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RESEARCH ARTICLE

# Energy saving through partial homogenization of milk over conventional milk homogenization

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**Abstract:** The present study was conducted to check the feasibility of partial homogenization of market milk used for the preparation of tea (commonly known as '*chai*' in India) and thereby estimate the energy-saving potential of the process. In the case of partial homogenization of milk, cream with different fat content (15%, 20%, and 25%) was homogenized at three first-stage pressures viz., 1000 psi, 1200 psi, and 1500 psi while keeping the second-stage pressure constant at 500 psi. The homogenization of milk was conducted at 65°C and 70°C temperatures. The homogenized cream was used to prepare standardized milk having 4.5% fat and 8.5% solids-not-fat. The temperature and pressure for homogenization were optimized based on the desirable least creaming index of samples of standardized milk at 48 h of refrigerated storage (4±2°C). In the case of conventional homogenization of milk, milk was first standardized to 4.5% fat and 8.5% solids-not-fat and then homogenized at 2000 psi and 500 psi for the first and second stages respectively. Tea was prepared from milk obtained from both the homogenization processes and they were subjected to sensory evaluation. The energy consumption in both cases was measured from the energy meter installed at the homogenizer motor. The study revealed that, without affecting the quality of homogenized milk, about 68% of energy could be saved in partial homogenization of milk as compared to conventional homogenization of milk.

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## Introduction

Homogenization refers to the process of forcing the milk through a homogenizer with the object of sub-dividing the fat globules (De, 2001). The greater part of the fat volume in milk consists of globules with a diameter ranging from 2 to 6 µm (Ahmad, 2012). Homogenization of milk has become a standard industrial process, universally practiced as a means of stabilizing the fat emulsion against gravity separation (Huppertz, 2022, Bylund, 2003). Using pressures between 20 and 100 MPa, the dairy industry has been securing the quality and stability of its products for decades (Dos Santos, 2022). The aim of homogenization is to prevent the unsolicited fat separation occurring in milk, destined for long storage and also to increase viscosity of milk to prepare a greater number of tea cups from a given quantity. The standardized pasteurized milk is not homogenized except tea-special milk (AMUL Brand) intended to be used for preparation of tea. Complete homogenization is the most commonly used form of homogenization of milk wherein the entire quantity of milk is passed through the homogenizer. In partial homogenization, only cream portion is subjected to homogenization; skim milk used to standardize the fat content of cream remains unhomogenized. Partial homogenization of milk can be used to reduce energy and operating costs (Bylund, 2003). The effect of partial homogenization on quality of dairy products have been studied by a few researchers (Jana et al. 2016), however, no study has been conducted to evaluate the effect of partial homogenization of milk on quality of milk and tea (commonly known as '*chai*' in India) prepared from such milk. The homogenization of milk is one of the energy intensive processes in the dairy industry (Samuelsson and Lindberg, 2018). Partial homogenization can be adopted to reduce energy consumption and processing cost in dairy industry. According to the International Energy Agency (2019), improved energy efficiency in industrial processes could reduce the world's energy needs in 2050 by one third, and help control global emissions of greenhouse gases. Hence, the present study was conducted to evaluate energy saving potential of partial homogenization of milk over conventional homogenization of milk. The sensory evaluation of tea prepared from the milks obtained from both the homogenization processes were carried out to check the feasibility of partial homogenization of milk over conventional homogenization of milk.

## Material and Methods

**Optimizing temperature of partial homogenization**

Required quantity of skimmed milk (0.05% fat) and pasteurized cream (40% fat) were procured from milk co-operative society of Anand city of Gujarat. They were used to prepare standardized cream with varying fat content i.e. 15%, 20% and 25%. Standardized creams were subjected to homogenization at 65°Cand 70°C by varying first stage pressure i.e. 1000 psi, 1200 psi and 1500 psi; second stage pressure was 500 psi. These creams were used to prepare standardized milk of 4.5% fat which was then subjected to pasteurization at 78°C for 1 min and immediately cooled to 4°C. Milk samples were evaluated for cream line formation through visual observation by storing them in one liter beakers at 4°C for 48 h. Beakers used for the storage of samples had same dimensions. Based on visual observation of cream line formation in milk samples, temperature of cream homogenization was optimized.

