halves were joined in their original position to form a flush interface. The surface was seasoned uniformly with 150 gm of shredded Mozzarella which was stored at 4°C. The pizza base was then placed in hot air oven at 200°C temperature for 15 minutes. Then pizza base with melted cheese on it was placed on the slab with a reference line aligned with interface line. One half of the pizza base was clamped manually and the other half was allowed to stretch manually until the last string of the melted cheese was broken. Stretching length was measured from the reference line to the point of breakage of last string of melted cheese (Walsh *et al* 1998).

3.6 Procedure for modified Screw mixer

To conduct the trial, motor driven shaft inside the barrel was connected with screw by single bolt and then the exit die was tightened to the barrel end with two bolts and one centre bolt (Fig. 3.10) connecting to the end of motor driven shaft. Then barrel end was fully closed with exit plate by tightening the bolt joined with the exit die for retaining the hot water for some time in the barrel for proper kneading operation. After whey drainage Mozzarella curd was collected and weighed on digital weighing balance. The value of rpm of screw was set by using FRENIC-Mini Inverter attached to the 1/4 hp three phase AC motor. This inverter was also used for setting of varying rpm values throughout the trials. The mechanism was a continuous process so the curd was divided into three parts for proper slow feeding and kneading operation. Water sample varying from 0.5 to 1.5 litres were taken throughout the trials and heated to 80°C for using in feeding along with the curd in the bowl. After tightening exit plate by the a thin bolt joined with the exit die at one end of barrel the operation of feeding started. One part of curd out of three was put in the barrel and then water was being continuously fed at 80°C at slow rate. Screw started rotating inside the barrel and kneading operation started. After 1 minute of kneading operation the exit plate was removed and the cheese began to come through the barrel die (Fig. 3.10). Time taken for the kneading operation for all the trials was 3 minutes. After switching OFF the power supply some part of the cheese was collected from the exit. After the

operation of proper kneading and stretching the drain pug was opened for the removal of warm water and then the exit die was removed by loosening the bolts attached to the barrel end. Remaining cheese in the barrel was recovered by removing the screw from the barrel by removing bolt joining the motor driven shaft.



Fig. 3.10: Kneaded Mozzarella cheese coming through exit die

3.7 Testing the properties of Mozzarella cheese prepared from modified Screw mixer

3.7.1 Stretchability

It is one of the most important physical properties of Mozzarella cheese which depends upon optimum acid development and temperature of hot water. After curd formation, the curd is immersed in hot water and stretched properly. Stretching of curd gives elastic property and sheen surface to the cheese (Venkateswarlu 1997).

Procedure: Pizza base was cut equally in two halves and the halves were joined in their original position to form a flush interface. The surface was seasoned uniformly

with 150 gm of shredded Mozzarella which was stored at 4°C. The pizza base was then placed in hot air oven at 200°C temperature for 15 minutes as shown in Fig. 3.11 and 3.12. Then pizza base with melted cheese on it was placed on the slab with a reference line aligned with interface line. One half of the pizza base was clamped manually and the other half was allowed to stretch manually until the last string of the melted cheese was broken as shown in Fig. 3.13. Stretching length was measured from the reference line to the point of breakage of last string of melted cheese (Guinee and O’Callaghan 1997).



Fig. 3.11: Shredded Mozzarella cheese on pizza base



Fig. 3.12: Forced Convection Oven



Fig. 3.13: Stretched cheese after oven heating

3.7.2 Meltability

It is defined as the ease with which cheese flows or spreads upon heating (Muthukumarappan *et al* 1999). This property of cheese affects its sensory and baking qualities when it is used for topping Pizza (Venkateswarlu 1997).

Procedure: 10 gm of grated cheese sample was taken for the meltability test. Grated cheese was filled in glass tube. After filling, the sample was gently tapped to get settled in the tube properly to the height of 3.5 cm. The opening end of the tube was covered with aluminium foil with some holes in it for the circulation of gas. Tube was kept at 4°C for the duration 30 minutes in vertical position. After storage sample was placed in hot oven with 100°C temperature for 15 minutes. The length of melted cheese was measured with scale after keeping it at room temperature as shown in Fig. 3.14 and 3.15 (Oberg *et al* 1993).



Fig. 3.14: Shredded cheese in glass tubes before oven heating

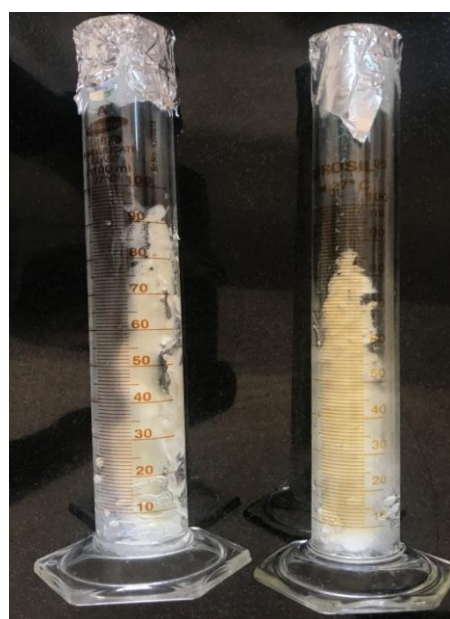


Fig. 3.15: Melted cheese after oven heating

3.7.3 Moisture Content

The maximum standard value for moisture content is 58% prescribed for Mozzarella cheese and the maximum value of moisture content was 58% (Schiftan and Komatsu 1979).

Procedure: 3 ± 0.1 gm of samples were weighed accurately (Fig. 3.16). After weighing of dry aluminium dishes without putting sample in them, then we put weighed cheese samples in them and again weighed them. After labelling the samples the dishes with samples were transferred into the force air oven for 150 minutes. Through the whole oven heating duration the oven temperature was maintained at $102 \pm 2^\circ\text{C}$. After heating for 150 minutes the samples were then placed into the desiccator (Fig. 3.18). After keeping the samples in desiccator for 30 minutes they were weighed properly (Fig. 3.17).



Fig. 3.16: Cheese sample weight before oven heating



Fig. 3.17: Cheese and aluminium dish weight after oven heating



Fig. 3.18: Aluminium dishes containing dried cheese samples placed in dessicator

3.7.4 Fat Content

The minimum standard value of fat content is 28% in a dry matter (Schifftan and Komatsu 1979).

Procedure: 3 ± 0.01 gm of grated cheese was taken as sample in stoppered funnel. 10ml of sulphuric acid was transferred into butyrometer by automatic measure without wetting its neck. After slowly addition of warm water (30-40°C) with an up to 6 mm layer formation water was allowed to flow down side of the bulb. Sample of 3 gm was transferred to the neck of butyrometer with the help of glass rod. With the help of automatic measure 1ml of iso-amyl alcohol was added gently in butyrometer. Then warm water (30-40°C) was added to the bottle until it filled to about 5 mm below the shoulder. After closing the neck with stopper the butyrometer was well shaken without inverting it until the complete dissolving process of the sample was done. After inverting the bottle for thoroughly mixing it was transferred to the centrifuge. Bottle was centrifuged for 5 min. and then it was taken out. Reading of fat column was noted down (Fig. 3.19).



Fig. 3.19: Fat test of sample in cheese butyrometer

3.7.5 Free Oil Formation

It is a defect that diminishes the appearance of the melted cheese on pizza. This defect has gained an importance due to increasing consumer concern over dietary fat levels. So, low fat cheese is mostly preferred by consumers (Kindstedt and Rippe 1990).

Procedure: With the help of stoke borer a disc shaped sample was taken with 5 ± 0.3 mm thickness. Sample cut by borer was placed on the Whatman No. 40 filter paper. Three discs were taken for one type of a sample on a single Whatman No. 40 filter paper (Fig. 3.20). Forced air oven was used to having samples for heat treatment. Sample was kept in the oven at 110°C for 5 minutes. After taking out melted cheese sample (Fig. 3.21) from the oven the boundary or periphery of the fat ring around the sample was traced instantly (Fig. 3.22). Traced areas of the fat rings were retraced on the graph paper for finding the surface area of oil ring around sample. Areas were taken in mm^2 units for accuracy (Breene *et al* 1964).

