RESEARCH PAPER *Research Journal of Animal Husbandry and Dairy Science* ➪ e ISSN-2231-6442
Volume 6 | Issue 2 | Dec., 2015 | 153-157 ■ **DOI: 10.15740/HAS/RJAHDS/6.2/153-157**
Visit us: *www.researchjournal.co.in*

Development of small scale frustum cone shaped butter churn

ADARSH M. KALLA, C. SAHU, A.K. AGRAWAL, A. KHARE, K.K. CHOUDHAURY, A. SHRIVASTAVA AND **GEETESH SINHA**

ABSTRACT : A novel small scale improved butter making unit called ‘Frustum Cone Shaped Butter Churn was developed with working capacity of 5 liter curd/batch. This paper deals with development of parts of churn *i.e.* inner and outer frustum cone, stirring tube, head and closure and insulation etc. For better insulation foamed polyethylene was used to offset the effect of ambient on temperature of curd filled inside the churn. For controlling the speed of the motor, gear and pulley arrangement with v-belt was used. The highest overrun and yield of butter were recorded to be 24.41 per cent and 1.63 kg/5 l. curd at higher churning temperature of 12°C and higher churn speed of 85 rpm. However, the optimum speed of churn for good quality butter production was found to be 60 rpm at churning temperature of 10°C.

KEY WORDS : Belt-pulley, Butter, Curd, Churn, Foamed polyethylene, Frustum cone shaped butter churn

HOW TO CITE THIS PAPER : Kalla, Adarsh M., Sahu, C., Agrawal, A.K., Khare, A., Choudhaury, K.K., Shrivastava, A. and Sinha, Geetesh (2015). Development of small scale frustum cone shaped butter churn. *Res. J. Animal Hus. & Dairy Sci.*, **6**(2) : 153-157.

INTRODUCTION

Butter is one of the most valuable components obtained from the milk. Butter is extensively used by the bakery, chocolate and confectionary industries. People utilize it to spread on bread and in cooking. The improved tools have reduced the tedious and time consuming butter churning activities at farm. The development of creamery industries has started from 19th century which has given birth to various batch types of butter churners. A variety of methods were evolved and devices have been developed to produce butter on a small scale. Butter churns have varied over time as technology and materials have changed. Various materials *viz.,* animal stomach skin, wood, glass, ceramic and metal containers were used as material of construction for butter churn (Eltayeb and Mahjoub, 2003; Ahmad 2009; De, 2012 and Anonymous, 2014).

However, the manufacturing of butter with attractive characteristics has long been a problem. Preparation of butter from cream rather than whole milk is more efficient because of the high fat content (O’Mahony, 1988) present in the cream. Cream having fat crystals of 3-dimensional network shape (Deman and Beers, 1988) gives a higher butter yield. In the Indian subcontinent, the traditional churning utensils used are often made of clay. In rural areas, majority people use clay jars *i.e. mataka,* designed in such a way that its bottom part is wide and upper part is narrow. A traditional stirrer, called *mathani* is actually a wooden shaft of a maximum one meter length. Blades are attached at the bottom end while on upper side provision is made for attaching belts/ropes which facilitates rotation of shaft on both clockwise and anticlockwise directions by hand. But this locally made

MEMBERS OF RESEARCH FORUM

Address for correspondence :
Geetesh Sinha, Department of Dairy Engineering, College of Dairy Science and Food Technology, RAIPUR (C.G.) INDIA
Email : geeteshsinha20@gmail.com

Associated Authors’ :
Adarsh M. Kalla, C. Sahu, A.K. Agrawal, A. Khare, K.K. Choudhaury and A. Shrivastava, Department of Dairy Engineering, College of Dairy Science and Food Technology, RAIPUR (C.G.) INDIA

simple churning device is highly time consuming giving low yield of butter.

