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Janki Suthar
Assistant Professor, Department of Dairy Technology, Mansinhbhai Institute of Dairy and Food Technology, Dudhsagar Dairy Campus, Mehsana, Gujarat, India

Jana AH
Professor and Head, Department of Dairy Processing and Operations, SMC College of Dairy Science, Anand Agricultural University, Anand, Gujarat, India

Modha HM
Assistant Professor, Department of Dairy Technology, SMC College of Dairy Science, Anand Agricultural University, Anand, Gujarat, India

Smitha Balakrishnan
Assistant Professor, Department of Dairy Chemistry, SMC College of Dairy Science, Anand Agricultural University, Anand, Gujarat, India

Corresponding Author:
Janki Suthar
Assistant Professor, Department of Dairy Technology, Mansinhbhai Institute of Dairy and Food Technology, Dudhsagar Dairy Campus, Mehsana, Gujarat, India

Effect of fat content and homogenization of milk on the recovery of milk constituents and quality characteristics of *paneer*

Janki Suthar, Jana AH, Modha HM and Smitha Balakrishnan

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Abstract
The study was carried out to assess the influence of varying milk fat content and milk homogenization pressure on the composition, recovery of milk constituents and the quality characteristics of *paneer*. In order to ameliorate the ill effects of milk homogenization on *paneer* texture, the homogenized milk was blended with unhomogenized milk in 4:6 proportion before preparing *paneer*. Milk was standardized to 4.1, 4.3 and 4.5 % milk fat and homogenized at two pressures (i.e. 5.88 and 0.98 MPa, 4.90 and 0.98 MPa); product was coded BMP4.1, BMP4.3 and BMP4.5 respectively. Control *paneer* was prepared from 4.5 % fat unhomogenized milk. Milk standardized to 4.1 % milk fat, using blend of homogenized (4.90 and 0.98 MPa pressure) and unhomogenized milk (4:6, w/w) led to *paneer* having significantly higher fat recovery (98.22 %), yield (16.84 %) and improved textural properties as compared to control product (unhomogenized, 4.5 % fat milk). The *paneer* obtained from blended milks (BMP4.3, BMP4.5) were softer, less springy, but having lower adhesiveness as compared to control (CP) and completely homogenized milk (CHP) *paneer*. There was an improvement in the fat recovery with concomitant decrease in protein recovery of *paneer*, when homogenization pressure was increased. The total sensory score of control *paneer* was superior over all of the blended milk *paneer* samples, but similar to the score obtained by CHP. Preparation of *paneer* BMP4.1 is beneficial with respect to minimal cost of milk in producing the product with attendant improved recovery of milk constituents and per cent yield, at the same time complying with the fat-on-dry matter requirements of FSSA. Preparation of *paneer* from exclusively homogenized milk (CHP) is not recommended since they had the least yield.

Keywords: *Paneer*, homogenization, blending of milk, milk fat content, milk solids recovery, textural properties, sensory scoring

Introduction
*Panee*r is heat and acid coagulated, fresh, soft variety of cheese. *Paneer* is rich in protein, fat and contains some amount of minerals and vitamins; a good nutritional product for the vegetarians. *Paneer* is being used in many Indian culinary dishes [1]. In India, the compound annual growth rate (CAGR) for *paneer* is about 12.5 % per annum during period of 2014-2019 [2].

The quality of *paneer* is affected by a number of factors such as type and quality of milk [3,4], fat content of milk [5], pre-treatments to milk [6], type and strength of coagulant, coagulation temperature and pressing operation [7, 8, 9]. Many of these factors have an influence on the recovery of milk constituents and thus the yield of *paneer*.

