



A Continuous Heat-Acid Coagulation Unit for Continuous Production of Chhana

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Abstract

Chhana, an Indian counter part of soft cottage cheese, is a heat-acid coagulated product of milk. The production of chhana is manual, batch wise, time consuming, labor intensive, and lacks quality control in the chhana. In the present research, a continuous heat-acid coagulation unit attached with a vacuum assisted strainer has been developed for continuous production of chhana. The moisture content of the chhana obtained in the unit was 0.583 kg per kg milk whereas the yield of chhana was 0.203 kg per kg milk, when the total milk solid in the milk used for coagulation was 0.141 kg per kg milk. The total milk solid recovery in chhana was 0.602 kg per kg milk solid when holding time of chhana was 135s and 680 mm Hg vacuum was maintained inside the vacuum chamber.

Kew words : Chhana, heat-acid coagulation, recovery of milk solids, yield of chhana

Introduction

Chhana is a heat-acid coagulated product of milk. The concentrated and preserved milk solids in form of *chhana* provide sound nutrition and novelty of flavor and texture to consumers. Pattern of milk consumption in India indicates that about 6 per cent of milk is coagulated for production of *chhana* (Sahu and Doo, 2007). *Chhana* forms the base and or filler material for manufacture of *paneer*, *rasogolla*, *sandesh*, *shrikhand*, *chhana-kheer*, *gulabjaman* etc. It has been reported that in India the market volume of *chhana*-based sweets is about 1 million tonnes with a value of Rs 7,00,000 crores (Sahu, 2007).

Chhana is a rich source of fat and protein. It also contains fat-soluble vitamins *A* and *D*. With high protein and low sugar content, *chhana* is highly recommended for diabetic patients (De, 1980). According to the definition of the Bureau of Indian Standard (BIS, 1969), *chhana* should not contain more than 70% moisture and milk fat should not be less than 50% of the dry matter. According to the Prevention of Food Adulteration Rules (1976), *chhana* is defined as a milk product obtained by

precipitating a part of milk solid by boiling whole milk of cow and or buffalo or a combination thereof by addition of lactic acid, citric acid or any other suitable coagulating agent and subsequent drainage of whey.

Traditionally, for preparation of *chhana*, milk is heated to its boiling point in an open pan. The heated milk is allowed to cool to 75-80°C by constant stirring. The milk is added with 1 to 2% citric acid solution to coagulate the milk. Coagulation of milk basically involves destabilization of casein micelles. Acid affects the stability of casein directly by disturbing the charges carried by particles and indirectly by releasing the calcium ion from colloidal calcium-caseinate-phosphate complex. The destabilization results in formation of large, firm and cohesive structural aggregates of casein micelles in which milk fat, other colloidal and soluble solids are entrained along with deproteinated whey. During the coagulation process, the milk and acid solution is stirred slowly with the help of a ladle. The process is continued until the milk gets precipitated

in lumps, which settle down at the bottom of the pan. The clear whey floating on the top is filtered through a muslin cloth. The product, thus, obtained is known as *chhana*. Yield and quality of *chhana* depends on the type of milk, heat treatment given to milk prior to acidification, coagulation temperature, acidity of milk-acid mixture and residence time of the coagulated *chhana*-whey mixture before separation of milk solids from whey (Jonkman and Das, 1993).

The limitations of the existing method of coagulation process for *chhana* preparation are:

- (i) Extent of heating and cooling rates of milk prior to acidification is not carried out optimally.
- (ii) Heat treatment of milk and acidification is carried out batch wise and thus, consumes long time.
- (iii) Quality of *chhana* varies from batch to batch due to non-uniform treatment of process parameters.
- (iv) Batch wise drainage of whey using muslin cloth by using manual labor is not a hygienic operation.
- (v) Human intervention during the coagulation process leads to microbial contamination of and reduces shelf life.

