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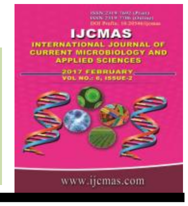

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Effect of Condensation Method on Quality Attribute of Kulfi

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A B S T R A C T

Condensation is cumulative process for the total solid by evaporating the water content in the product. The method of condensation varies with product to product preparation or by the facility of the processing plant. The three type of condensation methods like open pan condensation, vacuum pan condensation and combination of vacuum pan and open pan methods were used to condense the pre standardized milk (5% fat and 8% SNF) up to two folds, followed by the addition of 13% sugar for preparation of the *kulfi* mix. Simultaneously mix was cooled to ambient temperature with continuous agitation to avoid the separation of the cream layer. The freezing of *kulfi* was completed by immersion freezing in liquid brine solution. The effect of the condensation method on freezing time, melting rate, hardness and sensory attribute of the *kulfi* was measured. The open pan condensation method was ascertained better in maintaining the body and texture, colour and melting rate of *kulfi* as compare to other methods.

Introduction

Frozen desserts are delicious and calorie-rich foods relished by all age groups and popular throughout the world. *Kulfi* is 500 year old a popular frozen dessert (Aneja, 1992) of Indian origin and it occupies a privileged position amongst the traditional Indian dairy products. *Kulfi* is also known as *qulfi, kulfa, kulphy* etc (Pandit, 2004). The word *kulfi* derives its origin from the Hindustani word *kulaf* meaning a 'lock' or a 'container' that has to be unlocked. And, indeed the recess of the metal cone that encases the frozen delight has to be pried open to release the confection (Aneja, 1992). *Kulfi* is very popular in many parts of the country mainly due to its palatability and low price. It is similar to ice cream in formulation and processing, but differs from ice cream in that it contains little or no air. It is conventionally produced by concentrating whole milk to about two folds followed by addition of sugar and freezing it in aluminium or plastic moulds. The mixture should be suitably heat treated before freezing. The product shall have a pleasant agreeable aroma and taste with uniform consistency, free from big sized crystals and coagulated milk particles (Pal, 2006). Then the freezing of *kulfi* is done by immersion freezing in an ice and salt or liquid brine solution or by extrusion through a freezer with very low overrun.

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The choice of dairy ingredients and formulation of *kulfi* mix are determined by regulatory standards, the desired quality of frozen dessert, marketing strategy, consumer demand, relative price and availability of ingredients. But, the body or consistency of *kulfi* is related to the mechanical strength of the mix and its resistance to melting.

Information regarding the engineering aspects of *kulfi* freezing processing including effect of condensation methods and their influence on product structure and quality are sparsely reported.

These aspects are important in the design, analysis and control of the process and product quality.

In light of these points, a research study has been taken to comparatively evaluate the three types of condensation methods like open pan condensation, vacuum pan condensation and combination of vacuum pan and open pan methods effect on quality attributes of the *kulfi*.

Materials and Methods

The different condensation methods adopted for the concentration of mix to prepare the *kulfi* is detailed in figure 1.

Collection and standardization of milk

Fresh clean *Deoni* cow milk was collected from the ICAR- National Dairy Research Institute (SRS), Bengaluru, Livestock Research Center and standardized to 5% fat and 8.5% SNF by weight. This standardized *Deoni* cow milk was used throughout this study.

Condensation

Condensation is cumulative process for the total solid by evaporating the water content in the product. The three type of condensation methods like open pan condensation, vacuum pan condensation and combination of vacuum pan and open pan methods were used to condense the pre standardized milk (5% fat and 8.5% SNF) up to two folds

Open pan condensation

After adding the 13% cane sugar computed (on product basis) to the standardized milk the milk is concentrated in the open jacket steam vessel (make; Jacket.HYD, T.P.60 P.S.L.G) up to two fold level (2:1), the maximum temperature of *kulfi* mix has achieved during concentration was 102-103^{o}C (Fig. 2.).

Vacuum pan condensation

In vacuum pan condensation method, after addition of 13% sugar to the mix (computed on product basis), single effect evaporator (APV, Kolkatta) with water evaporation capacity of 20L/h (Fig. 3) was used for concentrating the *kulfi* mix to the desired total solids (TS) up 2:1 level.