Homogenization of milk is known to improve the recovery of milk solids (especially fat) in the resultant product; however, for *paneer* preparation, such treatment has some adverse influence on the body and texture of product. Hence, there is scanty literature on the use of homogenized milk for *paneer* making. Low pressure (i.e. up to 4.9 MPa pressure) homogenization of milk resulted in Mozzarella cheese having greater moisture content, increased fat recovery and improved the yield of product [10]; the appearance of product was also improved. Homogenization of milk has also afforded beneficial effect on Queso blanco cheese with regard to recovery of milk fat and total solids [11]. One isolated literature pointed out that homogenization of milk did not improve any quality aspects of *paneer* [12].

In order to ameliorate the adverse effect of milk homogenization on the physical characteristics of *paneer*, a method was standardized [13] in which homogenized milk was blended with unhomogenized milk in 4:6 proportion, standardized to specific milk fat content for preparing *paneer*. Since, homogenization of milk improves the fat recovery of product, it was decided to prepare *paneer* from lower fat milks (i.e. 4.1, 4.3 % fat vs. 4.5 % for control) and see whether the *panee*r made thereof complies with the minimum fat-on-dry matter (i.e. minimum 50.0% FDM) specified by FSSA [14] and has suitable sensory quality.

Materials and methods

The mixed milk (cow and buffalo milk) was procured from Anubhav Dairy, an experimental dairy plant of Anand Agricultural University, Anand, Gujarat, India. The mixed milk was separated into cream (40.0-45.0 % fat) and skim milk (≤ 0.2 % fat). The skim milk was used to standardize the milk for paneer making. Anhydrous citric acid was obtained from M/s. Loba Chemie Pvt. Ltd., Mumbai. Calcium chloride, dihydrate was obtained from M/s. Merck Ltd., Mumbai.

Preparation of *panee*r: *Paneer* was prepared using the process standardized [12] with certain modifications. The filtered mixed milk was standardized to three fat levels (i.e. 4.1, 4.3 and 4.5% fat) using skim milk. Control *paneer* was made from unhomogenized milk standardized to 4.5 % fat. Rest of the standardized milks were subjected to two homogenization pressures [viz., 5.88 and 0.98 MPa (P1), 4.90 and 0.98 MPa (P2)] at milk temperature of 65ºC. The homogenized milk was blended with unhomogenized milk at fixed proportion (4:6 w/w) as recommended [13]. The blended milks (homogenized with unhomogenized) were added with 0.005 % $CaCl_2$ in order to obtain a firmer coagulum. The milk for control *paneer* was not added with calcium salt. Such milks (3.0 kg for each lot, control milk and 2 experimental milks) were heated to 82˚C with holding period of 5 min. Coagulation of milk was carried out using 1.0 % citric acid solution at milk temperature of 70˚C. This was followed by separating the whey from coagulum, hooping the curd, pressing at 1.5-2.0kg cm^{-2} for 25min. The *paneer* blocks so obtained were immersed in pasteurized chilled (5ºC) water for 1 hour and after removal and draining, the product was vacuum packaged in polyethylene bags (80 µm thick) and stored at refrigeration (5±2ºC) temperature.

Analyses

Milk: The fat and protein content of standardized milk was determined using procedure described in AOAC (2012) [15], total solids by gravimetric method using Mojonnier milk tester [16].

***Paneer*:** *Paneer* samples were analysed for fat content [17], protein content using Kjeldahl method [18], total solids by gravimetric method using Mojonnier milk tester [16], ash content [19] and pH using digital pH meter. Lactose content was arrived at by difference. The per cent recovery of fat, protein and TS in *paneer* were calculated.

Texture profile analysis

A Food Texture analyser (M/s. Lloyd Instrument, Model 1000, LRX, England; Sr. No. 160374) was used to assess the textural properties of *paneer* samples. The samples in cube (2.00 ±0.06 cm) were tempered at 23±1˚C for an hour before subjecting them to textural analysis employing 40.0 % compression using 5K Newton load-cell moving at a cross head speed of 50.0 mm/min. A two bite force-time compression curves were printed and corresponding tabulated values of textural parameters were displayed in the computer. For each paneer sample, five cubic samples were analysed for texture. Textural parameters such as hardness, cohesiveness, springiness and adhesiveness were taken from the displayed data, while gumminess and chewiness were derived [20].