Due to the above limitations, the traditional method of milk coagulation for *chhana* production is too rudimentary to meet large-scale demand in Indian Dairy Industry. Therefore, there is a need for R&D institutes to develop a time, energy and/or cost efficient unit suitable for continuous coagulation of milk for continuous production of *chhana*. The specific objective of the present research is to develop a continuous heat-acid coagulation unit for continuous production of *chhana* and to evaluate the unit for total milk solid recovery and yield of *chhana*.

Description of the Developed Continuous Coagulating Unit

The capacity of the heat-acid coagulation unit developed is 60 l.hr⁻¹ of milk. The unit comprises of mixing acid with heated milk, passing the milk-acid mixture through a heat-acid coagulation unit to give the required residence time for the

coagulation of milk solids to *chhana* and draining the whey through a vacuum assisted inclined strainer from the *chhana*-whey mixture. Fig.1 shows the process lay out of the unit. Descriptions of various components of the unit are shown in Fig. 2. The detailed descriptions of the various sections of the unit are given in the following sub-headings.

Dosing section

Dosing of milk and acid solution to the continuous coagulating unit is carried out by using a double plunger duplex pump (2). The pump is provided with a manual adjustment of flow from 0 to 100% of the capacity of the pump. Varying the stroke length of the piston could vary the flow rate of milk and acid solution. Milk is pumped to a heat exchanger (5), where it is heated and flows to a coagulation column (8), whereas the acid solution (3) is directly pumped to the coagulation column. The intermittent flow characteristic of the pump creates an additional turbulence for the milk-acid mixture inside the coagulation column (8) for proper mixing for milk and acid solution.

Milk heating section

Due to the small flow rate of milk (60 l.hr⁻¹) in the developed unit, milk was heated by using a helical coil heat exchanger (5). The heat exchanger consists of a 6 mm diameter and 5 m long stainless steel tube coiled inside a mild steel jacket. By using saturated steam generated by an electrode boiler, milk at ambient temperature was heated to 90-95°C before acidification. Two thermocouples were provided at the milk inlet (6) and outlet of the heat exchanger to indicate the temperature of milk before and after the heat treatment. Pressure gauge provided in the heat exchanger indicated the saturated steam pressure inside the shell of the heat exchanger.

Coagulation section

The coagulation column (8) consists of a stainless steel tube of 50 mm diameter and 790 mm length. A SMS connection is provided at the bottom of the column. A stopcock is provided at the bottom of the SMS connection to allow drainage of whey and washed water through a drain guide without opening the SMS connection. Heated milk (6) and

acid solution (7) enter the column (8) at its lower end. The inlet of acid solution (7) is located little above that of milk (6) and placed opposite to each other so as to give good mixing of milk and acid solution. The milk is transformed into a mixture of *chhana* and whey when it travels up the column. The pulsating movement of the mixture, created by the dosing pump when it travels up the column insures the proper mixing of the mixture for its coagulation. The time taken by the milk-acid mixture to travel from bottom to the top of the column (14) is the coagulation time for the milk-acid mixture.

Holding section

The coagulated *chhana*-whey mixture from the coagulation column (8) flows down an inclined chute (9) made of stainless steel. The cross section of the chute is made trapezoidal which compresses the *chhana* mass gradually when it flows down to the discharge section. A flapper (16) attached at the lower end of the chute controls the residence time of the coagulum. The operation of the flapper is controlled depending on the desired residence time of the mixture.

Straining and discharge section

The *chhana*-whey mixture from the holding section (9) is allowed to fall on a perforated inclined strainer (10) lined with a nylon cloth of mesh size 60. A cylindrical vacuum chamber (11) is provided at the lower portion of the strainer. Two SMS union connections are provided at the two ends of the chamber for its easy cleaning. There is a slit along the chamber on its top surface. A flapper is provided at the discharge end of the strainer for intermittent discharge of strained *chhana* to the *chhana* collecting bowl. The strained whey is discharged to a whey-collecting tank (13) through a whey discharge line (15). Pictorial view of the *chhana* in the holding and straining sections are shown in Fig. 3. A vacuum pump (2) attached to the tank (13) creates adequate amount of vacuum inside the chamber (11). A ball valve connected at the bottom of the tank allows intermittent discharge of whey. A sight glass is provided in the tank for observing the level of whey inside the tank. Vacuum is maintained inside

the vacuum chamber by using a water ring vacuum pump.