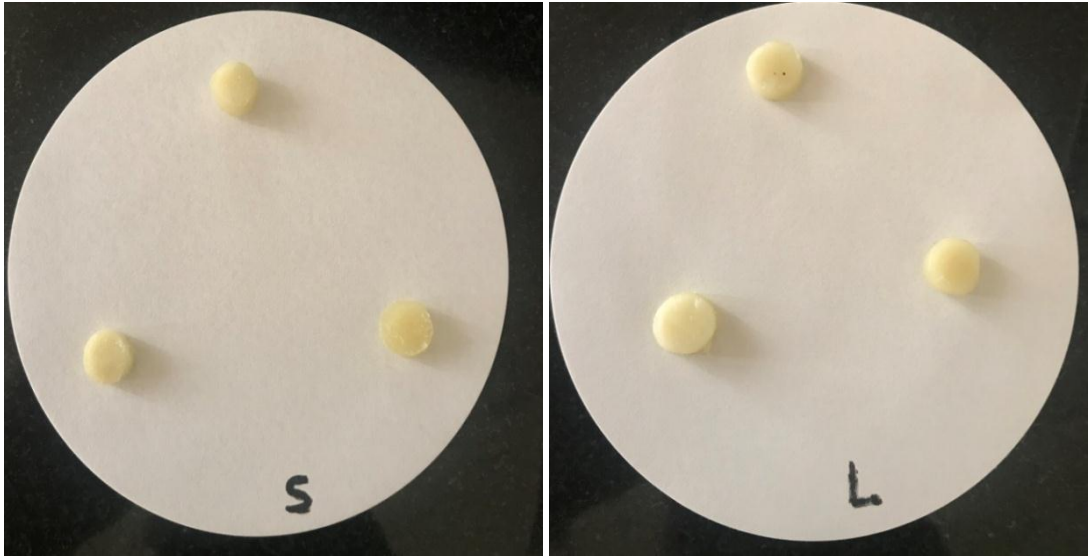


Fig. 3.20: Samples taken by borer on Whatman No. 40 filter paper



Fig. 3.21: Melted cheese sample on filter paper with oil rings formed after oven heating

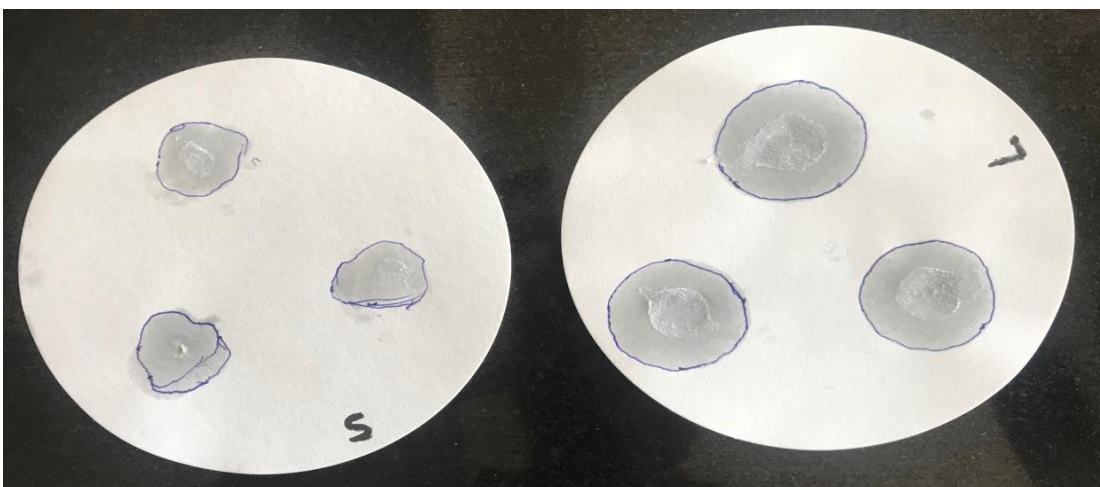


Fig. 3.22: Traced area of oil rings formed by Mozzarella cheese samples

CHAPTER IV

RESULTS AND DISCUSSION

The present study envisaged on feasibility of kneading and stretching operation of Mozzarella cheese with Screw mixer type kneader. Two mechanisms that is planetary mixer with hook attachment and screw mixer in a barrel were tested for kneading and stretching of curd to manufacture Mozzarella cheese. A modified unit of Screw mixer was designed and fabricated which could be used for proper kneading operation with optimum duration of kneading time.

This chapter contains design aspects of two existing mechanisms and the modified screw mixer and its components with their functions. Trials were conducted on the modified unit for comparing the effects of operational parameters (kneading water amount and rpm of screw) on the properties of Mozzarella cheese for optimizing the process of kneading operation.

The experimental data and results obtained are discussed covering various aspects as shown below.

1. Efficiency (on the basis of curd) evaluation of existing mechanisms
2. Evaluation of stretchability of Mozzarella cheese prepared from existing mechanisms
3. Development and fabrication of modified Screw mixer (Model 1)
4. Preliminary kneading trials on Modified Screw mixer (Model 1)
5. Modification and development of modified Screw mixer (Model 2)
6. Efficiency (on the basis of curd) evaluation for modified Screw mixer.
7. Evaluation of properties of Mozzarella cheese prepared from modified Screw mixer
8. Comparison of properties of cheese prepared from both conventional method and mechanized method

4.1 Efficiency (on the basis of curd) evaluation of existing mechanisms

In preliminary trial sessions of existing mechanisms first trial was completed with planetary mixer mechanism through which there was a proper kneading and stretching operation was done and the cheese was weighed properly. In this

mechanism after fitting the hook type probe in mixer the weighed Mozzarella curd (530, 412 and 495 gm) was put in the bowl along with water at 85°C temperature. 2 litres hot water used during operation. At lowest rpm possible in mixer that is at 52 rpm the kneading operation was started. After 2 minutes of kneading the cheese was weighed properly. The cheese value was found within 75-78% of curd weight. The quantity of curd used in this mechanism varied between 400-500 gm for trials. Properly stretched cheese was obtained with a shining and smooth surface. Hence, the operation of kneading and stretching was found to be successful with this mechanism. There was one limitation that this mechanism conduct batch type process and couldn't used for continuous production. So this mechanism was not found suitable to be upscaled for continuous Mozzarella cheese manufacture. To overcome this demerit second mechanism used was named screw mixer (Table. 4.1 and 4.2).

Generally screw mechanism is used for mixing and conveying purposes but sometimes it is also used for kneading operations in a continuous process. After attaching the hopper to the barrel feed opening the curd was put in the barrel with screw. After power supply the screw started rotating at 12 rpm inside the barrel and hot water was fed. RPM of screw was kept constant at 12 for all other trials. Curd was fed with small quantity varying 80-100 gm. After 1 minute of operation cheese started coming out of barrel exit die. During operation cheese was put again through hopper for proper kneading. Operation was conducted for 10 minutes. Cheese thus obtained was well kneaded and stretched with smooth and shining surface. This mechanism was well suitable for continuous process but there were heavy losses found because only 60-65% of efficiency on the basis of curd was obtained in all the trial sessions. Efficiencies of both existing mechanisms on the basis of curd were compared (Fig. 4.1). The screw wasn't detachable so the huge amount of cheese got stuck in the barrel and screw. Because the hopper was detachable so there was some clearance between the hopper end and the barrel feed opening. Some part of cheese got stuck in this clearance area. For reducing the losses and increase the feed capacity some modifications were suggested in this mechanism:

1. Drains plug availability at the bottom of barrel for proper water drainage.
2. Fixing both hopper and barrel and sealing the clearance gap by gas or arc welding.

3. Making detachable screw from barrel with a lock pin system.
4. Increasing diameter and length of screw for improve feed capacity and kneading time.
5. Proper output opening for Mozzarella cheese.