Sensory analysis

For sensory evaluation of *paneer* samples, ten judges were selected based on Duo-Trio test from the staff members of the department of dairy technology of the college. The score card (maximum score 100.0) suggested for *paneer* [21] was used to score the *panee*r samples.

Statistical analysis

The mean values of duplicate readings of each attribute of the product (*panee*r) were put in one way ANOVA (Analysis of Variance) using SPSS tool for statistical analysis. The experiment was replicated four times.

Results and discussion

The control sample (CP) was prepared from unhomogenized milk standardized at 4.5 % fat, another control sample (CHP) was prepared from homogenized 4.5 % fat milk. The three experimental *pane*er samples were prepared from blending of homogenized and unhomogenized milk (4:6 w/w) standardized to 4.1, 4.3 and 4.5 % milk fat. *Paneer* made from blended milk were denoted as BMP4.1, BMP4.3 and BMP 4.5 respectively; the numerical denoting the standardized milk fat content of milk. Likewise for BMP4.3 and BMP4.5. Milk was homogenized at two pressures viz., 5.88 and 0.98 MPa (i.e. P1) and 4.90 and 0.98 MPa (i.e. P2) (two stage homogenization). The optimized proportion of homogenized and unhomogenized milk in the milk blend was based on the report of Suthar *et al.* (2018) [13]. The blended milks and homogenized milk (for CHP) were added with calcium salt at level of 0.005 % since homogenization of milk led to a softer product. Other parameters of *paneer* making were kept constant viz., preheating temperature (82˚C/5 min.), coagulation temperature (70˚C), strength of coagulant (1.0% citric acid w/v), pressing and chilled water (5ºC) dipping.

Most commercial manufacturers of *paneer* standardize the milk in the vicinity of 4.5 % fat to obtain good quality product complying with fat on dry matter (FDM) standard laid down by FSSA [14]. Superior fat recovery in *paneer* can lead to yield improvement, at the same time enable *panee*r to be prepared from lower fat (i.e. < 4.5 % fat) milk, yet complying with the FSSA requirements (especially FDM).

Proximate composition of *paneer*

Any modification in the pre-treatment (i.e. heat treatment, homogenization, etc.) meted to milk has an impact on the chemical composition of resultant *paneer*. The paneer so obtained has to comply with the legal requirements. Hence, determining the composition of *paneer* is important for its marketability.

Table 1 depicts the proximate composition of control (CP and CHP) and experimental (BMP4.1, BMP4.3, BMP4.5) *paneer* samples. The values of moisture and FDM indicated that all the *paneer* samples conformed to the FSSA requirements i.e. moisture was less than 60.0 %, while FDM was above the minimum value of 50.0 %. When considering P1 homogenization pressure, *paneer* sample BMP4.3 had significantly (P<0.05) higher moisture content when compared to rest of the four *paneer* samples. However, the moisture content of CP and CHP was at par with each other (Table 1). At constant homogenization pressure P2, there was a significant (P<0.05) increase in the moisture content of *paneer*, with increasing fat content of the blended milk (homogenized with unhomogenized; 4:6 w/w) used. Considering pressure P2, *paneer* sample BMP4.5 had the highest moisture content; such moisture content was significantly (P<0.05) greater than the moisture of rest of the four *paneer* samples. Nevertheless, the moisture content of *paneer* samples CP, BMP4.1 and CHP was at par with each other (Table 1, pressure P2 was considered). When comparing two homogenization pressures, only *paneer* BMP4.1 tended to show significantly (P<0.05) lower moisture content when employing higher pressure (i.e. P2) (Table 1). Since BMP4.1 had the least FDM content, such *paneer* tended to have lower moisture content when employing higher homogenization pressure. The fat in dairy product serves as the point of weakness in the coagulum, leading to increased moisture content in the product matrix. Hence, even though increased homogenization pressure tends to increase the moisture content of product, the lower fat content (i.e. BMP4.1) restricted the moisture content in such product [22].