All the concentrations were carried out at 0.829 kg/cm^2 vacuum pressure, which corresponded to a temperature of concentration of 63-65^0 C.

Combination of vacuum pan and open pan condensation

Pre-standardized milk was initially concentrated in the vacuum pan nearly to the two folds by maintaining 0.829 kg/cm^2 vacuum pressure which corresponded to a temperature of concentration of 63-65°C, then 13% sugar (computed on product basis) was added to concentrated milk and desired concentration was achieved through open pan condensation at about 102-103°C.

Freezing

The mix was cooled to ambient temperature with continuous agitation to avoid the separation of cream layer, The freezing of *kulfi* was completed by immersion freezing in liquid brine (26% NaCl by wt.) solution.

Packing and hardening

After freezing the *kulfi* was taken out from the cone and wrapped in butter paper and kept it for 8h for hardening at -18^{o}C in Celfrost Chest freezer (Make: CF-100, Volume: 100ltrs.). A hardening is reported to remove heat to quickly as possible from the ice cream (Hui, 2006) in order to inhibit the ripening/recrystalization of the ice crystals.

Analytical methods

Melting rate

Melting stability of *kulfi* was determined as per the method described by Raju *et al*., (1989). The material consist of drawing 70 g of *kulfi* sample on to a wire net (250 pores per sq. inch) placed on a funnel over a measuring jar immediately after removal from the hardening chamber for 15 minutes at 35 ± 1°C (Fig. 4). The amount of *kulfi* in ml melted in 15 minutes was noted as melting stability and the melting rate was expressed as ml/15 min.

Hardness

Textural profile analysis (TPA) was performed using TA.XT Plus Texture Analyzer (Stable Micro Systems, Texture Technologies Corp., Goldaming, UK) equipped with 50 kg load cell (Fig. 5). The frozen hardened *kulfi* sample 10mm thickness and 35mm diameter sample after immediately removing from the freezer was compressed in a reciprocating motion to give shearing force texture profile curve. The compression depth of 10 mm was achieved using a Warner Bratzler Blade (HDP/WBR) set with rectangular slot blade, The blade had a knife edge at one end and a flat guillotine edge at the other. In operation, the blade was firmly held by means of the blade holder which screws directly into the Texture Analyzer.

Once the trigger force of 2g was attained, the knife edge proceeded to shear the *kulfi* to the depth of 10mm before returning to its original position at constant speed (10mm/s). the maximum force expressed by sample at the point of return of the probe was measured as sample hardness, the greater the value the harder the sample.

Measurement of colour

The colour of *kulfi* cone after hardening was measured using a computer based image analysis technique. The samples were placed on a flatbed scanner (Canoscan 9000F, Mark II) and scanned at 600 dpi resolution. The images were then imported into Adobe Photoshop 7.0 software and the 'L', 'a' and 'b' values were obtained from the histogram window (Adobe Photoshop 7.0 User Guide for Macintosh and Windows, 1998). The software uses a scale, ranging from 0 to 255, to characterize L (lightness), 'a' and 'b'. These values were converted into CIELAB L*, a* and b* values using the following formulae (Yam and Papadakis, 2004).

$$L^* = \left[\frac{L}{255}\right] \times 100 \qquad \text{Eq.1}$$

$$a^* = \left[\frac{240a}{255}\right] - 120 \qquad \text{Eq. 2}$$

$$b^* = \left[\frac{240b}{255}\right] - 120 \qquad \text{Eq. 3}$$

Yellowness index (YI), Whiteness Index (WI) and Browning Index (BI) were calculated from the L*, a* and b* values using the following formulae.

$$YI = 142.86\left(\frac{b^*}{L^*}\right) \quad \text{(Pagliarini } et\ al., 1990) \qquad \text{Eq.4}$$

$$WI = 100\sqrt{(100-L^*)^2 + a^{*2} + b^{*2}} \qquad \text{Eq.5}$$

(Pagliarini *et al*., 1990)

$$BI = \frac{100(L-0.31)}{0.172} \qquad \text{Eq.6}$$

Where, L*, a* and b* represented the colour values of *kulfi* after hardening.

Sensory evaluation of kulfi

The sensory evaluation was done by a selected panel of judges on a 9 point hedonic scale for appearance, flavour, melting characteristics, body and texture and overall acceptability. A score of 9 corresponded to highest acceptability while a score of 1 corresponded to least acceptability of the products (Dewangan, 2012).

