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**Charanjit Singh**
M. Tech Research Scholar, College of Dairy Science and Technology, Thiruvananthapuram, Kerala, India

**Gopika Talwar**
Assistant Professor, College of Dairy Science and Technology, Thiruvananthapuram, Kerala, India

**Amandeep Sharma**
Assistant Professor, College of Dairy Science and Technology, Thiruvananthapuram, Kerala, India

**Nitika Goel**
Assistant Professor, College of Dairy Science and Technology, Thiruvananthapuram, Kerala, India

**Corresponding Author:**
**Gopika Talwar**
Assistant Professor, College of Dairy Science and Technology, Thiruvananthapuram, Kerala, India

# Effect of stretching and kneading mechanism on properties of mozzarella cheese

**Charanjit Singh, Gopika Talwar, Amandeep Sharma and Nitika Goel**

**Abstract**
Cheese is the fresh or matured product obtained by the drainage of whey after coagulation of milk through use of rennet and starter. In the present investigation, indigenous prototype for kneading and stretching mechanism was developed and evaluated on the basis of yield efficiency. Two existing mechanisms *viz*. planetary mixer (two attachments) and screw mixer were tested for kneading and stretching and found that efficiency of existing screw mixer was lower. After some modifications the new design of screw mixer was fabricated. In modified unit, rpm was varied as 10, 15 and 20 rpm along with water used for kneading as 0.5, 1 and 1.5 litres. Cheese yield efficiency decreased with increase in both rpm and amount of kneading amount from 80.95% 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:** Mozzarella cheese, stretching, kneading, prototype, mechanization

## Introduction

Mozzarella cheese belongs to the pasta-filata family, which isunripened, white, and soft cheese that has to be consumed fresh (Jana and Tagalpallewar 2017) [8]. Traditionally it was developed from buffalo milk but now it can be produced from bovine milk (Thybo *et al*. 2020) [17]. As per the available source of milk, the flavour attributes of mozzarella cheese may vary as mild and slightly sour (Seth and Bajwa 2015; Janaand Tagalpallewar, 2017; Fasale *et al*. 2017) [15, 8, 4].

Commonly starter culture method was used for the curd preparation of mozzarella cheese but this was a time consuming technique. Therefore, direct acidification is widely used for the curd preparation which is a quick process. In this method, Mozzarella cheese was manufacturedby proper acidification of milk followed by coagulation using enzyme called rennet. After curd preparation, for proper consistency cutting and cookingwas done in whey at 36-40 °C. Then after whey drainage the operation of stretching and moulding of curd was conducted in hot water for obtaining the desired stretch ability and melting characteristics in cheese (Ingaldi and Jagusiak-Kocik 2013) [6].

This last operation of heating and stretching of curd in hot water helps in obtaining the smooth and shiny texture of cheese that differentiates the mozzarella cheese from other types (Fasale *et al*. 2017; Smith *et al*. 2017) [4, 16]. This thermomechanical treatment is accounted for the unique characteristics of mozzarella cheese (Yu and Gunasekaran 2004; McMahon and Oberg 2011) [18, 12]. The unique stretching and melting properties are considered valuable for the production of pizza as it is key ingredient (Jana 2001; Zhu *et al*. 2015) [7, 19]. As with any thermomechanical treatment, the stretching characteristics of mozzarella cheese is mainly rely on material to be used, stretcher geometry and operating conditions.

Conventionally, thermomechanical process is done manually therefore labour requirement is quite high which leads to drudgery as the labour has to do both 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, as well as vats employed. So the mechanization is must in the kneading and stretching process for the reduction in drudgery and establishing better control over moisture and fat content of the cheese is obtained. Recently commercially available planetary mixer and single or twin screw mechanism were used for stretching and kneading the molten cheese to obtain the desired shape (Yu and Gunasekaran 2004) [18].

Generally, screw mechanism is an extrusion process in which a sufficient amount of pressure is applied within the barrel to force the molten cheese into the die (mold).