The maximum FDM content was associated with *paneer* CHP (pressure P1) which shared such high value with product BMP4.5; such values of FDM was significantly (P<0.05) greater than the values associated with rest of the three products (i.e. CP, BMP4.1, BMP4.3) (Table 1). The least FDM content (i.e. 50.41 %) was associated with control *paneer* CP. Considering pressure P2, *paneer* samples BMP4.1 and CP were associated with lower values of FDM; such values was significantly (P<0.05) lower than the FDM values associated with *paneer* samples BMP4.3, BMP4.5 and CHP. Maximum FDM content was associated with *paneer* BMP4.5 (considering P2 pressure); such value was at par with the FDM values associated with *paneer* samples BMP4.3 and CHP (Table 1).

Table 1: Effect of milk fat content and homogenization condition on the proximate composition of *paneer*

Parameters	Pressure	CP	BMP4.1	BMP4.3	BMP4.5	CHP	S.Em.	CD (0.05)	CV %
Moisture (%)	P1	51.49±0.45^{a}	53.42±0.12^{bA}	54.79±0.56^{cA}	52.93±1.32^{bA}	50.98±0.40^{aA}	0.35	1.05	1.32
	P2		52.11±0.97^{abB}	53.35±1.29^{bcA}	55.04±2.29^{cA}	50.75±1.48^{aA}	0.72	2.16	2.73
Fat (%)	P1	24.45±0.19^{a}	23.90±0.26^{b}	23.22±0.23^{aA}	24.38±0.41^{c}	25.65±0.38^{d}	0.15	0.45	1.23
	P2		23.99±0.61^{a}	24.12±0.36^{aB}	23.86±0.74^{a}	25.87±0.74^{b}	0.29	0.86	2.33
FDM	P1	50.41±0.25^{a}	51.31±0.57^{b}	51.36±0.23^{b}	51.81±0.59^{bc}	52.32±0.45^{c}	0.22	0.67	0.87
	P2		50.64±0.59^{ab}	51.69±1.10^{bc}	53.07±1.08^{cd}	52.32±0.73^{cd}	0.41	1.23	1.58
Protein (%)	P1	19.81±0.14^{a}	18.96±0.11^{bc}	18.18±0.25^{d}	18.78±0.65^{c}	19.32±0.28^{ab}	0.17	0.52	1.82
	P2		18.73±1.04^{ab}	18.45±0.64^{bc}	17.59±1.01^{c}	19.22±0.68^{ab}	0.39	1.17	4.15
Lactose (%)	P1	2.36±0.16^{a}	2.24±0.05^{a}	2.34±0.09^{a}	2.37±0.17^{aA}	2.33±0.03^{a}	0.13	NS	11.74
	P2		2.30±0.07^{b}	2.26±0.06^{b}	2.00±0.04^{cB}	2.26±0.05^{b}	0.04	0.13	3.99
Ash (%)	P1	1.96±0.09^{a}	1.71±0.03^{bA}	1.53±0.06^{cA}	1.61±0.02^{cA}	1.72±0.05^{bA}	0.029	0.089	3.49
	P2		1.87±0.05^{abB}	1.82±0.04^{bB}	1.50±0.02^{cB}	1.89±0.07^{abB}	0.03	0.09	3.40
pH	P1	5.94±0.04^{a}	6.00±0.02^{b}	6.03±0.04^{b}	5.99±0.02^{b}	5.98±0.01^{b}	0.014	0.044	0.48
	P2		5.95±0.03^{a}	6.00±0.04^{a}	5.98±0.06^{a}	5.95±0.05^{a}	0.023	NS	0.78