**Optimizing the cream fat and the pressure of partial homogenization**

Required quantity of skimmed milk (0.05 % fat) and pasteurized cream (40% fat) were used to prepare standardized cream of different fat percentages i.e. 15%, 20% and 25%. Standardized creams were then subjected to homogenization at optimized temperature by varying first stage pressure i.e. 1000 psi, 1200 psi and 1500 psi; second stage pressure was 500 psi. These creams were used to prepare standardized milk of 4.5% fat which was subjected to pasteurization at 78°C for 1 min. and immediately cooled to 4°C. Milk samples were evaluated for Creaming Index (CI) and viscosity (Centipoise) by quiescently storing them in one liter beakers at 4°C for 48 h. Beakers used for the storage of samples had same dimensions.

CI of milk samples was performed by USPHS method (Bylund, 2003). According to the method, a sample of 1000 ml milk is stored for 48 h at 4°C, after which the fat content of the top 100 ml (sample A) and remaining 900 ml (sample B) were determined by MilcoScreen™ (Manufacturer: Foss, Denmark). CI of milk was calculated as follows

$$CI = \frac{A-B}{B} \times 100$$

Where, A: fat (%) of top 100 ml of sample at 48 h of storage at 4°C

B: fat (%) of remaining 900 ml of sample at 48 h of storage at 4°C

Viscometer (Make: Brookfield, Model: DV) was used to measure the viscosity of milk samples using S61 spindle at 100 rpm and 25°C. One litre milk was taken for the analysis. Based on CI and viscosity of milk samples, the level of cream fat and first stage homogenization pressure for cream were optimized.

**Comparison of CI and viscosity of optimized partially homogenized milk with the conventionally homogenized milk**

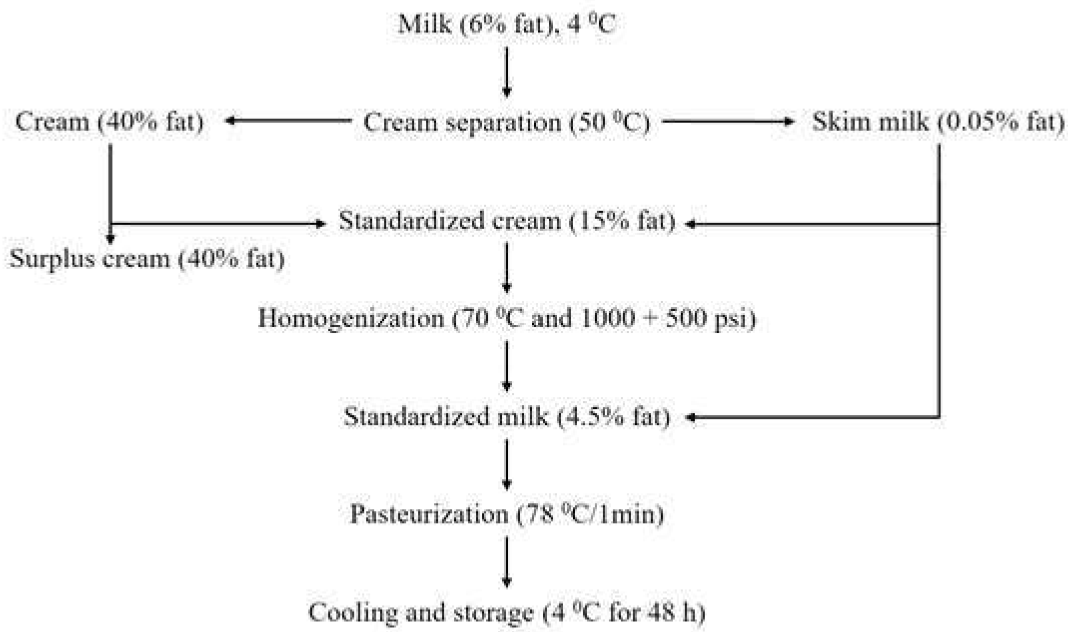


**Fig. 1** Optimized process flow chart for partial homogenization of milk

***Preparation of partially homogenized milk*:** Required quantity of skimmed milk (0.05 % fat) and pasteurized cream (40% fat) were used to prepare standardized cream of optimized fat contents. Standardized creams were then subjected to homogenization at optimized temperature and pressure. These creams were used to prepare standardized milk of 4.5% fat. The further steps followed is indicated in figure 1.

***Preparation of conventionally homogenized milk*:** Required quantity of skimmed milk (0.05 % fat) and full cream milk (6.00% fat) were used to prepare standardized milk with 4.5% fat.

Both the milks were then subjected to pasteurization at 78°C for one minute and immediately cooled to 4°C. The further steps followed is indicated in figure 2. Milk samples were evaluated for CI and viscosity by storing them quiescently in one-liter beakers at 4°C for 48 h. Beakers used for the storage of samples were having the same dimensions. The same methods were used for analysis of milk samples for the CI and viscosity as mentioned below.