Table 4.1: Efficiency of existing Planetary Mixer on the basis of curd

Curd (gm)	530	412	495
Cheese (gm)	410	314	382
Warm water Temperature (°C)	85	85	85
Kneading Time (min.)	3	3	3
RPM	52	52	52
Kneading Water (L)	2	2	2
Efficiency (%)	77.35	76.21	77.17

Table 4.2: Efficiency of existing Screw mixer on the basis of curd

Curd (gm)	405	468	454
Cheese (gm)	246	308	297
Warm water Temperature (°C)	85	85	85
Kneading Time (min.)	10	10	10
RPM	12	12	12
Kneading Water (L)	2	2	2
Efficiency (%)	60.74	65.81	65.41

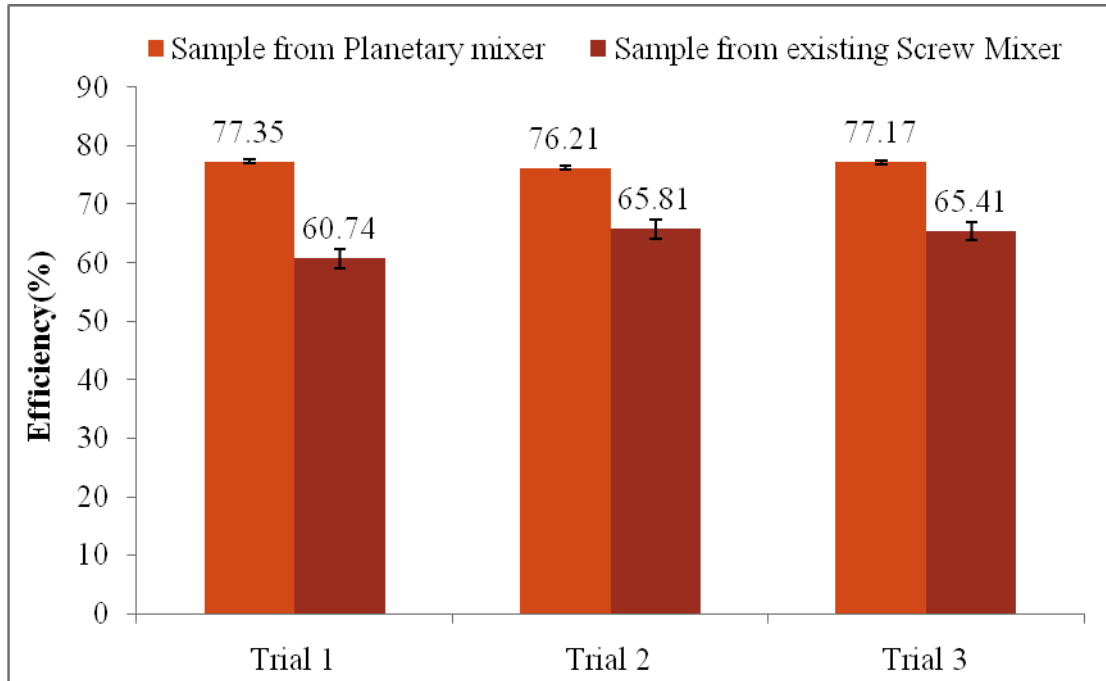


Fig. 4.1: Comparison of Efficiencies of both existing mechanisms on the basis of curd

4.2 Evaluation of Stretchability of Mozzarella cheese prepared from existing mechanisms

Stretchability of Mozzarella cheese was tested on cheese prepared in preliminary trials from both existing mechanisms and later on the values were compared. In first trial with existing screw mechanism the rpm was kept constant at 12. After noting the efficiency of existing screw mixer on the basis of curd the sample was tested for Stretchability test. Three trials were conducted for testing three samples for generating three values of stretching length. The kneading water temperature was also kept constant at 85°C. The kneading time was 10 minutes for trials. Three values of stretching length were calculated 49.3, 48 and 49 cm. The next trial was conducted with planetary mixer for comparing the values. RPM was kept constant at 52 throughout the trial session. This time again the kneading water temperature was kept constant at 85°C. 2 minutes of kneading time was kept in all trials which was much lower than Screw mixer. 50.1, 54 and 50.8 cm were the stretching length for Mozzarella with planetary mixer. So the stretching length values were higher in case of planetary mixer in all three trials. Hence, it was concluded that planetary mixer performed better in case of Stretchability test. But the difference in these values was low which can be ignored as shown in (Table 4.3) and (Fig. 4.2).

Table 4.3: Values of stretchability test of Mozzarella cheese prepared from existing mechanism

Cheese sample from Mechanism	Planetary Mixer	Screw mixer
RPM	52	12
Kneading time (min.)	2	10
Cheese Sample (gm)	150	150
Oven Temperature (°C)	200	200
Oven Time (min.)	15	15
Stretching Length (cm) (Trial 1)	50.1	49.3
Stretching Length (cm)(Trial 2)	54	48
Stretching Length(cm) (Trial 3)	50.8	49
Average Value	51.63	48.76

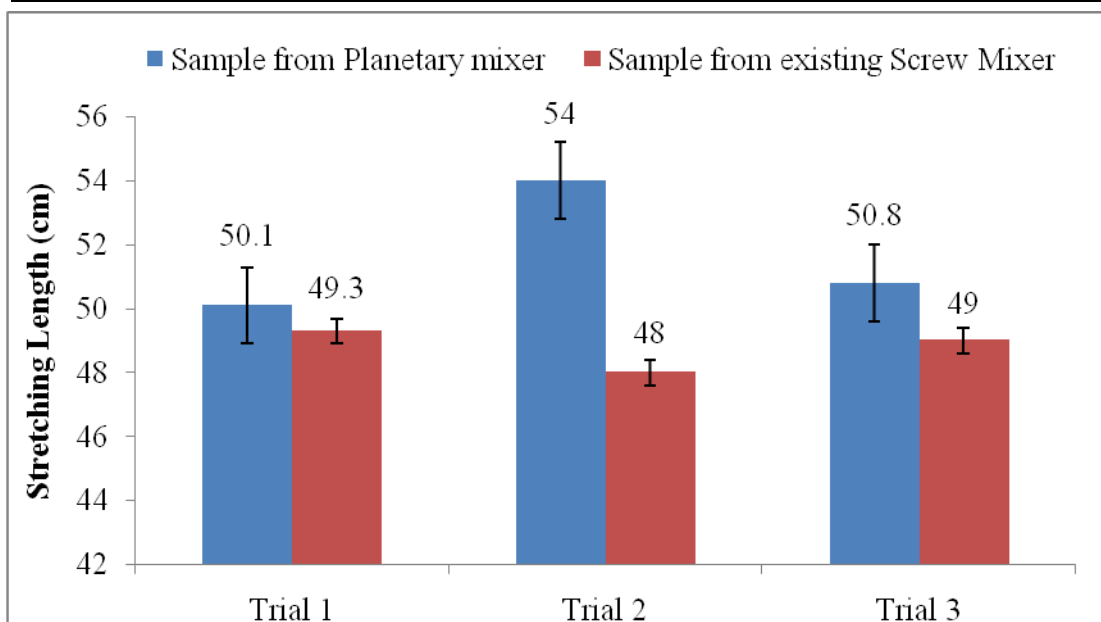


Fig. 4.2: Comparison of values of Stretchability test of Mozzarella cheese prepared from existing mechanism

4.3 Development and fabrication of modified Screw mixer (Model 1)

Modified Screw mixer unit was developed as a small unit with simple design at first. The unit was divided into three parts:

- Frame section
- Kneading section

- Power transmission section
- Power supply section

Frame section: Frame is generally made of cast iron material so, this section was fabricated with a stand made of mild steel material having small space covering with a rectangular shape. For better stability the bottom ends of the legs of stand were welded with small circular plates. The upper section of the stand was covered with a sheet for the placement of screw section on it as shown in Fig.4.3.



Fig. 4.3: Rectangular Frame

Kneading Section: Kneading section was fabricated with important components like screw, barrel (Fig. 4.5), barrel stand, fixed hopper and exit die. All these components were made of mild steel. For increasing the capacity of this section the diameter of screw (Fig. 4.4) was increased with 3 mm and the length was increased in 3 cm comparing previous unit. The size of screw and barrel was increased but clearance was maintained as earlier. For making a detachable screw, the screw was fabricated with a hollow shaft with a groove with nut for the purpose of inserting driving shaft (Fig. 4.6) into the hollow screw shaft.