Figures placed after ± indicates standard deviation; Duncun value in small case indicate significant difference (P<0.05) viewed horizontally, Duncan value in capital letter indicate significant difference (P<0.05) viewed vertically

The higher values of FDM content noted in *paneer* samples CHP and BMP4.5 could be attributed to the use of milk having the highest fat content (i.e. 4.5 % vs. 4.1 or 4.3 %). The homogenization treatment is beneficial with regard to fat recovery (Table 2) in product, which led to improved FDM content of the resultant *paneer*; more so upon homogenization at higher pressure. Even though control *paneer* (CP) was also made from 4.5 % fat milk, it had the least FDM; such effect could be ascribed to the least recovery of milk fat in the product (Table 2), indicative of higher fat losses during *paneer* making. Surprisingly, higher homogenization pressure (i.e. P2) led to product having FDM content similar to the ones subjected to lower (i.e. P1) homogenization pressure (Table 1); irrespective of the fat content of milk used.

From the above discussion, it is clearly evident that full-fat *paneer* can be successfully prepared from standardized 4.1 % fat milk (with cost benefits) complying with the FSSA requirements, provided such homogenized milk is blended with unhomogenized milk at the proportion suggested in the experiment.

The homogenization of milk (up to 300.0 MPa pressure) was implicated in improving the emulsifying property of casein which led to improved fat recovery and thus higher fat content in Queso fresco cheese [23].

The protein content of *paneer* varied from 17.59 (BMP4.5 at P2 pressure) to 19.81 % (CP unhomogenized). The protein content of *paneer* samples CP and CHP were significantly (P<0.05) greater than the protein content of rest of the three *paneer* samples (vis., BMP4.1, BMP4.3, BMP4.5 – considering P1 pressure); the former two *paneer* had similar protein content (Table 1). When considering P2 pressure, the protein content of three *paneer* samples (viz. CP, CHP and BMP4.1) were at par with each other; such protein content was significantly (P<0.05) greater than the protein content of *paneer* samples BMP 4.3 and BMP4.5 (Table 1). The lower protein content associated with *paneer* samples BMP4.3 and BMP4.5 could be ascribed to the higher moisture content (Table 1) and reduced protein recovery (Table 2) in such products as compared to such aspects for *paneer* CP.

When considering pressure P1, the treatments failed to influence the lactose content of the resultant *paneer*. However, considering pressure P2, the lactose content of all homogenized *paneer* samples was significantly (P<0.05) lower than CP; BMP4.5 had the least lactose content. However, amongst homogenized milk *paneer*, samples BMP4.1, BMP4.3 and CHP had lactose content that was at par with each other (Table 1). Concurrently, the lactose content of *paneer* BMP4.5 was significantly (P<0.05) lower when employing pressure P2 than at pressure P1 (Table 1). The higher moisture content associated with *paneer* obtained from blended milks (containing homogenized milk) resulted in reduced lactose content proportionally due to dilution at high moisture content.

The ash content associated with CP was the highest, which differed significantly (P<0.05) from the values associated with rest of the *paneer* samples. However, when considering pressure P2, *paneer* samples BMP4.1 and CHP had similar ash content. Likewise, when considering P1 pressure, BMP4.3 and BMP4.5 as well as samples BMP4.1 and CHP had ash content that was at par with each other (Table 1).

Such variations in the ash content of *paneer* is obvious based on the differing moisture content; the pH of the product (Table 1) also affects the ash content (i.e. the partitioning of minerals between coagulum and whey). However, irrespective of fat content, except BMP4.5, all the *paneer* samples resulted in significantly (P<0.05) higher moisture content when higher homogenization pressure applied.