This mechanical has one main merit that it rapidly transforms the individual particles of curd into a heterogeneous but continuous, flowable product that can be easily passed through the molds. However, this resulted in dissimilar distribution of moisture throughout the fresh mozzarella cheese (Kuo *et al*. 2001) [9] hence, system is not in equilibrium (Luyten *et al*. 1991) [10].
Several investigations have been done on mozzarella cheese by various investigators (Renda *et al*. 1997; Bähler and Hinrichs 2013; Ma *et al*. 2013) [14, 1, 11], but the interactions involved in the stretching mechanism need more investigation. To manufacture the mozzarella cheese with some specific characteristics, it is necessary to understand the influence of thermomechanical treatment on desired properties of mozzarella cheese (Bähler *et al*. 2016) [2]. Therefore, the objective of the study is to develop and evaluate an indigenous prototype for kneading and stretching mechanism of mozzarella cheese. It was also investigated the impact of kneaded amount of water and screw speed on the quality characteristics of mozzarella cheese.

**Materials and method**

The mozzarella cheese was manufactured using the method standardized by CODST, GADVASU (Ludhiana) as direct acidification. Generally, in this method the entire operation of containment, cooking, stretching and kneading was done in hot water jacketed vat with both inlet and exit port. The flow diagram (fig. 1) describes the detailed procedure for manufacturing of mozzarella cheese and table 1 represents the operating parameters along with the amount of curd formed. But this experiment was done with some modifications. In this experiment, cooking, stretching and kneading were done in induction utensil and induction plate was used as heating source. After preparation of curd the stretching and kneading was done in two different existing mechanisms as screw mixer and planetary mixer. The cheese yield efficiency and stretching length were investigated for these existing mechanisms.

4 kg milk
↓
Standardization (in less than 4 °C)
↓
Pasteurization (72°C/15 Sec)
↓
Chilling (to 4 °C)
↓
Acidification with citric acid (to pH 5.2-5.4)
↓
Heating (28-30 °C)
↓
Addition of rennet (0.054 mg in 10ml water)
↓
Coagulation
↓
Cutting the curd (with vertical and horizontal knives)
↓
Cooking (to 36-39°C)
↓
Drainage of Whey
↓
Stretching and kneading under hot water (80-85°C temp)
↓
Moulding
↓
20-22% Brining (at 4°C)
↓
Packaging

**Fig 1:** Flow Diagram for the manufacture of mozzarella cheese using direct acidification method. (Bansal *et al.* 2018) [3]

**Table 1:** Operating parameters and formation of curd for manufacturing of mozzarella cheese

| Parameters | Trial 1 | Trial 2 | Trial 3 |
|---|---|---|---|
| Milk | 4 litres | 4 litres | 4 litres |
| RPM | 30 | 30 | 30 |
| Curd | 405gm | 468gm | 454gm |
| Yield | 256gm | 308gm | 297gm |
| Operating time | 10 minutes | 10 minutes | 10 minutes |
| Water added before temp | 85 °C | 85 °C | 85 °C |
| Water Added | 2 litres | 2 litres | 2 litres |

**Setup of planetary mixer for preliminary trial**

Planetary mixers were based on the principle of two types of motions of auger or blade inside the bowl. In first type blade rotates on its own axis and the second type rotation of blade covering round distance around the centre of bowl with some clearance between the blade and inner wall of bowl. Different types of attachments include wire mesh and hook was used for analysing the feasibility of kneading and mixing operation. After comparing the results for both attachments it was concluded that better kneading operation was done with hook type. So hook type attachment was used for the further trials. Before initializing the preliminary trials, RPM of planetary mixer was set to constant value of 52 and bowl was kept in its place and the dough hook probe was fitted for the stretching and kneading operation by opening the mouth of using lock adjustment. Water sample of 2 litres was heated to 85 °C for feeding it along with the curd in the bowl. By lifting the hook probe, lock body was opened for feeding through side and was closed after feeding was done. This is a batch process so that the whole part of curd was put in the bowl than the water was added at the 85 °C temperature and instantly the 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). Then the power supply was shut off and mixer was opened with lock adjustment the whey drainage, the cheese was collected and weighed on digital weighing balance. After checking the feasibility of operation, the experiment was replicated two more times to minimize the experimentation error.