Results and Discussion

The effect of the condensation method on freezing point, melting rate, hardness, colour parameter and sensory attribute of the *kulfi* were compared and is discussed below.

Freezing point

The freezing curve for the *kulfi* mix prepared using the different condensation methods is presented in figure 6. It can be seen that the different condensation methods did not have any considerable effect on the freezing point of *kulfi* mix and the freezing curve followed near identical path for the *kulfi* mix prepared using all the three condensation methods. This could be due to the constant total solids content maintained in *kulfi* mix used in the study for different condensation methods. A similar observation was also reported by Jie *et al.*, 2003 who deduced that the freezing point depended on the total solids present in the solution.

Melting rate

The effect of different condensation methods on the melting rate (ml/15 min) of *kulfi* is graphically represented in figure 7. From the figure, it was observed the melting rate of VP condensation method (28 ml/15min) was higher compared to 24 and 24.5 ml/15min for OP and VP+OP method respectively. The melting rate of VP treated sample was significantly higher than that of other treatments; while there was no significant difference noticed in melting rate of OP treated sample and VP+OP samples.

The lower melting rate score for OP and VP+OP treated *kulfi* sample could be attributed to lower ice mass fraction formed due to reduced free water proportion. At elevated temperatures (as in the case of open pan processing), the whey protein produces heat induced gels that are capable of holding large amount of water and other food components (Fox and Mcsweeney, 2003). This bound water probably reduced the volume of free water in the *kulfi* mix for freezing, leading to lower melting rate.

Hardness

The hardness value (N) of *kulfi* samples prepared using different condensation methods is shown in figure 7. The hardness value (N) recorded for *kulfi* sample treated by VP condensation method was 42, as against 34 and nearly 35 observed for OP and VP+OP condensation methods, respectively. The hardness value of VP treated sample was significantly higher than that of *kulfi* mix condensed by other two methods, due to increased mass fraction of ice content in the final frozen *kulfi* samples.

Colour index of kulfi

The colour index of *kulfi* was estimated using the Eq. 4, 5 and 6 is graphically represented in figure 8. The yellowness index computed for OP and VP+OP methods was 31 and 32, respectively. It was found that VP condensation method sample achieved very poor yellowness index of 21. The increase in the YI in OP method OP+VP method could be due to the complete denaturation of the protein and caramelization of sugar level at elevated temperature (102ºC) during concentration process in the open pan as compared to VP method (63-65ºC).

The browning index of the *kulfi* samples prepared using the three condensation methods followed a parallel trend to that of yellowness index, while the whiteness index of the samples reflected a reverse trend to yellowness index.

Sensory evaluation

Color and appearance

From table 1, it can be seen that the average score for color and appearance awarded for VP *kulfi* was 6.5, as against 7.5 for the samples subjected to OP and OP+VP, respectively. The color and appearance score of OP and OP+VP sample was significantly higher than that of VP treated *kulfi* samples. The lower color and appearance score for VP treated *kulfi* was mainly due to lack of desirable brownish appearance. This could be mainly due to reduction in condensation temperature in VP treatment, which is required for development of desirable brown color in *kulfi* through caramelization. The other two treatments OP and VP+OP ascertained same color and appearance score due to the effect of elevated temperature during condensation.

Body and texture

Body and texture score awarded for VP *kulfi* was 7, as against 9 for the samples subjected to OP and OP+VP respectively. Between OP and VP+OP treated *kulfi* there was no significant difference in body and texture score (Table 1). The low body and texture score of VP condensed *kulfi* was attributed to its high melting characteristic and hence softer body.

Flavor

Flavor score awarded for VP *kulfi* was 7.5, as against 8.5 and 8 for the samples subjected to OP and OP+VP respectively. Between OP and VP+OP treated *kulfi* there was no significant difference in flavor score (Table 1). Elevated temperature during open pan processing aided in the development of a caramelized flavor in the *kulfi*, which resulted in higher flavor scores during sensory evaluation.