Fig. 4.4: Screw



Fig. 4.5: Barrel



Fig. 4.6: Screw and Drive Shaft

The exit die was a thin section of circular plate attached at the end of the barrel with two nut placements and an opening. The hopper was properly attached to the the barrel feed opening by means of welding without leaving any clearance. So the hopper was made undetachable for reducing the loss.

Power transmission section: Affordable pulley and belt type transmission was used in this section (Fig. 4.7) instead of using costly gear and chain type transmission. This section had components like driving pulley, v-belt, driven pulley, bearing housings and a driven shaft with a groove for nut placement to attach and lock the screw on it. Bearing housings with driven shaft were properly aligned by welding iron blocks under them for proper insertion of shaft into the barrel.



Fig. 4.7: Belt and Pulley transmission setup

Power supply section: This section comprised a three phase AC motor of 1/4 hp output power and a FRENIC-Mini Inverter which was used for varying the rpm speed of the motor shaft. Three phase motor was used in this section because the rpm regulator (FRENIC-Mini Inverter) was fully compatible with it. Motor was placed on the welded plate on the side supports of the legs at the lower part of frame. Regulator was placed on the right top corner of the frame by attaching screws.

4.4 Preliminary kneading trials on Modified Screw mixer (Model 1)

The first trial was taken with the kneading of curd for Mozzarella cheese preparation. After locking the screw on driven shaft and joining the exit die a specific rpm was set from the regulator. The motor was switched on and then feeding of curd started with small amount varying from 80-100 gm. But the screw got jammed due to low torque.

After failing the trial the next trial was taken on the Mozzarella curd with the feed varying from 80-100 gm along with hot water (2 litres) at 80°C. On high rpm speed by regulator it was possible to rotate the screw but once the screw rotated with uneven speed with large speed fluctuation the curd was not properly kneaded. Also in low rpm screw jammed again so the overall trials failed due to low value of torque.

To increase the torque value the 1/4hp single phase motor was replaced with 1/2 hp three phase motor. Instead of using motor with high power factor a gear reduction box was placed to increase the torque value. Gear reduction box was used to give high rpm on the input side and decrease the high rpm value on the output side with high torque effect which was desirable for kneading and stretching of Mozzarella cheese.



Fig. 4.8: Modified Screw mixer (Model 1)

4.5 Modification and development of modified Screw mixer (Model 2)

Preliminary kneading trials on modified screw mixer were not successful due to low torque value. It required modification in the power transmission section. Gear reduction box with speed reduction ratio of 1/25 was used along the motor. Motor pulley was now attached to the gear box driven pulley. Motor at high speed gave the output to the screw through the gear box was 22 rpm with high torque value. So now there was an option to vary the rpm value up to 22.

Preliminary trail was taken with the kneading of curd and it was successfully conducted in the modified unit (Fig. 4.9). So than trials were conducted with varying rpm and kneading hot water. After successfully doing the trials by varying two parameters (rpm and water quantity) the properties of cheese samples were properly analyzed and the change in properties was observed. The schematic diagram of the unit is shown in Fig. 4.10.

Values of changes occurred in the properties of cheese with having variations in suggested two parameters was noted down and it was compared.

Later all the values of properties of cheese were compared with the properties of cheese made with hand process by conventional method (by hand).



Fig. 4.9: Modified Screw mixer (Model 2)

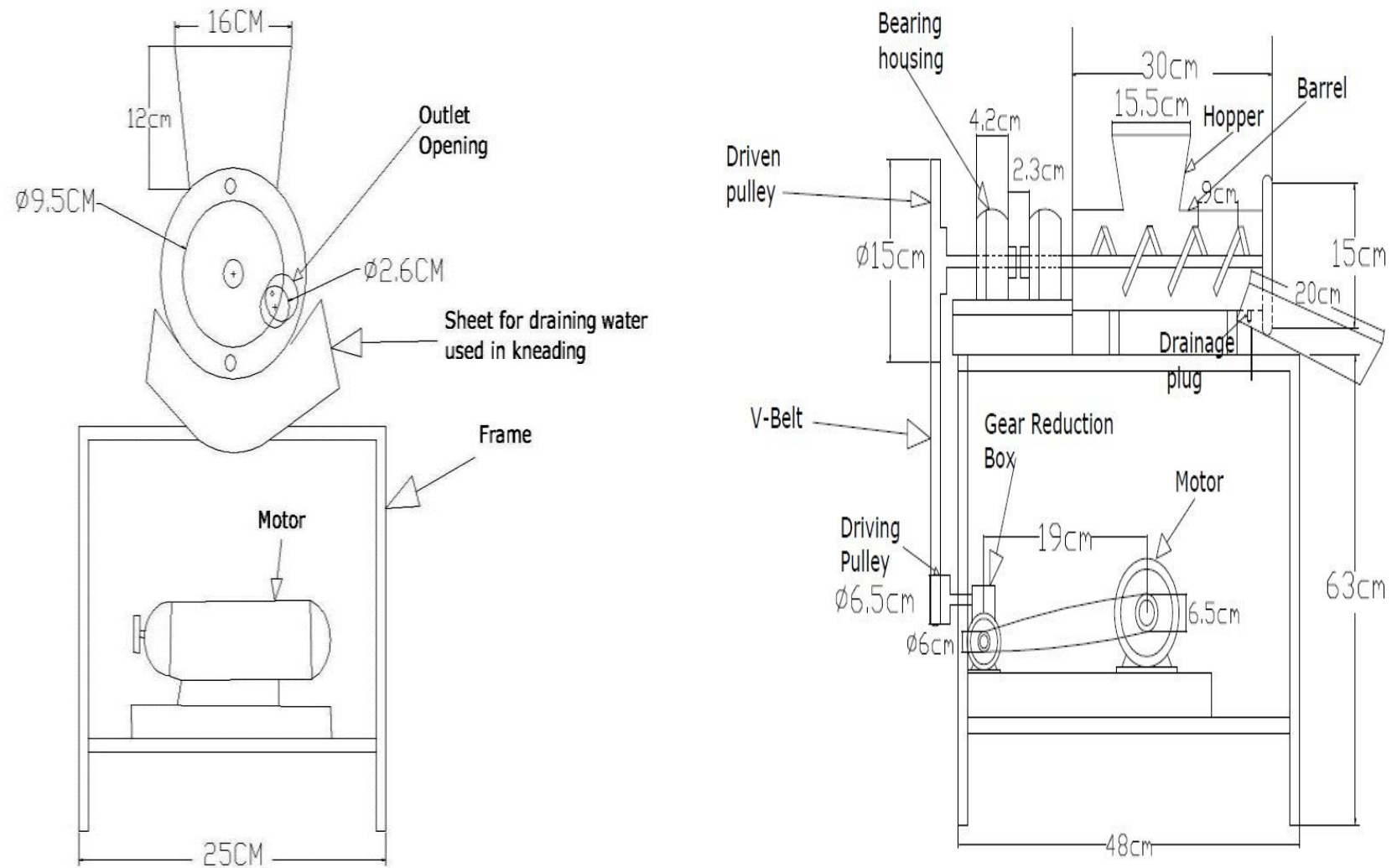


Fig. 4.10: Schematic diagrams of the unit with Front View (left) and Side View (right)

Table 4.4: Dimensions of the modified unit

Name of Component	Dimension (cm)
Hopper Width at the top	16
Hopper length at the top	16
Barrel length	30
Barrel diameter	9.5
Diameter of screw	9
Length of screw	29
Diameter of exit outlet	2.6
Diameter of exit die	15
Thickness of exit die	1.5
Frame Height	63
Frame length	48
Frame width	25

4.6 Efficiency evaluation for modified Screw mixer

After considering the limitations of existing screw mixer the design for modified Screw mixer was decided and fabricated. Fabricated modified unit was created for optimistic approach and better efficient performance. In the next trial sessions with the modified unit kneading time was kept low for optimizing the operation. The operation for kneading time was kept 3 min. for whole trial session. In this session of trials two variables were considered to be varied rpm of screw and kneading water amount. Efficiency generated from the modified unit varied majorly under the effect of rpm of screw rather than kneading water amount. It was concluded that efficiency was decreasing with increase in rpm of screw. Minimal effect was observed under the effect of variation in kneading water amount under same rpm. In case of 10 rpm the efficiency increased from 78.99 to 80.95% with increase in kneading water amount. At 15 rpm the efficiency decreased with increase in kneading water amount from 79.37 to 78.01%. At 20 rpm the efficiency decreased from 78.99

to 80.95% with increase in kneading water amount from 77.52 to 75.85%. So, two different effects were observed with variation in kneading water amount. In this whole trial water temperature was kept constant at 80°C. The efficiency on the basis of curd was found between 75-80% including all varying patterns in trial. So both parameters had their effects on the efficiency as shown in Table 4.5 and Fig 4.11.