**Setup of screw mixer section for preliminary trial**

Screw mixer mechanism was developed in department of dairy engineering, college of dairy science and technology, GADVASU, Ludhiana. This section was used for kneading and stretching operation of curd along with hot water for analyzing the feasibility of manufacturing of mozzarella cheese. The main components of this section were detachable hopper, screw, screw drive shaft and exit block with plate type structure. In this, hopper was connected to the barrel feed openingfor proper feeding operation of curd along with hot water and for avoiding the spillage of water from the barrel.The barrel was connected to exit block with plate type structure at the exit pointand the barrel exit was closed by some sort of cloth for retaining the hot water for some time in the barrel for proper kneading operation. There was a screw in the barrel which is connected to the shaft of a gear with chain drive setup. The chain drive setup connected with a gear reduction box for power transmission. Further, the gear reduction box was connected to the ac motor via chain drive. The screw mixer section has been shown in fig.2 and detailed dimensions of each component are shown in table 2. It is imperative to observe the optimum value of power consumption for better setup of power unit in future in modified screw mixer the following trials was conducted.

Before initializing the preliminary trials, RPM of screw was set to constant value of 12 as it was a continuous process so the curd was divided into three parts for proper feeding and kneading operation. Water sample of 2 litres was heated to 85 °C for feeding it along with the curd. After cross checking of blockage in barrel exit by cloth the operation of feeding started. Firstly, one part of curd out of three was put in the barrel and then water was being continuously fed at 85 °C at slow rate. After 2 minutes of kneading operation the blockage made by the cloth was removed and the cheese began to come through the barrel exit. After whey drainage mozzarella curd was collected and weighed on digital weighing balance. 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 operation, the experiment was replicated two more times to minimize the experimentation error. To overcome the limitations of existing screw mixer, some modifications were done to increase the capacity of screw mixer.

**Table 2:** Dimensions of the ScrewMixer 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 | 22.5 |
| Diameter of screw | 8.75 |
| Length of screw | 21.5 |

**Fig 2:** Screw with Hopper (left) and Exit Section (right)

**Development and fabrication of modified screw mixer (Model 1)**

A small unit of modified screw mixer unit was developed and consisted of screw, barrel, barrel stand, fix hopper and exit block as shown in fig. 3. For increasing the capacity of kneading section the diameter of screw was increased with 3mm and the length was increased in 3cm in comparison to existing screw mixer. With increment in screw size the barrel size was also increased but with keeping the same clearance value. There is also a provision of drain plug at the bottom of barrel for proper water drainage. Another modification was to make the screw detachable so the screw was fabricated with a hollow shaft with a groove with nut forthe purpose of inserting driving shaft into the hollow screw shaft. The exit block was a thin section of circular plate attached at the end of the barrel with two nut placements and an opening. The pulley and belt type power transmission was fabricated instead if using the costly gear and chain type. The main components of pulley and belt type power transmission were 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 some iron blocks under them for proper insertion of shaft into the barrel. For supply the power, a single phase ac motor of 0.25hp and FRENIC-Mini Inverter was used for varying the rpm speed of the motor shaft.

The first trial was taken with the kneading of wheat flour dough. After locking the screw on driven shaft and joining the exit block, a specific value of rpm was set from the regulator. The motor was switched on and then feeding was started with small amount of cheese vary from 80-100gm. But the screw got jammed due to low torque and kneading operation was unsuccessful. Further, the next trial was carried out using mozzarella curd and feed rate varying from 80-100gm along with hot water at 80°C. By keeping the rpm at high speed by regulator the kneading mechanism was conducted and found that the screw rotated with uneven speed having high fluctuations in speed which leads to uneven kneading of curd. It was also observed that at low value of RPM, screw was jammed again and trail was failed due to low value of torque. To increase the value of torque, 0.25 hp single phase motor was replaced with 1hp single phase motor but the results were not changed. Further, a gear reduction box was employed to increase the torque value.

**Fig 3:** Modified screw mixer (Model 1)

**Modification and development of modified screw mixer (Model 2)**

Due to the unsuccessful of preliminary kneading trials on modified screw mixer, some modifications were done in the power transmission section as shown in fig. 4 and detailed dimensions were given in table 3. 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 22rpm with high torque value. Now the experiment was carried out with modified unit and kneading time was kept low i.e. 3 minutes for optimizing the operation. For modified unit, the influence of varied RPM of screw and kneading water amount on cheese yield and quality parameters as stretchability, meltability, moisture content and free oil formation were investigated.