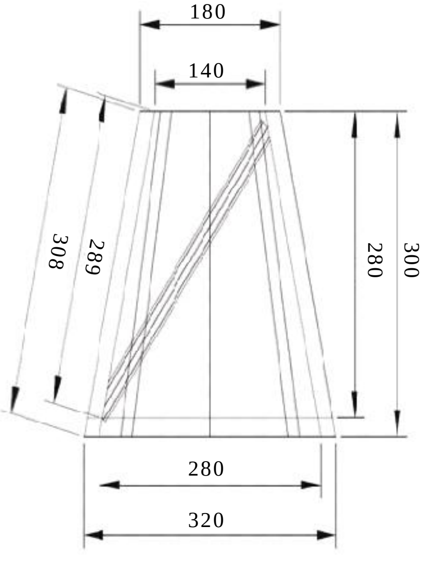
In this way, there is an intense need of a better churn capable to provide high output with less input cost. The design must also satisfy the farmer needs by considering the ergonomic factors. A motor driven small scale butter churner will be a most sought after device for processing small quantity of milk at farm level. In the present study, a motor driven Frustum Cone Shaped Butter Churn (FCSBC) was developed which comprised of a ½ hp A.C. motor, gear box for speed reduction, shaft and butter churn body.

MATERIAL AND METHODS

The machine was fabricated at the nearby fabricator workshop of Raipur city in central India. The present investigation is pertaining to a method of producing butter from curd by developed frustum cone shaped apparatus. The selection of proper materials for butter churn construction was done looking to their easy availability in the market. The FCSBC was consisted of conical stainless steel inner drum, galvanized iron outer drum along with head, stirring tube, shaft, motor and stand which are the other components of the apparatus.

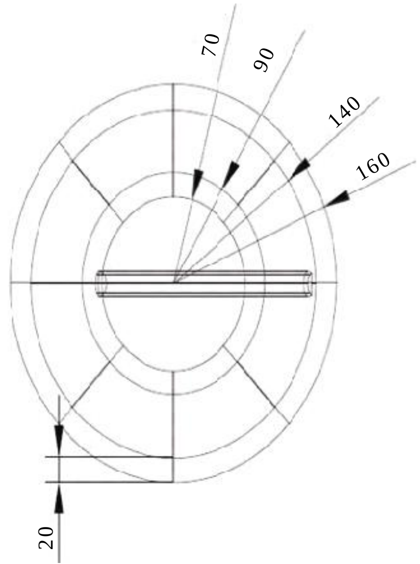
Inner and outer frustum cones :

The Fig. A(a) and (b) shows the side and top view of FCSBC. The stainless steel AISI 304 sheet was used to fabricate the inner frustum cone of butter churn. The body was designed with 10 liter holding capacity of curd but with a working capacity of 5 liters. This is because of necessity to provide free fall of curd from top when churn is inverted during rotation. Thus, the required mechanical work is incorporated on fat to break their globule wall and converting its phase from 'oil in water' to 'water in oil'. The thickness of the ss sheet was kept as 4 mm. The outer frustum cone made of galvanized iron was designed with an objective to provide a jacket so that a hollow space is formed between both the two frustum cone bodies. In this jacketed space, chilled water was filled for cooling purposes. As shown in Fig. A (a) and (b), the dimensions of the outer cone frustum were 180 mm upper diameter, 320 mm lower diameter, 308 mm slant height and 300 mm vertical height while the dimensions of inner cone frustum were 140 mm upper diameter, 280 mm lower diameter, 289 mm slant height and 280 mm vertical height.



All dimensions in mm

Fig. A (a) : Side view of the frustum cone body of butter churn



All dimensions in mm

Fig. A (b) : Top view of the frustum cone body of butter churn

Stirring tube :

As shown in Fig. B, a single stirring tube fitted obliquely from the lower to upper end and this passes through the inner frustum cone. The stirring tube extends from jacketed space of a corner just above the base plate and ends at jacketed space of another corner just below the opening head. The hallow tubular space of 20 mm diameter causes the cooling water to be circulated through the opposite ends of jacketed space and thereby increases

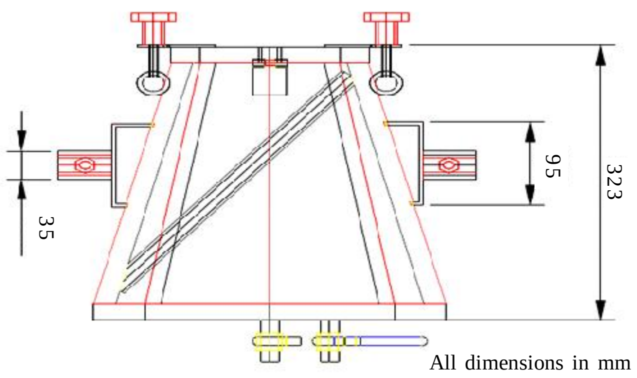


Fig. B : Front view of the frustum cone body of butter churn

the rate of heat transfer.