Table 4.5: Efficiency of modified screw mixer on the basis of curd

Curd (gm)	319	325	315	320	349	341	347	339	352
Cheese (gm)	252	259	255	254	273	266	269	260	267
Warm water Temperature (°C)	80			80			80		
Kneading Time (min.)	3			3			3		
RPM	10			15			20		
Kneading Water (L)	0.5	1	1.5	0.5	1	1.5	0.5	1	1.5
Efficiency (%)	78.99	79.69	80.95	79.37	78.22	78.01	77.52	76.69	75.85

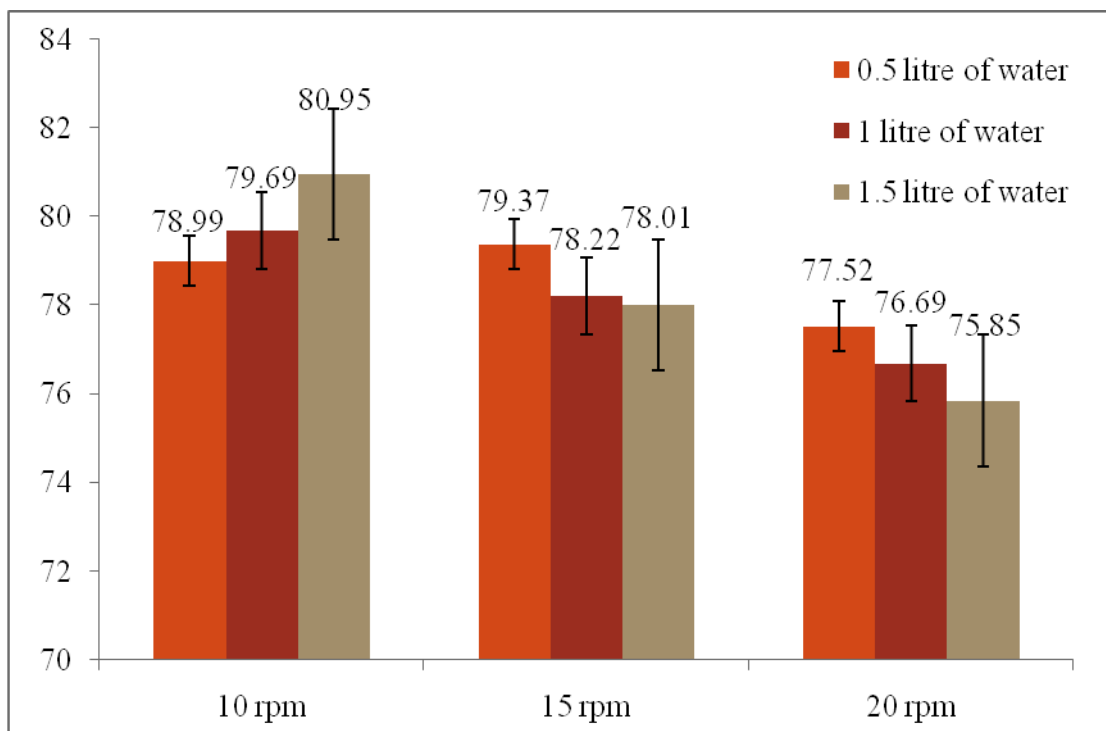


Fig. 4.11: Efficiency of modified screw mixer unit

4.7 Evaluation of properties of Mozzarella cheese prepared from modified Screw mixer

After observing the effect of variation in rpm and kneading water amount these Mozzarella cheese samples prepared from modified Screw mixer were evaluated by testing five properties of Mozzarella with different testing sessions. Stretchability, meltability, free oil formation, moisture content and fat content were the properties which were tested for cheese prepared from modified unit. Two parameters (rpm and water used for kneading) of operation of preparation were varied for observing their effect on these five properties. RPM and the kneading water amount were the two operational parameters which were varied in the final trial sessions with modified unit. After varying these two parameters the values of these properties were noted down and later then the change occurred in the values was observed.

4.7.1 Evaluation of stretchability of Mozzarella cheese

In preparation of cheese with modified unit the stretchability test was conducted. The same procedure of this test was repeated on the cheese sample prepared from conventional method. In this testing session on nine samples prepared from varied operational parameters (rpm and kneading amount water) nine values of the stretching length were obtained. Both the operational parameters were effective on the stretchability of the cheese samples. But the major effect was due to variation in rpm. Lowest stretching length was observed in cheese prepared with lowest rpm and lowest kneading water amount in trial. At 10 rpm the stretching length first increased from 43.4 to 49.6 cm and then decreased from 49.6 to 48.7 with increase in kneading water amount. At 15 rpm the stretching length increased with increase in kneading water amount from 49.3 to 55.1 cm. At 20 rpm the stretching length first decreased from 54 to 51.9 cm and then increased from 51.9 to 60.8 cm with increase in kneading water amount. The highest stretching length 60.8 cm was obtained in case of highest rpm 20 and highest kneading water amount 1.5 litres. So there was a significant increase in the stretchability with increase in both the operational parameter. Stretching length 55.1 cm obtained in case of 15 rpm and 1.5 litres of kneading could be considered. But the best result was observed from the highest operational parameters as shown in Table 4.6 and Fig 4.12.

Table 4.6: Values of stretchability test of Mozzarella cheese prepared from modified Screw mixer

Kneading time (min.)	3			3			3		
Cheese Sample (gm)	150			150			150		
Oven Temperature (°C)	200			200			200		
Oven Time (min.)	15			15			15		
RPM	10			15			20		
Kneading Water (L)	0.5	1	1.5	0.5	1	1.5	0.5	1	1.5
Stretching Length (cm)	43.4	49.6	48.7	49.3	51.8	55.1	54	51.9	60.8

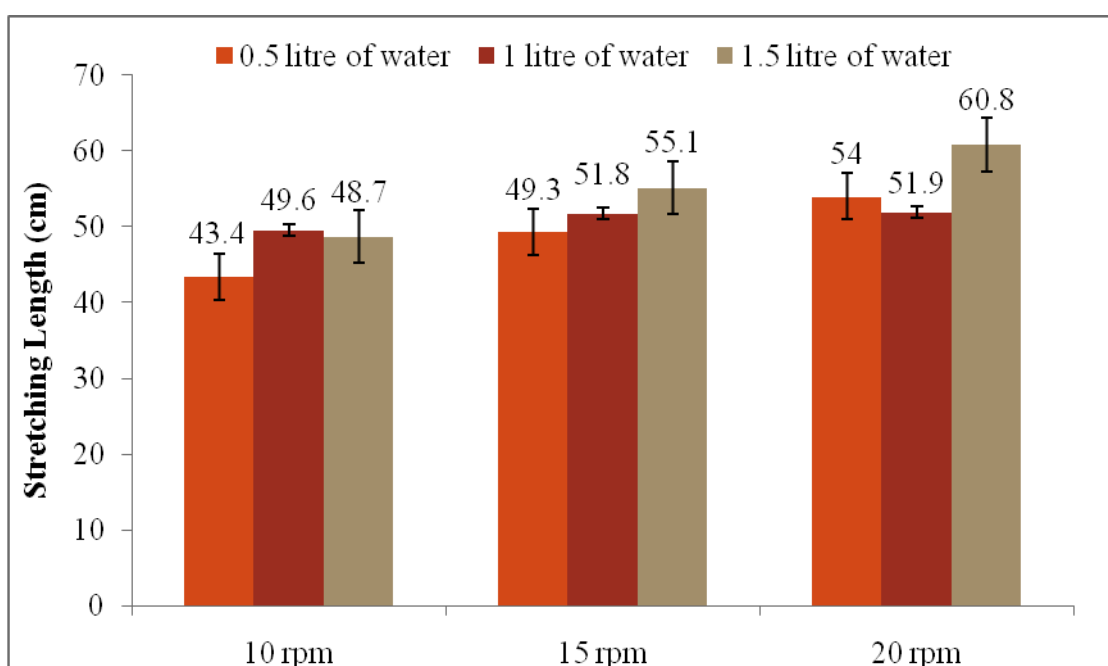


Fig. 4.12: Stretchability Test values of Mozzarella cheese prepared from modified Screw Mixer