Melting characteristic

One of the desirable attributes for *kulfi* is its ability to retain its frozen state during consumption without any meltdown or rundown. Hence, the sensory panel was asked to score for the melting characteristic of the product during sensory evaluation. From table 1, it can be seen that the melting characteristic score awarded for VP *kulfi* was 6.5, as against 8.5 the samples subjected to OP and OP+VP respectively. Between OP and VP+OP treated *kulfi* there was no significant difference in melting characteristic score. The lower melting characteristic score for OP and VP+OP treated *kulfi* sample was mainly due to less ice mass fraction (free water) proportion.

Overall acceptability

The overall acceptability score of VP treated *kulfi* sample awarded was around 6.8, as against 8.3 and 8.5 for treatment OP and VP+OP. Between OP and VP+OP treatment techniques, no significant difference was observed on overall acceptability score but VP treated *kulfi* the overall acceptability score significantly decreased as compared to other treatments and observation reported in table 1.

Table.1 Sensory score for quality attributes of kulfi for different condensation methods

Sensory parameters	Vacuum Pan	Open Pan	Vacuum pan+ Open Pan
Colour and appearance	6.5[a]	7.5[b]	7.5[b]
Flavor	7.5[a]	8[a]	8[a]
Body and Texture	7.5[a]	9[b]	9[b]
Melting characteristic	6.5[a]	8.5[b]	8.5[b]
Overall acceptability	6.87[a]	8.37[b]	8.5[b]

*Results are means of six measurements for each treatment

Fig.1 Process flow for the preparation of kulfi using different condensation methods