Opening head and closing base plate :

As shown in Fig. B, the circular flange type head made of SS 304 was designed with a thickness of 20 mm and diameter of 180 mm. It was made in such a way that it can be fixed to the churner by using a thumb screw fitted on side wall. The circular hole of 26 mm diameter was drilled for fixing the sight glass which was a perspex glass of 4 mm thickness. On top of joint of inner and outer frustum cones, 1 mm thick gasket was used to avoid leakage of curd. The lower end of both frustum cones was closed by welding a base plate of 20 mm thickness.

Shaft and bearings :

A shaft is a rotating machine element which is used to transmit power from one place to another. The power is delivered to the shaft by tangential force and the resultant torque (or twisting moment) set up within the shaft permits the power to be transferred to various machines linked up to the shaft. The transmission shaft was made of low carbon steel by hot rolling. It was forged and turned to size in a lathe. The shaft was selected based on considerations such as high strength, ability to be heat treated and good machinability. The diameter of the shaft was 25 mm as shown in Fig. C (a) and (b), and the shaft was connected at the centroid of the outer frustum cone body.

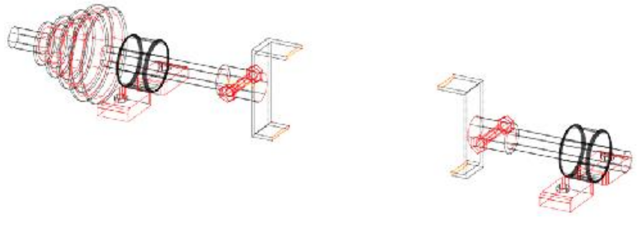


Fig. C (a) : 3D view of the shaft and bearing arrangement

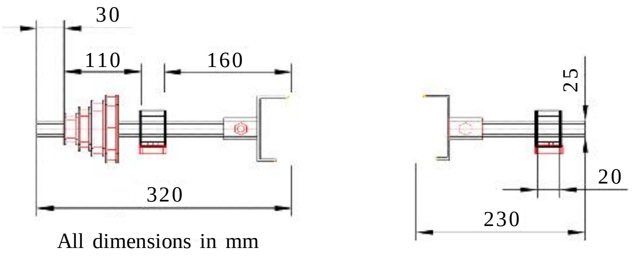


Fig. C (b) : Front view of the shaft and bearing arrangement

Motor and gear box :

The ½ hp single phase A.C. motor was used and a worm gear box of 1:20 ratio was used for speed reduction. The speed cone consisting of step down pulleys of 100, 75, 62.5, and 50 mm were used and connected to 25 mm diameter shaft which was connected to the churner body and gear box shaft.

Insulation of churner body :

In the developed FCSBC, provision was made for maintaining the churning temperature by the chilled water filled in the jacketed space. However, as usual the heat transfer would take place from ambient to the chilled water. In order to minimize this gain of heat, the churn was covered with an insulating material (foamed polyethylene) over it (Fig. D). This was done by covering the insulation over the whole curved surface, bottom base plate and top opening head. The ultimate aim of providing insulation was maintaining chilled water for maximum

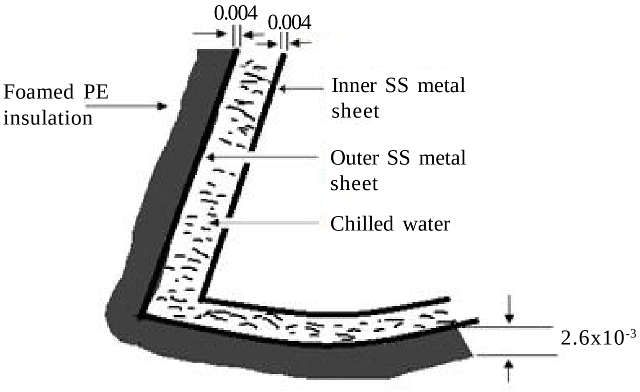


Fig. D : Schematic diagram of insulation and metal wall of FSCBC

duration of time.