4.7.2 Evaluation of Meltability of Mozzarella cheese

Meltability values found in case of 10 rpm with three different varying kneading water amounts were the lowest. The highest value was observed in case of 20 rpm with 1.5 litres of kneading water amount. Gradual increase in meltability values was noted with increase in rpm. But in case of variation in kneading water amount the results were random. In this testing session the major effect was observed due to variation in rpm. At 10 rpm the meltability value first increased from 10.2 to 10.5 cm and then decreased from 10.5 to 10.4 cm with increase in kneading water

amount. At 15 rpm the meltability value first increased from 11.7 to 13.3 cm and then decreased from 13.3 to 13.1 with increase in kneading water amount. At 20 rpm the meltability value increased with increase in kneading water amount from 13.2 to 17.4 cm. Difference in meltability values was low in case of variation in kneading water amount with 10 and 15 rpm. But the difference in meltability values was notable in case of variation in kneading water amount at 20 rpm. So in this case also both the operational parameters were observed to be effective as shown in Table 4.7 and Fig 4.13.

Table 4.7: Values of meltability test of Mozzarella cheese prepared from modified Screw mixer

Kneading time (min.)	3			3			3		
Cheese Sample (gm)	10			10			10		
Oven Temperature (°C)	100			100			100		
Oven Time (min.)	15			15			15		
RPM	10			15			20		
Kneading Water (L)	0.5	1	1.5	0.5	1	1.5	0.5	1	1.5
Melted Cheese Length (cm)	10.2	10.5	10.4	11.7	13.3	13.1	13.2	15.8	17.4

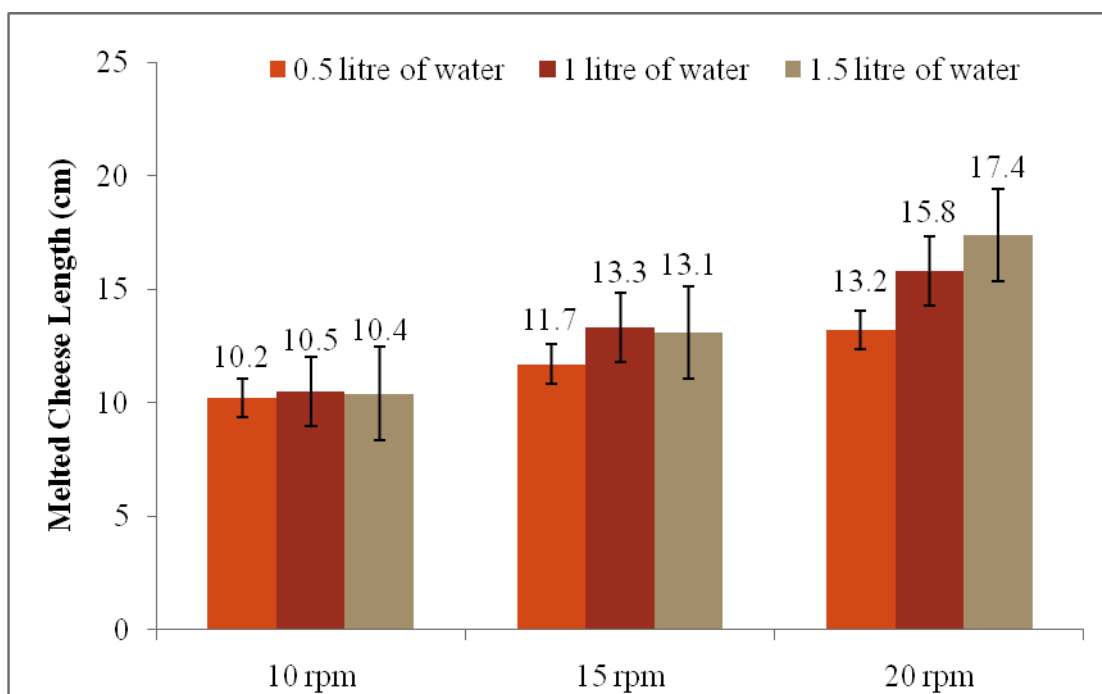


Fig. 4.13: Values of Meltability test of Mozzarella cheese prepared from modified Screw Mixer

4.7.3 Evaluation of Moisture content of Mozzarella cheese

Moisture content value was determined by using following equation:

$$\text{Moisture Content (\%w/w)} = \frac{(W_1 - W_2)}{(W_1 - W)} \times 100$$

Where,

W - Empty dish weight

W_1 - weight of aluminium dish in gm with cheese (Before drying)

W_2 - weight of aluminium dish in gm with cheese (After drying)

After Moisture content values in cheese samples gradually increased with increase in both the operational parameters. Three replicates were taken with their mean values. At 10 rpm the mean value of moisture content increased with increase in kneading water amount from 43.70 to 45.86%. At 15 rpm the mean value of moisture content increased with increase in kneading water amount from 43.76 to 48.64%. At 20 rpm the mean value of moisture content increased with increase in kneading water amount from 45.63 to 51.10%. This time no one was majorly or minorly effective because both the operational parameters had almost equal effects on the moisture values of cheese samples. Lowest moisture content value was observed at 10 rpm and with 0.5 litre of kneading water amount. With gradual increment in both parameters value increased gradually so as we reached in the last case with 20 rpm and 1.5 litres of kneading water amount the moisture value was the highest of all in all the samples as shown in Table 4.8 and Fig 4.14. So in this evaluation both parameters made equal contribution in effectiveness of moisture content

Table 4.8: Values of Moisture content test of Mozzarella cheese prepared from modified Screw mixer

Kneading time (min.)	3			3			3		
Cheese Sample (gm)	3			3			3		
Oven Temp. (°C)	102±2			102±2			102±2		
Oven Time(min.)	150			150			150		
RPM	10			15			20		
Kneading Water (L)	0.5	1	1.5	0.5	1	1.5	0.5	1	1.5l
Moisture Content (%) 1	43.491	44.401	45.501	44.421	44.735	48.350	45.343	49.557	50.814
Moisture Content (%) 2	43.292	44.689	45.951	43.274	45.024	48.816	45.897	49.491	50.240
Moisture Content (%) 3	44.105	44.909	46.121	43.593	45.115	48.748	45.644	49.107	52.257
Mean Values	43.70±1.09	44.67±2.64	45.86±2.62	43.76±1.09	44.96±2.64	48.64±2.64	45.63±1.09	49.38±2.64	51.10±2.62