The pH of Control *paneer* was the least (i.e. 5.94) which differed significantly (P<0.05) from the values associated with rest of the *panee*r samples (i.e. 5.98 to 6.03 pH); homogenization pressure considered was P1. The four homogenized milk *paneer* had pH values that was at par with each other (Table 1). Considering homogenization pressure P2, none of the *paneer* samples (homogenized or unhomogenized) differed significantly from each other (Table 1). The least pH value associated with control *paneer* (CP) could be ascribed to the lower moisture content associated with such product.

The pH of *paneer* prepared from unhomogenized cow milk is reported to be 5.74 and 5.58 when made using acetic and citric acid respectively [24]. The pH of *paneer* prepared from toned milk (unhomogenized) using citric acid was 5.73 [25].

Recovery of milk solids and the yield of *paneer*

Paneer BMP4.1 prepared from blended milk (milk homogenized at P1 pressure) tended to have significantly (P<0.05) higher (i.e. 98.73 %) fat recovery as compared to rest of the *paneer* samples (viz., CP, BMP4.3, BMP4.5, CHP). The least fat recovery (i.e. 91.58 %) was associated with control *paneer* CP. When considering P2 pressure, *paneer* samples BMP4.1 and BMP4.3 had significantly (P<0.05) higher fat recovery as compared to *paneer* samples CP, BMP4.5 and even CHP; the former two *paneer* samples had similar fat recovery values (Table 2). Use of higher homogenization pressure (i.e. P2) led to significantly (P<0.05) lower fat recovery values (i.e. in range 94.1 to 97.7 %) as compared to those employing pressure P1 (i.e. 93.99 to 98.73 %); such effect held true only for *paneer* samples BMP4.1 and BMP4.5 (Table 2).

Recovery of fat tends to be greater in *paneer*, when the initial fat content of milk was kept lower. Such was the case with *paneer* BMP4.1 which was prepared from milk standardized to 4.1 % milk fat. Hence, such sample had the maximum fat recovery. Control *paneer* (CP) making involves losses of milk solids including milk fat during coagulation and subsequent processing including pressing. When employing higher homogenization pressure (P2), the number of fat globules formed are numerous as compared to the treatment at lower pressure (P1); this reduces the amount of protein (casein) available that can adsorb onto the newly formed fat globules during homogenization, leading to moderate losses of milk fat during *paneer* making [26].

Table 2: Effect of milk fat content and homogenization pressure on the yield and recovery of milk constituents in *paneer*

Parameters	Pressure	CP	BMP4.1	BMP4.3	BMP4.5	CHP	SEm	CD (0.05)	CV %
Yield (Kg paneer/100 kg milk)	P1	16.56±0.06^{ab}	16.84±0.09^{c}	17.82±0.18^{eA}	17.35±0.25^{d}	16.51±0.04^{a}	0.07	0.23	0.88
	P2		16.89±0.29^{b}	17.25±0.18^{cB}	17.96±0.45^{d}	16.38±0.43^{a}	0.16	0.48	1.89
Fat recovery (%)	P1	91.58±0.25^{a}	98.73±0.10^{eA}	95.83±0.31^{d}	93.99±0.54^{bA}	94.79±0.32^{c}	0.17	0.51	0.35
	P2		97.71±0.52^{cB}	96.75±1.35^{c}	95.20±0.69^{bB}	94.10±0.69^{b}	0.39	1.19	0.83
Protein recovery (%)	P1	94.39±0.79^{a}	92.18±1.57^{bA}	93.43±0.91^{abA}	93.93±1.39^{aA}	92.01±0.57^{bA}	0.56	1.68	1.19
	P2		90.23±2.27^{bB}	90.87±1.35^{bB}	90.80±1.62^{bB}	90.17±0.95^{bB}	0.75	2.26	1.64
TS recovery (%)	P1	60.01±1.07^{a}	61.00±0.37^{a}	61.46±0.39^{a}	60.83±1.28^{a}	60.26±0.32^{a}	0.39	NS	1.32
	P2		61.33±2.57^{a}	61.50±0.86^{a}	60.16±1.29^{a}	60.25±1.62^{a}	0.80	NS	2.64