**Comparison of sensory scores of tea prepared using optimized partially homogenized milk and conventionally homogenized milk**

Tea was prepared from 'partially' and 'conventionally' homogenized milk and subjected to sensory analysis using nine-point hedonic scale (Nicolas et al. 2010).

**Measurement of energy consumption during partial homogenization and conventional homogenization of milk**

Energy consumption of homogenizer during partial and conventional homogenization of milk were measured using three phase energy meter (Debastiani et al. 2014).

**Calculation of energy savings through partial homogenization of milk vis-a-vis conventional homogenization**

Total energy savings during partial vis-a-vis conventional homogenization of milk was calculated using the following formula

$$\% \text{ Energy saving} = \frac{C-P}{C} \times 100$$

Where, C = Energy consumed during conventional homogenization (kWh)

P = Energy consumed during partial homogenization (kWh)

## Results & Discussion

**Optimizing temperature of partial homogenization through cream line formation in standardized milk**

Visual observation of cream line formation at the surface of milk samples was done (Table 1). Beakers containing milk were tilted to observe the degree of cream line. Sign '+' shown in Table 1 indicates the thickness of cream layer at the top of milk samples. Highest cream line was observed in milks prepared from 25% fat cream followed by 20% fat and 15% fat when homogenized at 65°C and 1500 psi and 1200 psi pressure. This may be due to high fat content in cream. The lowest cream line was observed at 70°C for all the milk samples prepared from cream of different fat content, as high temperature leads to efficient homogenization. Hence, 70°C temperature was optimized for the partial homogenization**.**

**Optimizing the cream fat and the pressure of partial homogenization through CI of standardized milk**

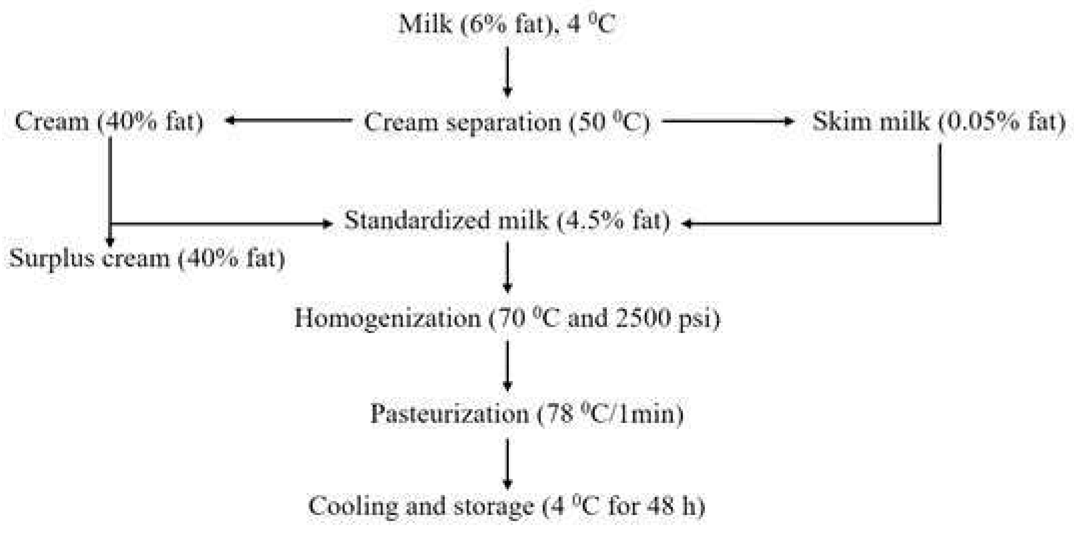


**Fig. 2** Process flow chart for conventional homogenization of milk

Standardized milk of 4.5% fat was prepared from cream of different fat content homogenized at 70°C with varying first stage pressure. CI of the milk samples stored at 4°C for 48 h were estimated by determining the fat content of top 100 ml and remaining 900 ml volume separately (Table 2). Varying fat (%), first stage homogenization pressure and interaction effect showed significant difference ($p<0.05$) in CI milk samples. Low CI (d" 10) is desirable for efficient homogenization. CI of milk prepared from cream of 15% fat content and homogenized at 1000 psi first stage pressure was 5.23 which was lowest compared to all other treatments; such effect was significant ($p<0.05$).