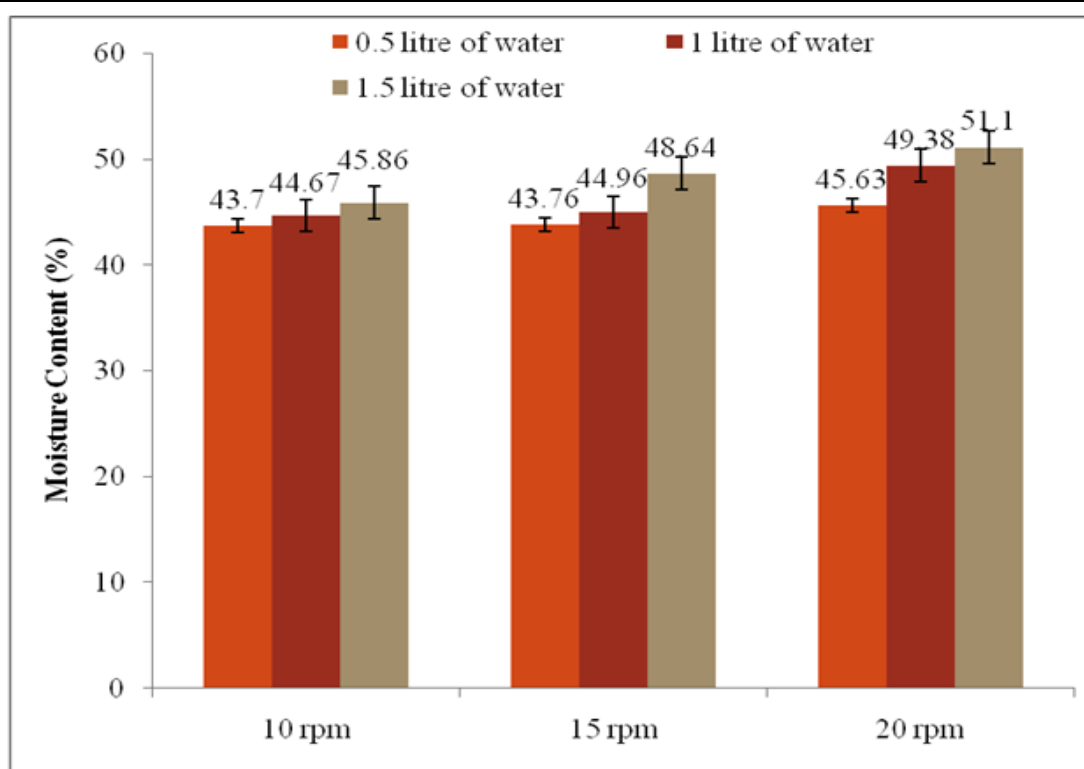


Fig. 4.14: Values of Moisture content test of Mozzarella cheese prepared from modified Screw Mixer

4.7.4 Evaluation of Fat content of Mozzarella cheese

Fat content values were obtained by using cheese butyrometer which was a time saving operation. In case of fat content random values were obtained with variation in both operational parameters. Lowest value was obtained at rpm 15 with 1.5 litres of kneading water amount and the highest value was found in case of 20 rpm with 1.5 litres of kneading water amount which did not show any result of effectiveness of variation in the operational parameters as shown in Table 4.9 and Fig 4.15. So no particular effect was observed in fat content of all nine samples prepared from modified Screw mixer.

Table 4.9: Values of Fat content test of Mozzarella cheese prepared from modified Screw mixer

Kneading Time (min.)	3			3			3		
Cheese sample (gm)	3			3			3		
Warm water Temp. (°C)	35			35			35		
Centrifuge Time (min.)	5			5			5		
RPM	10			15			20		
Kneading Water(L)	0.5	1	1.5	0.5	1	1.5	0.5	1	1.5
Fat Content (%)	23.5	24.5	24	23.5	24	23	24	23.5	25

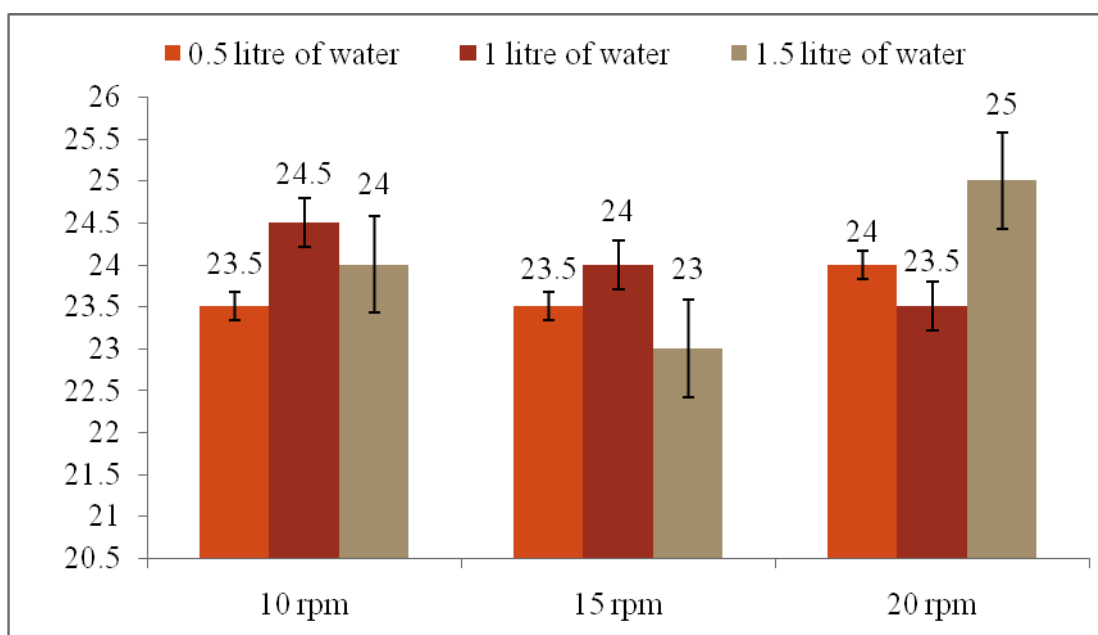


Fig. 4.15: Values of Fat content test of Mozzarella cheese prepared from modified Screw Mixer

4.7.5 Evaluation of Free oil formation of Mozzarella cheese

By plotting the traced areas of the fat rings on graph paper free oil areas were estimated by counting of each small cubes of 1 mm² for accuracy. Three replicates were taken with their mean values. At 10 rpm the mean value of free oil area increased with increase in kneading water amount from 196.33 to 311 mm². At 15 rpm the mean value of free oil area increased with increase in kneading water amount from 377.66 to 651 mm². At 20 rpm the mean value of free oil area increased with increase in kneading water amount from 447.33 to 863 mm². According to the all generated values the results of effect of variation in kneading water amount was random in some amounts and in some amounts was linear with fixed rpm values. But in term of variation in rpm the effective results were linear. So as the rpm values increased the oil formation values also increased. In this testing both parameters variation showed the effect on values of free oil formation in cheese samples as shown in Table 4.10 and Fig 4.16.

Table 4.10: Values of Free oil formation test of Mozzarella cheese prepared from modified Screw mixer

Kneading Time (min.)	3			3			3		
Oven temp. (°C)	110			110			110		
Oven Time (min.)	5			5			5		
RPM	10			15			20		
Kneading Water (L)	0.5	1	1.5	0.5	1	1.5	0.5	1	1.5
Free Oil Area (mm ²) 1	202	281	285	372	409	631	486	771	939
Free Oil Area (mm ²) 2	189	186	359	368	424	847	494	757	936
Free Oil Area (mm ²) 3	198	299	289	393	649	475	362	915	714
Mean Values	196.33± 129.50	255.33± 280.50	311± 278.46	377.66± 129.50	494± 280.50	651± 278.46	447.33± 129.50	814.33± 280.50	863± 278.46

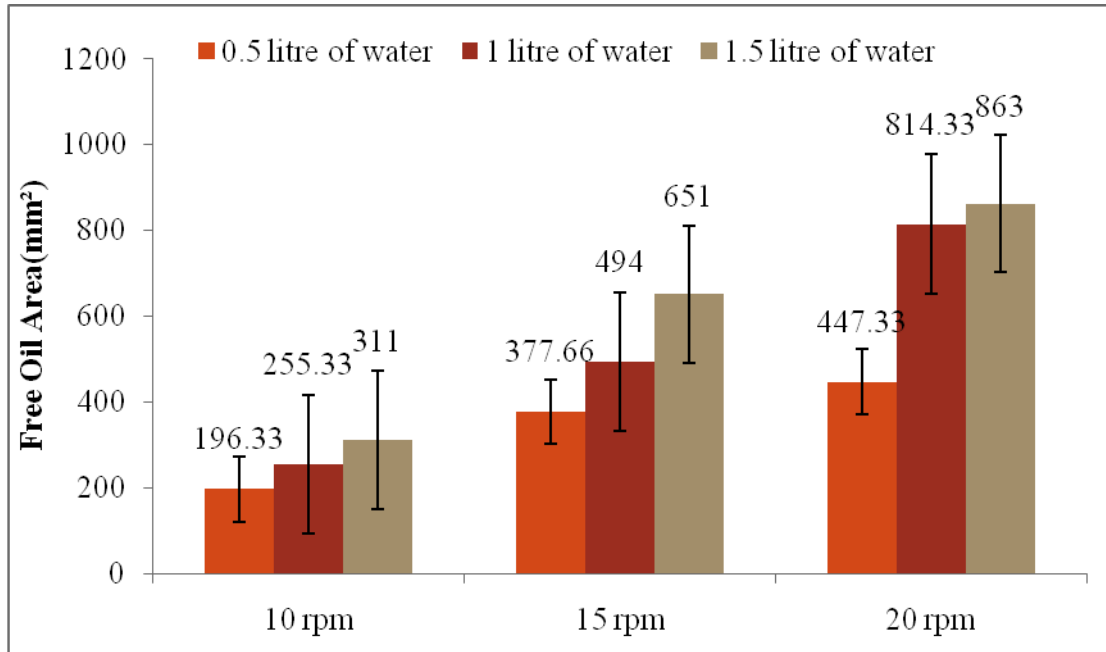


Fig. 4.16: Values of Free oil formation test of Mozzarella cheese prepared from modified Screw Mixer