Performance Evaluation of the Continuous Coagulation Unit

Quality of milk sample

Flow rate of milk: 60 l.hr⁻¹

Initial temperature of milk: 21°C

Composition of milk: water = 0.861 kg.kg milk⁻¹, carbohydrate = 0.046 kg.kg milk⁻¹, fat = 0.04 kg.kg milk⁻¹, protein = 0.047 kg.kg milk⁻¹, and ash = 0.0073 kg.kg milk⁻¹

Coagulating agent

Coagulating agent: Citric acid solution

Flow rate of coagulating agent: 12 l.hr⁻¹

Temperature: 25°C

Strength of citric acid: 1.62%

Heat treatment of milk

Temperature of heated milk: 95±2°C

Vacuum level

Vacuum level inside whey collecting tank: 680 mmHg

Holding time of *chhana* in the strainer: 1 min

Residence time of the milk-acid mixture in the coagulating column

Time taken by the milk-acid mixture to move from the inlet of the milk and acid solution to the top of the coagulum column was considered as the residence time for the milk-acid mixture. The combined flow rate of milk and acid solution in the coagulating column was 60+12=72 l.hr⁻¹. The diameter of the column was 4.5 cm. Therefore, the velocity of the milk-acid mixture inside the column was $[(1+0.2)*1000]*[\delta*0.25*0.045^2]^{-1}$ i.e., 0.755 m.min⁻¹. Since the height of the coagulating column was 0.8 m, the residence time of the milk-acid mixture inside the column was 0.8*0.755⁻¹ i.e., 1.06 min. An additional residence time could be set between 0 to 3 min by changing the timing of the flapper (16) fixed at the discharge end of the trapezoidal chute (9).

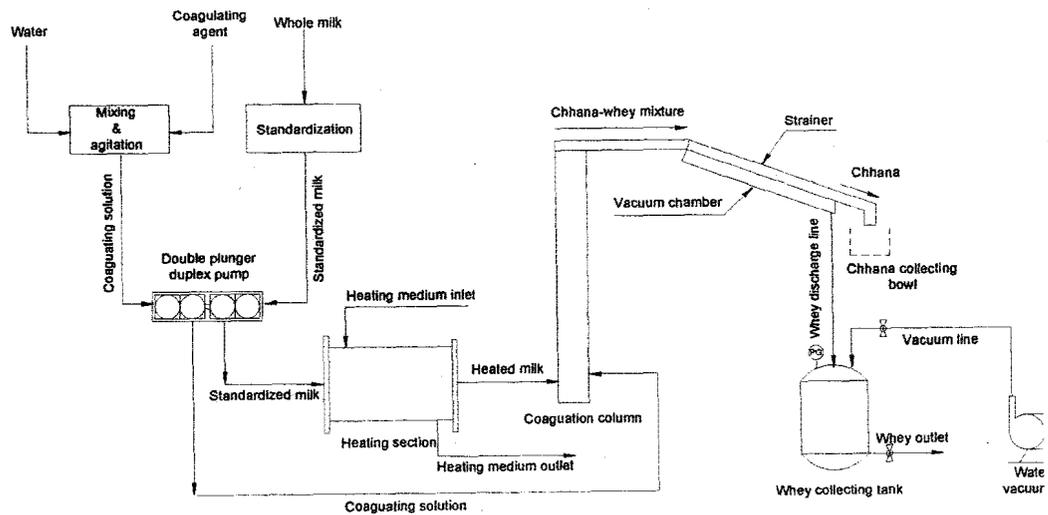


Fig.1 Process lay out of the continuous coagulation unit with vacuum assisted strainer