Figures placed after ± indicates standard deviation; Duncan value in small case indicate significant difference (P<0.05) viewed horizontally; Duncan value in capital letter indicate significant difference (P<0.05) viewed vertically

When considering homogenization pressure P1, the protein recovery values of CP and BMP4.5 was significantly (P<0.05) greater than the values associated with rest of the *paneer* samples (i.e. BMP4.1, BMP4.3, CHP); the former two *paneer* had similar protein recovery values (Table 2). When considering pressure P2, the protein recovery of CP (i.e. 94.39 %) was significantly (P<0.05) greater than the pertinent values associated with rest of the four *paneer* samples; the later four *paneer* samples had protein recovery values that was at par with each other (Table 2). When applying two different homogenization pressures, use of lower pressure (P1) was advantageous with regard to protein recovery for all the homogenized milk *paneer* (i.e. BMP4.1, BMP4.3, BMP4.5, CHP) (Table 2).

Since the coagulum formed from homogenized milk is softer than the counterpart made from unhomogenized milk, the chances of losses of fine coagulum particles tends to be higher in case of former treatment, adversely impacting the protein recovery. Homogenization of cream at higher pressure (i.e. 9.0 plus 2.5 MPa) had some adverse effect on the protein recovery of Iranian white cheese as compared to use of lower (6.0 + 2.5 MPa) pressure [27].

The treatment (fat content of milk, homogenization) used failed to exert any marked influence on the TS recovery of *paneer*. However, looking at the data closely, it is observed that *paneer* samples BMP4.1 and BMP4.3 had slightly higher TS recovery (i.e. 61.00-61.50 %) as compared to TS recovery associated with *paneer* CP as well as BMP4.5 and CHP (Table 2).

Bhattacharya *et al.* (1971) [28] reported that the TS recovery of *paneer* was enhanced (i.e. ranged from 47.08 to 60.81 %), as the fat content of milk used for product making was raised from 0.1 to 6.0 %. When considering homogenization pressure P1, *paneer* samples CP and CHP had similar yield values. Such yield values of former two *paneer* was significantly (P<0.05) lower when compared with rest of the three products (viz., BMP4.1, BMP4.3 and BMP4.5); the latter three blended milk *paneer* also had yield values that was significantly (P<0.05) different from each other (Table 2). Taking P2 pressure into cognizance, the yield of three *paneer* samples viz., CP, BMP4.1 and CHP were at par with each other. *Paneer* samples BMP4.3 and BMP4.5 had significantly (P<0.05) greater yield as compared to the former two *panee*r samples (Table 2). Homogenization pressure P1 (lower) tended to give significantly (P<0.05) higher yield as compared to pressure P2, taking into consideration *paneer* BMP4.3 only (Table 2).

The increase in the yield of *paneer* prepared from blended milks can be attributed to the marked improvement in the fat recovery (Table 2) as well as the higher moisture content

(Table 1) in such products. Yield advantage in White cheese when adopting lower homogenization pressure (i.e. 7.5 MPa vs. 15.0 MPa) has been reported by Ocak *et al.* (2014) [29].
Homogenization of milk is reported to improve the yield of directly acidified soft cheeses such as Queso Blanco [11] and Mozzarella [30]. The adjusted yield (on basis of dry matter content) of White cheeses prepared from unhomogenized, and from those homogenized milk at pressures of 7.5 MPa and 15.0 MPa was 16.36, 18.47 and 18.19 % respectively [29]. Homogenization (up to 300.0 and 30.0 MPa pressure, 2 stage homogenization) of heat treated milk led to an increase in 11.0-18.0 per cent increase in moisture and increase in 7.0 % yield of total curd solids in rennet coagulated soft cheese. During coagulation of milk, the fat globules got entrapped within the protein complex, recovering such constituent in homogenized product [31].