**Fig 4:** Modified screw mixer (Model 2)

**Table 3:** 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 block | 15 |
| Thickness of exit block | 1.5 |
| Frame Height | 63 |
| Frame length | 48 |
| Frame width | 25 |

**Quality parameters**

**Stretchability**

It is an essential physical parameter of mozzarella cheese which depends on optimum acid development and temperature of hot water. Stretching length of mozzarella cheese was measured as per the method given by Guinee and O'Callaghan 1997, in which the pizza base was cut equally in two halves and the halves were joined in their original position to form a flush surface. The surface of pizza base was seasoned uniformly with shredded mozzarella cheese of about 150 gm and the pizza base was kept in hot air oven at 200 °C for 15 minutes. The cheese on the surface of pizza base was melted and then the pizza base 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 mozzarella cheese was broken. Stretching length was measured from the reference line to the point of breakage of last string of melted cheese.

**Meltability**

Meltability of mozzarella cheese was measured by weighing the 10 gm of grated cheese sample and filled it in a glass tube. Then the sample was gently tapped so that it was settled properly in a tube to height of 3.5 cm and the open end was covered with aluminum foil with some holes for proper circulation of gas. Further, the glass tube was kept at 4 °C for 30 minutes in vertical position and then it was kept at 200 °C for 15 minutes in hot air oven. The length of melted cheese was determined with measuring scale after keeping it at room temperature (Oberg *et al.* 1993) [13].

**Moisture content**

The force air oven method was used to measure the moisture content of mozzarella cheese in which a known weight of about 3 ± 0.1 gm of mozzarella cheese samples was kept at 102 ± 2 °C for 150 minutes. After drying the samples were placed in desiccator for 30 minutes and then the weighed using digital weighing balance.

**Free oil formation**

The free oil formation of mozzarella cheese was estimated by cutting the disc shaped sample with the help stoke borer and three discs of sample was cut then placed it on Whatman No. 40 filter paper. Further the samples were kept at 110 °C for 5 minutes in hot air oven. After taking out the melted cheese samples from the oven, boundary or periphery of fat ring around the samples were traced instantly. Traced areas of fat rings were then drawn on the graph paper for estimating the surface area ($mm^2$) of fat ring.

**Results and discussion**

The impact of existing mechanisms i.e. planetary mixer and screw mixeron cheese yield and stretching length was analysed. The effect of screw speed and kneaded amount of water on quality parameters of mozzarella cheese for modified screw mixer was also analysed.

**Effect of existing and modified mechanism on cheese yield of mozzarella cheese**

The mechanism of stretching and kneading in planetary mixer was found to be successful as cheese yield of about 77% of curd weight was obtained and shown in table 4. The obtained stretched cheese had shinning and smooth texture. But this mechanism is not suitable for continuous process. To overcome this drawback the stretching and kneading operation was conducted in screw mixer. The cheese yield of about 64% was obtained from existing screw mixer mechanism (Table 4). The huge amount of cheese was stuck in barrel and screw as screw was not detachable. Also some amount of cheese is lost in clearance between the hopper end and barrel feed opening. Therefore some modifications were done in this mechanism. After the modifications have been done in screw mixer, the yield of cheese was increased upto 75-80%. The effect of rpm of screw and kneaded amount of water on cheese yield was also observed and shown in fig. 5. It was found that the value of cheese yield was declined from 80.95% to 75.85 % as the RPM of screw augmented from 10 to 20 for 1.5 litres of kneaded water. The minimal effect of kneading water amount on cheese yield under the same rpm was observed. In case of 10 rpm the Cheese Yield values augmented with the increment in kneading water amount from 0.5 to 1.5 litres whereas the opposite trend in cheese yield was found with the increasing kneading water amount for 15 and 20 rpm of screw. The maximum value of cheese yield of 80.95% was observed at 10 rpm and 1.5 litres of kneading water in modified screw mixer.