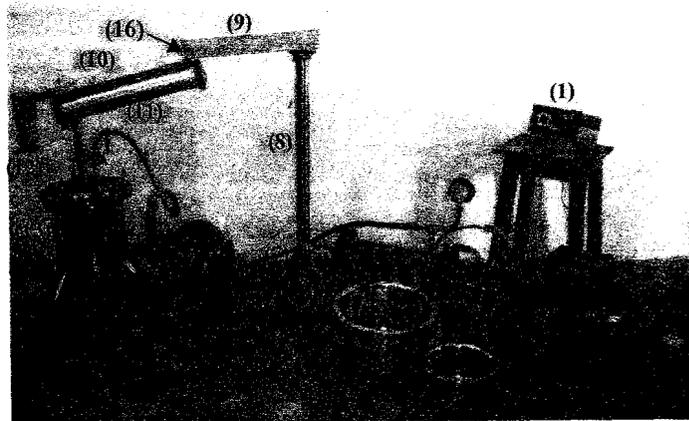


Fig.2 Pictorial view of the continuous coagulation unit

- (1) Temperature indicator (2) Dosing pump (3) Acid solution (4) Milk (5) Helical coil heat exchanger (6) Milk inlet (7) Acid solution inlet (8) Coagulating column (9) Trapezoidal chute (10) Strainer (11) Vacuum chamber (12) Chhana outlet (13) Whey collecting tank (14) Vacuum pump (15) Whey outlet and (16) Flapper

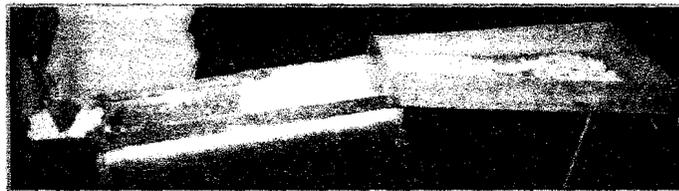


Fig. 3 Pictorial view of *chhana* in holding and straining sections

Holding time of the coagulated *chhana*-whey mixture in the holding chute

The continuous coagulation unit was run at different holding times in the holding chute (9)

varying from 0 to 180s by changing the opening time of the flapper (16). The flapper was kept open for 5s for the discharge of *chhana*-whey mixture to the straining section (10). The *chhana* on the

straining section was hold for 3 min to allow the drainage of whey due to the vacuum, maintained in the vacuum chamber (11).

During the test, the amount of *chhana* produced, and its moisture content for a particular holding time in a single run was measured. At this holding time of the *chhana*-whey mixture, the recovery of total milk solid was estimated from the amount of milk used in the test and its moisture content, and the amount of *chhana* produced and its moisture content. For example, at holding time of 0s, the total milk solid recovery was $1.48 \cdot (1 - 0.591) / 1.028 \cdot 10 \cdot (1 - 0.861) = 0.424 \text{ kg.kg milk solid}^{-1}$, where 1.48 is the amount of *chhana* produced. 0.591 is the moisture content of *chhana*. In a similar manner, the recovery of total milk solid at holding times of 30, 45, 60, 75, 90, 105, 120, 135, 150, 167, and 180s were estimated. These values of the total milk solid recoveries were plotted against the holding time (Fig. 4). It was observed that the total milk solid recovery in *chhana* increased from 0.442 to 0.613 kg.kg milk solid⁻¹ with increase in the holding time from 0 to 180s. The value of the total milk solid recovery takes a value of 0.602 kg.kg milk solid⁻¹ at the holding time of 135s, as evident in Fig. 4 and remained nearly constant thereafter. Therefore, the holding time of the *chhana*-whey mixture was fixed at 135s.

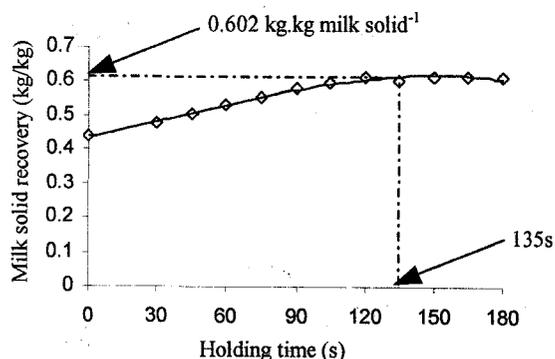


Fig. 4 Variation in total milk solid recovery in *chhana* with holding time

Singh (1995) while preparing *chhana* from buffalo milk having 7.25% fat reported the milk solid recovery value of 0.723 kg.kg milk solid⁻¹. The higher recovery of milk solid might be due to the higher fat content in milk, which was used for the milk coagulation. The recovery obtained in the