The volume (V_m) of the outer and inner cone frustums were calculated as 0.015 and 0.01 m^3, respectively. Hence, the jacketed space contains only 0.005 m^3 (0.015-0.01) of chilled water *i.e.* 5 liters. Based on the thickness of the metal *i.e.* 4 mm, the rate of heat gain through the metal body (without the insulating material), Q_{wt} was calculated by using the following equation (Gupta and Prakash, 1989).

$$Q_{wt} = \frac{T_0 - T_1}{R_1} \qquad (1)$$

where,

$$R_1 = \frac{l_m}{k_m A_m} \qquad (2)$$

R_1 = thermal resistance of metal wall (°C/W)

T_o = outside ambient temperature (°C)

T_i = cold water temperature (°C)

l_m = thickness of metal body (m)

k_m = thermal conductivity of iron (W/m °C)

A_m = surface area of the outer frustum cone (m^2)

The thermal resistance of metal body (R_1= 1.5x 10^{-4} °C/W) was calculated by considering thickness of metal body, l_m = 0.004 m, thermal conductivity of galvanized iron, k_m = 62.764 W/m°C (Gupta and Prakash, 1989) and area of the outer frustum cone, A_m = 0.41 m^2. The value for R_1 was calculated as 1.6 x 10^{-4} °C/W using equations (2).

With the values of R_1= 1.5 x 10^{-4} °C/W, T_o = 40°C (assumed) and T_i = 7°C the rate of heat gain, Q_{wt} was calculated using equation (1) which was 206250 W. This rate of heat gain is very high and it would hinder the purpose for which the FCSBC has been developed. Hence, it is thought necessary to use thermal insulation to maintain the water at lowest temperature for longer duration of time by achieving 99 per cent reduction in heat gain rate. For this, the thickness of foamed polyethylene was selected in such a way that it allowed only 2062.5 W (*i.e.* 1% of 206250 W) heat gain. The required thickness of insulation was calculated by following equation

$$Q_{wi} = \frac{T_0 - T_i}{R_1 + R_2} \qquad (3)$$

Q_{wi} = rate of heat gain with insulation (W)

R_1= thermal resistance of iron (°C/W)

R_2= thermal resistance of insulating material (°C/W)

T_o = outside ambient temperature (°C)

T_i = inside water temperature (°C)

By taking the value for rate of heat gain, Q_{wt} = 2060 W, outside ambient temperature, T_o = 40°C and inside water temperature, T_i = 7°C the thermal resistances for foamed polyethylene, R_2 was calculated as 0.01585 °C/W using equation (3).

Based on the resistance of insulating material, R_2, the thickness of the insulating material, l_i was calculated using following equation

$$l_i = R_2 \times k_i \times A_i \qquad (4)$$

where,

R_2 = thermal resistances of insulating material (°C/W)

l_i = thickness of insulating material (m)

k_i = thermal conductivity of foamed polyethylene (W/m °C)

A_i = area of the insulating material (m^2)

By considering the values for R_2 =0.01585 °C/W, k_i = 0.406 W/m °C (Gupta and Prakash, 1989) and A_i=0.41 m^2, the thickness of insulating material l_i was calculated using equation (4) as 2.6 x 10^{-3} m or 0.26 cm or 2.6 mm. Looking to the availability of foamed polyethylene in the local market, a sheet of 3 mm thickness was used. The schematic diagram of insulation on the surface of FCSBC is shown in Fig. D.

RESULTS AND DISCUSSION

The performance analysis of the developed butter churner was done by studying the effect of churn speed and churning temperature on the overrun and yield of butter.