Table 3 shows the viscosity of standardized milk prepared from cream of varying fat content homogenized at varying homogenization pressures. Varying fat (%) and first stage homogenization pressure showed significant effect ($p<0.05$) on the viscosity of standardized milk whereas their interaction effect was found to be non-significant. Based on CI and viscosity values, both 15% and 20% creams can be selected. However, due to good sensory score obtained for tea prepared from 15% fat cream, the standardized milk prepared from 15% fat cream homogenized at 1000 psi pressure was selected as optimized parameters.

Process flow chart for standardized homogenized milk prepared by optimized partial homogenization method is shown in Figure 1 while similar aspect for conventional homogenization of milk is shown in Figure 2. The experimental setup for homogenization is shown in Figure 3.

**Comparison of CI and viscosity of optimized partially homogenized milk vis-a-vis conventionally homogenized milk**

Table 4 shows the CI and viscosity values of partially and conventionally homogenized milks. As per Bureau of Indian Standard (1967), low creaming index (< 10) is desirable i.e. efficient homogenization. CI of partially and conventionally homogenized milks were 5.23 and 3.90 respectively which satisfied the standard. Viscosity of partially and conventionally homogenized milks were 0.98 and 1.01 cP respectively. The difference between these values are non-significant. Based on these observations, it can be concluded that partially homogenized milk is at par with conventionally homogenized milk in terms of CI and viscosity. Trout et al. (1935) studied the effect of homogenization on the viscosity of pasteurized whole milk. Bateman and Sharp (1928) reported that the viscosity of whole milk increases marginally

**Table 1**: Cream line formation in standardized milk (4.5% fat) as affected by cream fat and temperature & first stage pressure of homogenization

| Temperature and pressure of homogenization | Cream fat (%) | | |
|---|---|---|---|
| | 15 | 20 | 25 |
| 65°C, 1000 psi | ++ | ++ | +++ |
| 65°C, 1200 psi | ++ | ++ | ++++ |
| 65°C, 1500 psi | ++ | ++ | ++++ |
| 70°C, 1000 psi | + | + | +++ |
| 70°C, 1200 psi | + | + | +++ |
| 70°C, 1500 psi | + | + | +++ |

+: No visible cream line (Acceptable); ++: Slight cream line (Unacceptable);
+++: Thick cream line (Unacceptable); ++++: Too thick cream line (Unacceptable)

**Fig. 3** Experimental setup for homogenization

upon homogenization. Lisk (1924) reported that homogenization of whole milk at 3500 psi, increases considerably the viscosity of milk. At 1200 psi, the increase in viscosity was to a small extent only.

**Comparison of sensory scores of tea prepared using optimized partially homogenized milk and conventionally homogenized milk**

Sensory evaluation of tea prepared from partially and conventionally homogenized milk was carried out using 9-point hedonic scale. Sensory scores for all the parameters were found to be non-significant (p>0.05) for tea(s) made from partially and conventionally homogenized milks (Table 5).

The purpose of homogenization varies with the application. Consequently, the methods of measuring efficiency also vary. Creaming index and homogenization efficiency are inversely related. This implies that higher homogenization efficiency and lower creaming index are desirable to have efficient homogenization and prevent fat separation in product upon storage. Samuelsson and Lindberg (2018) reported that no effect of homogenization pressure on the proteins and the quality of the yoghurt could be found. The higher homogenization temperature led to a decrease in the fat globule size but none of the quality parameters nor the sensory analysis showed to be affected by the temperature change. This would mean that partial homogenization of yoghurt milk would be possible without compromising the quality.

**Table 2:** Effect on CI of standardized milk (4.5% fat) as affected by cream fat and first stage pressure of homogenization

| Homogenization pressure (psi) | Cream fat (%) | | | |
|---|---|---|---|---|
| | 15 | 20 | 25 | Average |
| 1000 + 500 | 5.23±0.55 | 6.31±0.20 | 16.46±0.37 | 9.33 |
| 1200 + 500 | 5.42±0.55 | 6.67±0.56 | 30.54±0.61 | 14.21 |
| 1500 + 500 | 6.02±0.74 | 7.33±0.34 | 75.67±0.58 | 29.67 |
| Average | 5.56 | 6.77 | 40.89 | |
| | SEm | | CD (0.05) | CV% |
| Fat | 0.174 | | 0.52 | |
| Pressure | 0.174 | | 0.52 | 2.95 |
| Fat× Pressure | 0.302 | | 0.90 | |

All values are mean of three replicates ± Standard Deviation (SD)