**Table 4:** Cheese Yield generated from existing planetary mixer and screw mixer

| | Planetary mixer | Screw mixer |
|---|---|---|
| Curd (gm) | 479 ± 49.48 | 442.33 ± 27.01 |
| Cheese Yield (gm) | 368.67 ± 40.31 | 283.67 ± 27.01 |
| Cheese yield efficiency (%) | 76.91 ± 0.50 | 63.99 ± 2.30 |
| Warm water Temperature (°C) | 85 | 85 |
| Kneading Time (min.) | 3 | 10 |
| RPM | 52 | 12 |
| Kneading Water (L) | 2 | 2 |

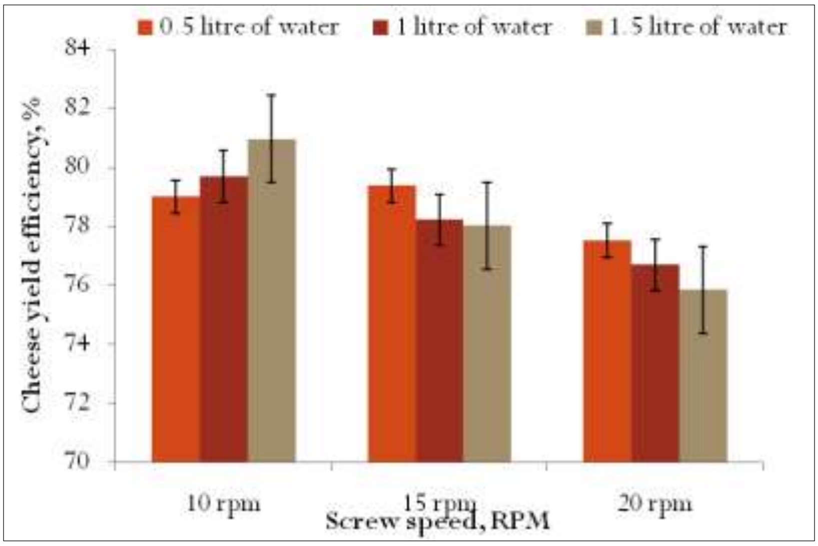


**Fig 5:** Cheese yield efficiency of modified screw mixer unit

**Effect of existing and modified mechanism on stretchability of mozzarella cheese**

From the table5, it was clearly seen that stretching length in case of planetary mixer was more than the existing screw mixer. It might be due to high rpm in planetary mixer. The impact of screw speed (RPM) and kneading water amount of stretching length was observed in case of modified screw mixer. The results revealed that both the operating parameters had a significant impact on stretchability of the cheese samples (Fig. 6). It was observed that with the increase in RPM of screw, the stretching length augments. Maximum value of stretching length of 60.8 cm was obtained corresponding to 20 pm and 1.5 litres of kneading water. For an optimistic approach, the best operating parameters for the manufacturing of cheese was 15 rpm and 1.5 litre of kneading water whereas the maximum value of stretchability was obtained the maximum value of operational parameters (Fig 6).

**Table 5:** Values of stretchability test of mozzarella cheese prepared from existing 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) | 51.63 ± 1.70 | 48.77 ± 0.56 |