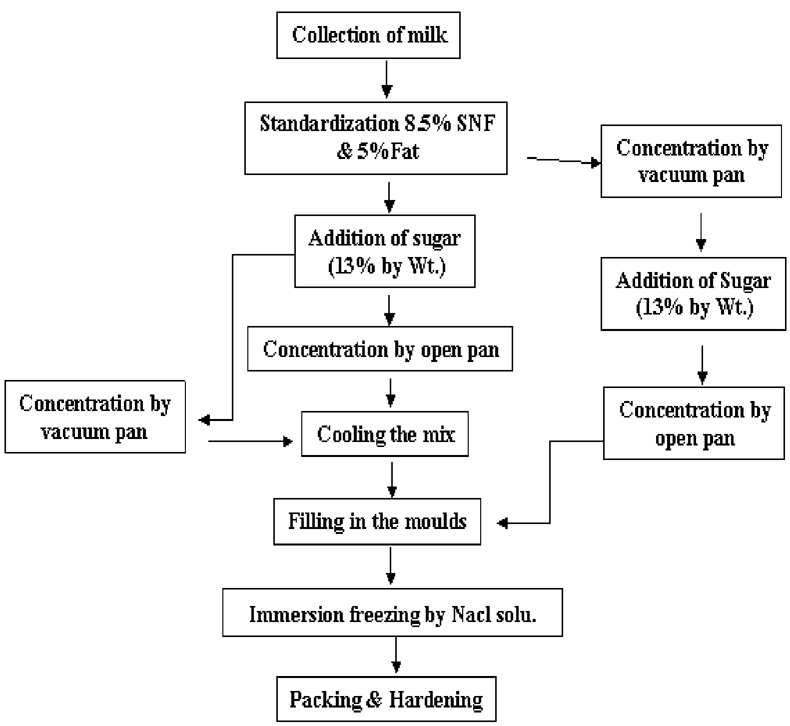


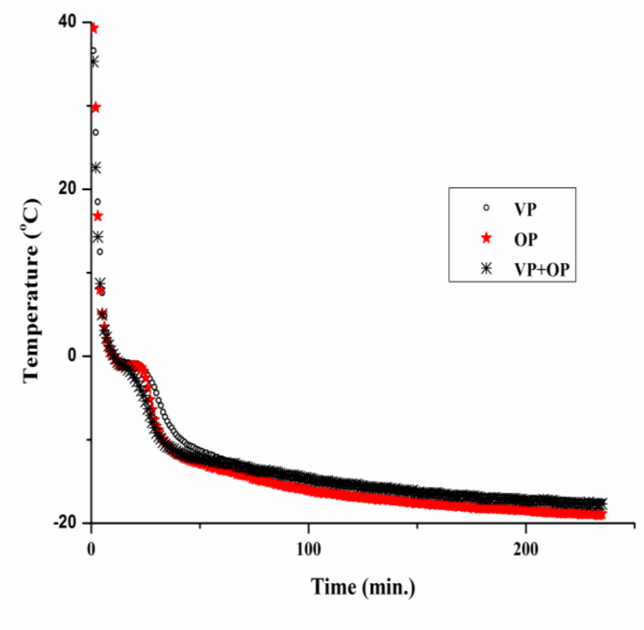
Fig.2 Open pan condenser

Fig.3 Single effect evaporator

Fig.4 Experimental setup for determination of melting rate

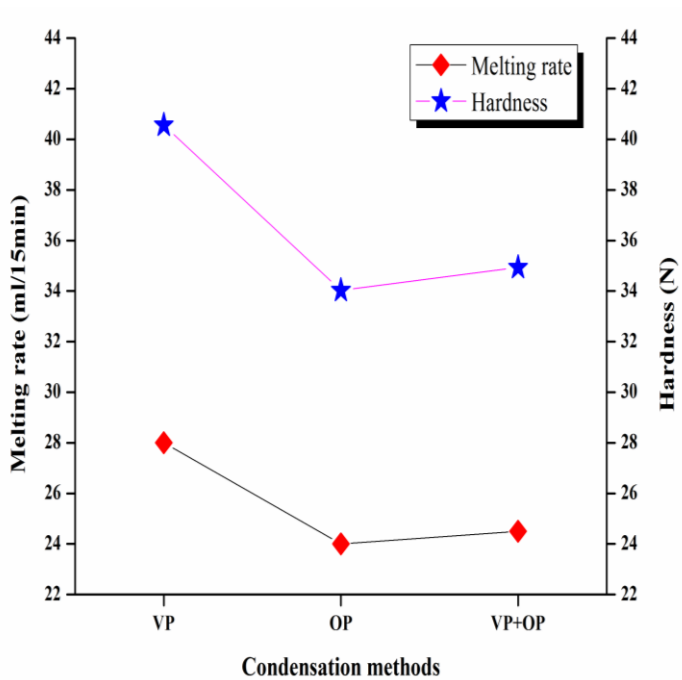
Fig.5 TA.XT Plus Texture Analyzer

Fig.6 Freezing curves of the kulfi with different condensation methods



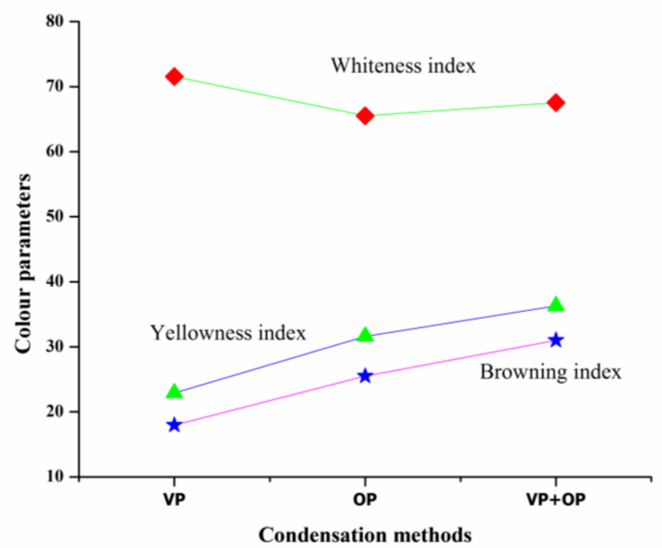
VP: Vacuum pan condensation, OP: Open pan condensation and VP+OP: Combination of OP and VP
*Results are means of three measurements for each treatment

Fig.7 Melting rate and hardness of the kulfi with different condensation methods



VP: Vacuum pan condensation, OP: Open pan condensation and VP+OP: Combination of OP and VP
*Results are means of three measurements for each treatment

Fig.8 Colour index of the kulfi with different condensation methods



VP: Vacuum pan condensation, OP: Open pan condensation and VP+OP: Combination of OP and VP
*Results are means of three measurements for each treatment

In conclusion, the effect of the condensation method on freezing time, melting rate, hardness, colour index and sensory attribute of the *kulfi* was measured. The open pan condensation method and combination methods were ascertained better in maintaining the body and texture, colour and melting rate of *kulfi* as compare to vacuum pan methods, but the combination condensation method is time and energy consuming as compare to other two methods.

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