present study is higher than the values reported by Jonkman and Das (1993) who prepared *chhana* from low fat cow milk and reported the values of total milk solid recovery between 0.433 and 0.482 kg.kg milk solid⁻¹. Choudhary *et al.*, (1998) observed that the recovery of total milk solid for cow milk was ranged between 0.512 and 0.649 kg.kg milk solid⁻¹.

Yield of *chhana*

From the composition of milk, the total solid content in the milk used for milk coagulation was $(0.046 + 0.04 + 0.047 + 0.007)$ i.e., 0.1403 kg.kg milk⁻¹. During the test, the moisture content of *chhana* obtained in the coagulation unit was 0.583 kg.kg *chhana*⁻¹ i.e. 1.4 kg.kg dry *chhana*⁻¹. Since the recovery of total milk solid in *chhana* was 0.602 kg.kg milk solid⁻¹, the amount of dry solid obtained in *chhana* from 1 kg milk was $0.1403 \cdot 0.602$ i.e., 0.0845 kg and the amount of moisture present in the *chhana* obtained from 1 kg milk was $1.4 \cdot 0.0845$ i.e., 0.1182 kg. Therefore, yield of *chhana* obtained from the continuous heat-acid coagulation unit was $0.1182 + 0.0845 = 0.2027 \text{ kg.kg milk}^{-1}$. Table 1 represents the average composition of milk, whey and *chhana* during testing of the continuous coagulation unit. Table 2 shows the average recovery of total milk solid and fat in the *chhana*.

Table 1: Average composition of milk, whey, and *chhana* during testing of the continuous coagulation unit

Particulars of analysis	Cow milk (5.2% fat)	Buffalo milk (6.3% fat)	Mixed milk (5.8% fat)
Milk			
Fat (%)	5.20	6.30	5.80
*SNF (%)	9.49	9.53	8.54
**TS (%)	14.69	15.33	14.84
pH	6.50	6.61	6.51
Acidity (%)	0.15	0.156	0.152
Whey			
Fat (%)	0.48	0.61	0.61
*SNF (%)	5.86	6.02	6.02
**TS (%)	6.34	6.64	6.64
pH	0.19	0.19	0.19
Chhana			
Fat (%)	22.30	25.98	24.10
Protein (%)	18.0	16.23	16.3
Moisture (%)	56.77	52.12	54.76
**TS (%)	43.23	45.24	45.24
pH	6.09	6.01	6.01

Note: *SNF=Solid-not-fat, **TS=Total solid, Values are average of three experiments

Conclusion

The traditional method of *chhana* production is manual and carried out batch-wise. The gravity draining of whey from the *chhana*-whey mixture does not facilitate quick and greater dewatering of *chhana*. Therefore, in the present research, a continuous heat-acid coagulation unit with a vacuum assisted strainer for the continuous production of *chhana* is developed. The unit reduces both time and energy and the recovery of total milk solid is equal to that obtained in the traditional method. The unit provides an improved quality of *chhana* with reduced microbial contamination and increased shelf life due to lack of human intervention during preparation of *chhana*. The unit can be incorporated with a suitable packaging line at the end of the *chhana* collecting outlet to facilitate packaging of *chhana* in a consumer friendly package.

Table 2: Average recovery of total milk solids and fat in *chhana*

Particulars of analysis	Cow milk (5.2% fat)	Buffalo milk (6.3% fat)	Mixed milk (5.8% fat)
Milk solids recovery (kg solid in <i>chhana</i> . kg solid in milk ⁻¹)	0.642	0.698	0.681
Fat recovery (kg fat in <i>chhana</i> . kg fat in milk ⁻¹)	0.90	0.922	0.90

Note: Values are average of three experiments

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