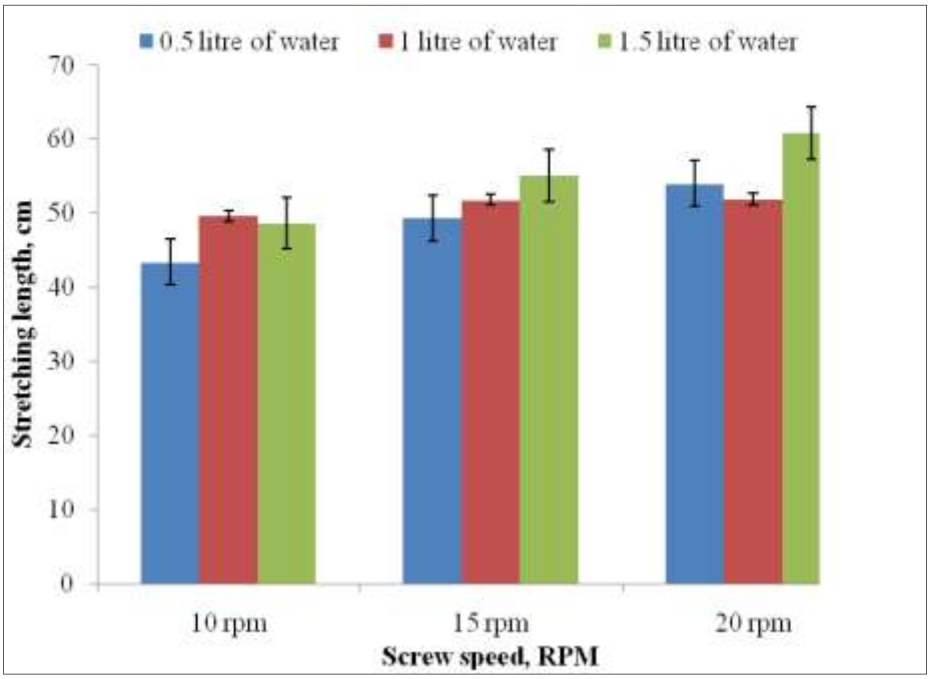


**Fig 6:** Stretching length of mozzarella cheese prepared from modified Screw Mixer

**Effect of modified screw mixermechanism on meltability of mozzarella cheese**

Meltability of cheese augments from 10.4 cm to 17.4 cm as the value of screw rpm increments from 10 to 20 for 1.5 litres of kneading water. It was observed from the fig. 7thatthe rate of increase of meltability was low for 10 to 15 rpm and a rapid increase in stretchability was observed as the screw rpm was increased from 15 to 20 rpm. But the effect of kneading water amount on meltability was random for 10 and 15 rpm whereas the meltability increases with the rise in kneading water. Maximum value of meltability of 17.4 cm was observed at 20 rpm and 1.5 litres of kneading water whereas minimum value of 10.2 cm was obtained corresponding to 10 rpm and 0.5 litres of kneading water.

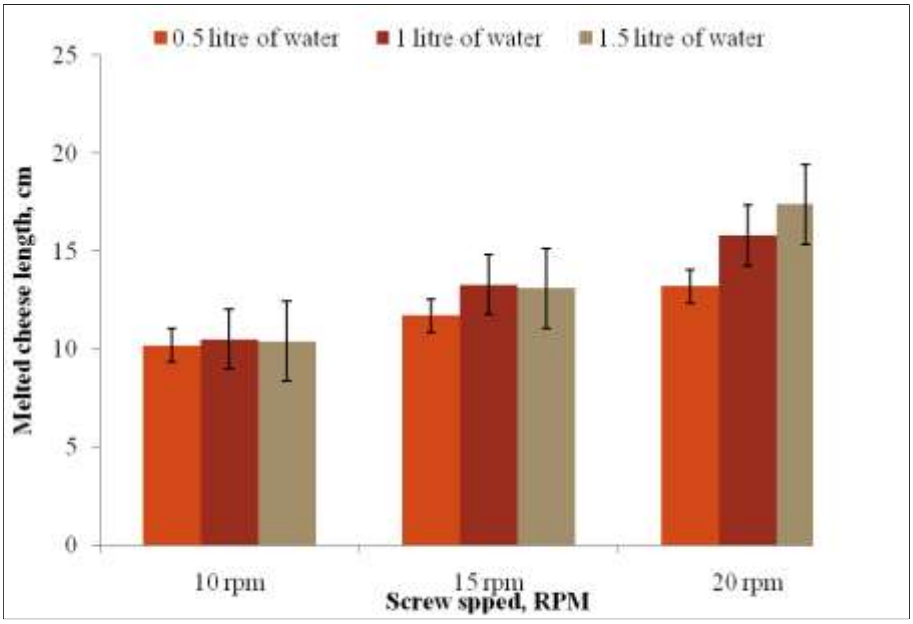


**Fig 7:** Variation in meltability with screw speed and kneading water amount for modified Screw Mixer

**Effect of modified screw mixer mechanism on moisture content of mozzarella cheese**

The screw speed (rpm) and kneading water amount showed a significant impact on moisture content of mozzarella cheese samples as shown in fig. 8. A gradual increase in moisture content was found with the increase in both the operating parameters. Lower value of moisture content value of 43.70% was observed corresponding at 10rpm and with 0.5litre of kneading water amount whereas the maximum value of 51.1% was found against 20 rpm and 1.5 litre of kneading water amount.