4.8 Comparison of properties of Cheese prepared from both conventional method and mechanized method

In conventional method kneading and stretching was done manually with hands covered with plastic gloves in 80°C hot water. Duration of kneading and stretching was 2 minutes. 1.5 litres amount of kneading water was taken for this operation. After testing and evaluation of samples prepared with this method the values of properties generated were compared with values from mechanized unit as shown in Table 4.11.

The efficiency of conventional method on the basis of curd was less than the efficiency of existing screw mixer mechanized method with variation in different operational parameters. Highest value of stretchability and moisture content was found in sample of conventional method. Highest value of meltability, fat content and free oil formation was found in sample of mechanized method in case of 20 rpm and 1.5 litres of kneading water used. The overall values of samples generated from conventional method were closer to the values of samples generated with mechanized unit in case with highest speed (rpm-20) and highest kneading water amount (1.5 litres).

Table 4.11: Values of properties of Cheese prepared from both conventional method and modified mechanized method

Parameter	Modified Mechanized Method									Conventional Method
	3			15			20			
Kneading time (min.)	3			3			3			2
RPM	10			15			20			-
Kneading water (L)	0.5	1	1.5	0.5	1	1.5	0.5	1	1.5	1.5
Unit Efficiency (%)	78.99	79.69	80.95	79.37	78.22	78.01	77.52	76.69	75.85	71.15
Stretchability (cm)	43.4	49.6	48.7	49.3	51.8	55.1	54	51.9	60.8	65
Meltability (cm)	10.2	10.5	10.4	11.7	13.3	13.1	13.2	15.8	17.4	17
Moisture Content (%)	43.70	44.67	45.86	43.76	44.96	48.64	45.63	49.38	51.10	51.16
Fat Content (%)	23.5	24.5	24	23.5	24	23	24	23.5	25	23
Free Oil Area (mm ²)	196.33	255.33	311	377.66	494	651	447.33	814.33	863	738

CHAPTER – V

SUMMARY

Cheese manufacturing is a good example of milk preservation. Cheese is one of the prized food item due to its diversified flavour and taste. More than 900 varieties of cheese are known worldwide which are classified on the basis of their form, manufacturing technique, starter culture used and ripening (Banks 1998). Mozzarella cheese also referred as pizza cheese is a soft unripened cheese variety of pasta-filata family. Mozzarella is manufactured typically from cow's milk but conventionally. It was made from buffalo milk. Mozzarella cheese comprises of 32% of total cheese produced in the world (Anon 2002). Mozzarella exhibits desirable functional attributes such as shredding, melting, stretching and browning which makes it appropriate to be used in form of pizza toppings, cheese blends, salads and sandwiches.

Mozzarella was developed in Italy due to its global popularity and high marketing value. Its consumption is one third of the total cheese consumption cheese consumption. It is a type of pasta filata cheese. Majorly this type of cheese is manufactured from the buffalo milk due to high fat requirement. India has a capability of large buffalo milk production as 56% of the total population of buffalo in the world is from India (Anon 2012). In case of Punjab, buffalo milk production it contributes 71% of total to central milk production (Anon 2016). There is increase in demand of cheese, but the dairy farmers are unable to fulfill this requirement. The reason behind this is lack of awareness for technique of Mozzarella cheese production and scarcity of mechanization at small scale. At present farmers are using conventional methods for Mozzarella manufacture in which kneading and stretching of curd is done with hand dipped in hot water. This hand operation is labour intensive and consumes lot of time. Though mechanized units are available, but they are suitable for large scale production and are costly. So there is a need of a small and economic mechanized unit for the stretching and kneading operation for Mozzarella cheese manufacture. In light of above views, the present study was planned with following objectives;

1. To study and evaluate the existing kneading and stretching mechanisms.
2. To standardize the operational parameters for selected mechanism for preparation of Mozzarella cheese.

So for the development of the unit, it was important to evaluate existing kneading mechanism the experiment was started with trials in existing mechanisms (existing Screw mixer and planetary mixer). Planetary mixers are based on the principle of two types of ongoing motions of auger or blade inside the bowl are used with attachments like whisk, hook, flat beater etc for mixing of pastes, adhesives, dough, powders and granulations with high shear rate and at high rpm. Screw mixers are based on operating principle behind Archimedes' screw are used to perform operations like mixing, dewatering, and compression along with conveying process of materials in bulk.

Various modifications were done while designing and fabrication of the modified unit. Unit was fabricated with Kneading section, Transmission section, Power Unit section and Frame section. In kneading section diameter of screw was increased with 3 mm and the length was increased with 3 cm as compare to the screw used in existing mechanism. Hopper was welded with barrel for making it non-detachable part of the section. Drainage plug was installed under the barrel for draining the water used in kneading and exit opening was covered with circular plate by screw. Clearance between screw and barrel was kept similar as compare to the screw used in existing mechanism

In transmission section, pulley and v-belt type of transmission system was used instead of gear and chain type. Gear reduction box connected with motor with belt and pulley was added in transmission for increasing the value of torque. In Power Unit section single phase AC motor with 1 HP was used in existing screw mixer unit but in modified unit, three phase AC motor with 1/2 HP was used with a speed regulator (FRENIC-Mini Inverter) to vary the rpm value.

After developing the modified unit, trials were conducted and the efficiency of the unit was observed on the basis of curd. The Mozzarella cheese manufactured from this unit was tested for the evaluation of its properties like stretchability, meltability, free oil formation, fat content and moisture content with varying some operational parameters. Two operational parameters, rpm (10, 15 and 20) and water used in kneading (0.5, 1 and 1.5 litres) were selected in trials for the variation. Mozzarella cheese manufactured using modified unit with varying operational parameters was compared with that made using conventional method (by hand). The properties

compared were stretchability, meltability, free oil formation, fat content and moisture content.

The following conclusions were drawn from the study:

1. Efficiency of existing screw mixer on the basis of curd varied from 60 to 65% was lower than the efficiency of planetary mixer which varied from 76 to 77%
2. In frame section smaller frame as compare to previous unit with rectangular shape was used as a frame and welding of circular plates was done under the legs of frame for better stability
3. In kneading section the diameter of screw was increased with 3 mm and the length was increased with 3 cm as compare to the screw used in existing mechanism. The hopper was welded with barrel for making it non-detachable part of the section. The drainage plug was installed under the barrel for draining the water used in kneading and an exit opening was covered with circular plate by screw.
4. In transmission section pulley and v-belt type of transmission system was used instead of gear and chain type and gear reduction box connected with motor with belt and pulley was added in transmission for increasing the value of torque.
5. In power unit section three phase AC motor with 1/2 HP was used with a speed regulator (FRENIC-Mini Inverter) to vary the rpm value.
6. Efficiency of modified unit on the basis of curd varied from 75-80% with varying operational parameters
7. Efficiency of modified unit in the basis of curd decreased with increase in both rpm and amount of kneading water.
8. Stretchability, meltability, moisture content and free oil formation increased with increase in the rpm as well as water used for kneading.
9. The value of water retention increased with increase in both rpm and amount of kneading water.
10. The results from conventional method were closer to the values generated in case with highest speed (rpm-20) and highest kneading water amount (1.5 litres).

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