Overrun :

The overrun increased with increase in churning

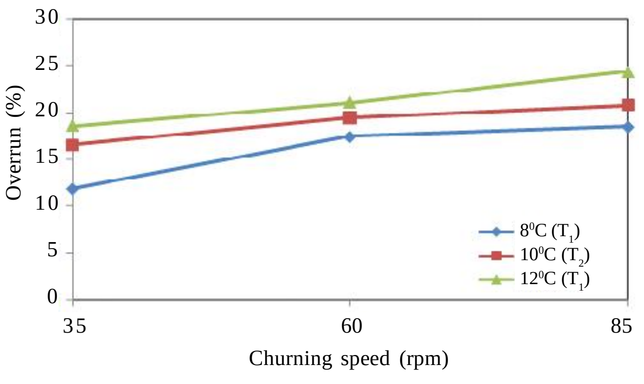


Fig. 1(a) : Effect of churning temperature and churn speed on the overrun of butter

temperature and churn speed as shown in Fig. 1 (a). The highest overrun of the butter was recorded to be 24.41 per cent at higher churning temperature of 12°C and higher churn speed of 85 rpm. The optimum overrun 19.49 per cent was obtained (with good body and texture) at churning temperature of 10°C and churn speed 60 rpm. The present study was in accordance with the findings of Mortensen (1945).

Yield :

The Fig. 1 (b) depicts that the yield of butter increased with increase in churning temperature and churn speed. The yield of the butter was recorded to be highest 1.63 kg at higher temperature of 12°C and higher churn speed of 85 rpm. However, butter formed was weak and leaky. The optimum yield of butter was obtained with the good texture at churning temperature of 10°C and churn speed of 60 rpm.

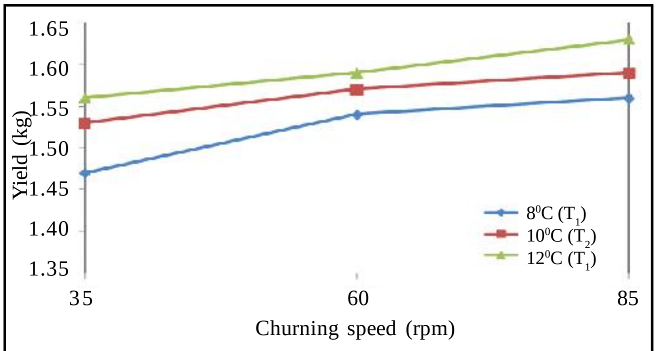


Fig. 1(b) : **Effect of churning temperature and churn speed on the yield of butter**

Conclusion:

The small scale Frustum Cone Shaped Butter Churn was developed with optimum production of butter at churn speed of 60 rpm and at churning temperature of 10°C. At this speed and temperature the butter with overrun (19.49%) and yield (1.57 kg/5 kg curd) was obtained.

LITERATURE CITED

Ahmad, T. (2009). *Dairy Plant – Engineering and Management*. 8th Ed. Pub by Kitab Mahal, 22-A, Sarojini Naidu Marg, Allahabad.

Anonymous (2014). Rising milk production future prospects. *Indian Dairyman*. **66**(7): 15.

De, S. (2012). *Outlines of dairy technology, India*, Oxford University Press, 163 p.

Deman, J.M. and Beers, A.M. (1988). Fat crystal networks-Structure and rheological properties. *J. Text. Stud.*, **18**(4): 303-318.

Eltayeb, M. and Mahjoub, E. (2003). The development of an improved churner for butter extraction. M. Tech Thesis, Appropriate Technology Department of National Center for Research, Sudan. p 24.

Gupta, C.P. and Prakash, R. (1989). *Engineering heat transfer*. 6th Ed., Nem Chand and Bros., Roorkee, India.

Mortensen, M. (1945). Materials balance method for determining losses of butter fat in the creamery. *Iowa Agri. Exp. Sta. Res. Bul.*, 337.

O'mahony, F. (1988). Rural Dairy Technology- Experience in Ethiopia. Manual Dairy Tech Unit. International Livestock Center for Africa. Addis Ababa, Ethiopia, p 4.

Received : *05.10.2015;* ***Revised:*** *16.11.2015;* ***Accepted :*** *29.11.2015*