**Table 3:** Effect on viscosity (cP) of standardized milk (4.5% fat) at 25°C as affected by cream fat and pressure of homogenization

| Homogenization pressure (psi) | Cream fat (%) | | | |
|---|---|---|---|---|
| | 15 | 20 | 25 | Average |
| 1000 + 500 | 1.05±0.04 | 1.01±0.02 | 0.97±0.02 | 1.01 |
| 1200 + 500 | 0.99±0.04 | 1.00±0.03 | 0.98±0.03 | 0.99 |
| 1500 + 500 | 0.99±0.02 | 0.99±0.02 | 0.95±0.03 | 0.98 |
| Average | 1.01 | 1.00 | 0.97 | |
| | SEm | | CD (0.05) | CV% |
| Fat | 0.009 | | 0.03 | |
| Pressure | 0.009 | | 0.03 | 2.73 |
| Fat × Pressure | 0.016 | | NS | |

All values are mean of three replicates ± SD, cP: centi poise; NS= Non-significant

**Table 4:** CI and viscosity of partially homogenized and conventionally homogenized milks

| Parameters | Partially homogenized milk# | Conventionally homogenized milk# | Recommended standard (BIS) | Remark |
|---|---|---|---|---|
| Creaming index | 5.23 ±0.55 | 3.9 ±0.67 | <10 | Acceptable |
| Viscosity (cP) at 25$^0$C | 1.03±0.06 | 1.01±0.03 | NA | Acceptable |

# values are mean of three trials ± SD; NA = Not Applicable

**Table 5**: Sensory score (9-point hedonic scale) of tea prepared using optimized partially homogenized milk and conventionally homogenized milk

| Parameters | Partially homogenized milk# | Conventionally homogenized milk# | Cal. t-value | p-value | Significance |
|---|---|---|---|---|---|
| Flavour | 8.44±0.50 | 7.88±0.83 | 1.64 | 0.12 | NS |
| Consistency | 8.47±0.71 | 7.98±0.72 | 1.38 | 0.19 | NS |
| Colour and Appearance | 8.44±0.50 | 8.38±0.74 | 0.20 | 0.85 | NS |
| Overall Acceptability | 8.45±0.45 | 8.00±0.77 | 1.41 | 0.18 | NS |

# Values are average of eight trials; NS = Non Significant; Tabulated t-value: 2.14 (cal. t-value less than tabulated value = NS); 5% level of significance

**Table 6**: Energy consumption during partial homogenization and conventional homogenization of milk

| Parameters | Partial homogenization | Conventional homogenization |
|---|---|---|
| Total energy (kWh)* | 1.40±0.35 | 4.47±0.28 |

**Table 7:** Energy saving in partial homogenization of milk over conventional homogenization at 500 L/h milk flow rate

| Energy consumption (kWh) | | Energy saving |
|---|---|---|
| Partial homogenization | Conventional homogenization | |
| 1.40±0.35 | 4.47±0.28 | [(4.47-1.40)/4.47] x 100 = 68.80% |

### Measurement of energy consumption during partial homogenization and conventional homogenization of milk

Energy consumed during cream separation and homogenization processes were measured using energy meter while preparing partially and conventionally homogenized milk (Table 6). It was observed that considerably less energy consumed in partial homogenization (1.40±0.35 kWh) compared to conventional homogenization (4.47±0.28 kWh) when same quantity of milks was prepared. This was due to lower operating pressure (1000 psi) of homogenization and less time (0.3 h) of operation of homogenizer during partial homogenization over conventional homogenization. Though energy consumption in case of cream separation during milk prepared by partial homogenization was little higher than conventional process, the total energy required to prepare same quantity of standardized homogenized milk was found to be less. Deynichenko et al. (2018) reported that the specific energy consumption of 3400 J/kg for milk emulsion.

### Calculation of energy savings through partial homogenization of milk vis-a-vis conventional homogenization at 500 litre per hour milk flow rate

Difference in the energy consumed between partial and conventional homogenization was divided by the energy consumed during conventional homogenization to arrive at the energy saving (Table 7).

## Conclusions

Homogenization efficiency was superior at 70°C compared to at 65°C based on cream line formation in standardized milk stored at 4°C for 48 h. The CI value was 5.23±0.55 at 1000+500 psi pressure of homogenization at 70°C temperature when cream of 15% fat was homogenized (partial homogenization). This is lowest and desirable among all the treatments. A non-significant difference in viscosity was observed for milks homogenized at optimized fat content of cream, temperature and pressure of homogenization as compared to milk subjected to conventional homogenization. In addition to this, tea prepared from these two milks were statistically alike ($p<0.05$) with regard to the sensory scores. It was found that partial homogenization of milk requires about 68.80% less energy compared to the energy required for conventional milk homogenization.

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