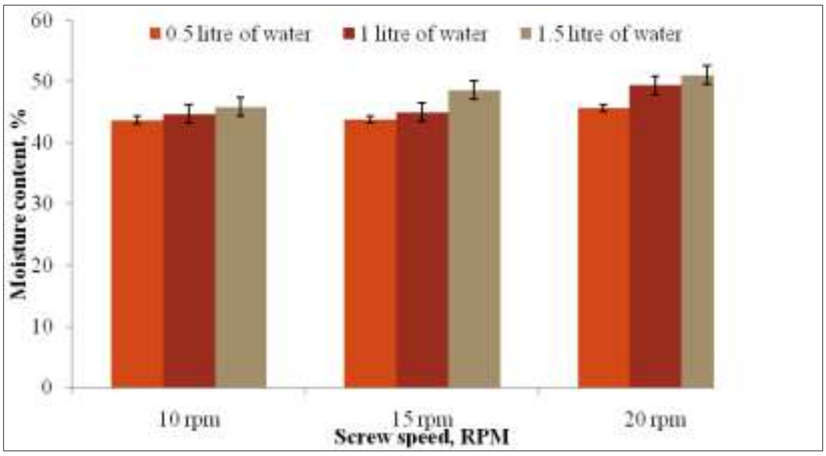


**Fig 8:** Variation in moisture content with screw speed and kneading water amount for modified Screw Mixer

**Effect of modified screw mixer mechanism on free oil formation of mozzarella cheese**

By plotting the traced areas of fat rings on graph paper free oil areas were estimated by counting of each small cubes of 1mm² for accuracy. The results revealed that the significant increase in free oil formation was found with the augmentation of screw speed (rpm) and kneading water amount.Fig. 9 revealed that kneading water amount showed an irregular effect of on free oil formation. With the increase in the value of screw rpm from 10 to 20, the value of free oil formation was increased from 311 to 863 $mm^2$ for 1.5 litres of kneading water. Corresponding to 20 rpm and 1.5 litres of kneading water, free oil formations showed a maximum value of 863 $mm^2$.

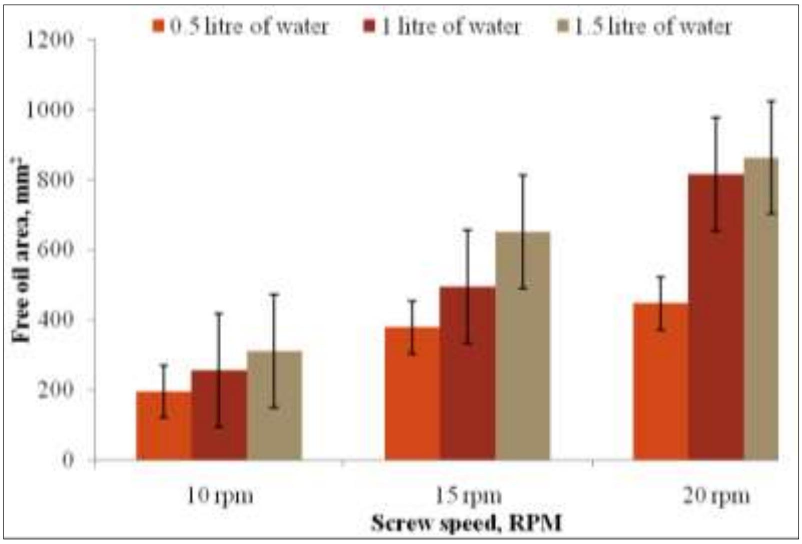


**Fig 9:** Variation in free oil area with screw speed and kneading water amount for modified Screw Mixer

**Conclusion**

Due to low rpm in existing screw mixer its efficiency on the basis of curd (60 to 65%) was found lower than the efficiency of planetary mixer (76 to 77%). To overcome these limitations, modifications in existing screw mixer has been done. Time consumption during kneading operation was observed more while using screw mixer than planetary mixer. Efficiency of modified unit on the basis of curd was found more thanplanetary mixer which varied from 75-80% with varying operational parameters. Efficiency of modified unit on the basis of curd decreased with increase in both rpm and amount of kneading water. Other quality parameters of mozzarella cheese like stretchability, meltability, moisture content and free oil formation increased with increase in the rpm as well as water used for kneading.

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