Textural properties of paneer

The texture of *paneer* plays an important role in subsequent operations (cutting, slicing, packaging, especially modified atmosphere packaging, etc.) for its end use application; for instance selling of diced *paneer*. Homogenization process is reported to have an adverse influence on the texture of coagulum, owing to increased moisture content and weaker coagulum structure [32].

Table 3: Effect of milk fat content and homogenization condition on the textural properties of *paneer*

Parameters	Pressure	CP	BMP4.1	BMP4.3	BMP4.5	CHP	SEm	CD (0.05)	CV %
Hardness (N)	P1	15.46 ± 0.28^{b}	14.36 ± 0.95^{ab}	13.88 ± 0.92^{aA}	13.17 ± 0.95^{aA}	17.40 ± 0.89^{cA}	0.42	1.27	5.65
	P2		13.95 ± 0.73^{c}	11.08 ± 0.72^{dB}	9.02 ± 0.69^{aB}	14.37 ± 0.66^{cB}	0.32	0.97	5.04
Cohesiveness	P1	0.386 ± 0.006^{d}	0.334 ± 0.01^{bA}	0.305 ± 0.01^{a}	0.355 ± 0.006^{cA}	0.332 ± 0.015^{b}	0.005	0.015	3.00
	P2		0.316 ± 0.01^{bB}	0.305 ± 0.01^{ab}	0.289 ± 0.016^{aB}	0.313 ± 0.008^{b}	0.006	0.017	3.51
Springiness (mm)	P1	5.65 ± 0.097^{a}	5.56 ± 0.017^{ab}	5.49 ± 0.077^{bc}	5.42 ± 0.091^{c}	5.62 ± 0.118^{ab}	0.043	0.131	1.57
	P2		5.64 ± 0.097^{a}	5.46 ± 0.094^{bc}	5.36 ± 0.109^{c}	5.58 ± 0.102^{ab}	0.049	0.151	1.80
Gumminess (N)	P1	623.13 ± 25.81^{d}	480.48 ± 41.80^{b}	423.78 ± 41.27^{aA}	467.53 ± 39.77^{abA}	577.31 ± 22.17^{dA}	17.59	53.04	6.84
	P2		441.92 ± 35.56^{c}	337.79 ± 26.99^{bB}	260.39 ± 15.45^{aB}	450.33 ± 27.18^{cB}	13.48	40.65	6.38
Chewiness (N-mm)	P1	35.02 ± 1.37^{d}	26.73 ± 2.33^{b}	23.28 ± 2.52^{aA}	25.35 ± 2.36^{abA}	32.46 ± 1.13^{dA}	1.01	3.05	7.09
	P2		24.90 ± 1.73^{c}	18.44 ± 1.56^{bB}	13.96 ± 0.94^{aB}	25.16 ± 1.83^{cB}	0.76	2.29	6.47
Adhesiveness (N-mm)	P1	1.66 ± 0.07^{a}	1.33 ± 0.08^{bB}	1.58 ± 0.06^{aB}	1.66 ± 0.07^{aB}	1.63 ± 0.09^{a}	0.04	0.12	5.12
	P2		1.75 ± 0.07^{aA}	1.80 ± 0.11^{aA}	1.81 ± 0.07^{aA}	1.67 ± 0.08^{a}	0.04	NS	4.92

Figures placed after ± indicates standard deviation; Duncun value in small case indicate significant difference ($P<0.05$) viewed horizontally; Duncan value in capital letters indicate significant difference ($P<0.05$) viewed vertically

The highest value of hardness (i.e. 17.40 N) was associated with *paneer* CHP (using P1 pressure); such value differed significantly ($P<0.05$) from the remaining four *paneer* samples including control *paneer* CP. When considering pressure P1, the hardness value of blended milk *paneer* samples (BMP4.1, BMP4.3 and BMP4.5) were at par with each other. In other hand, all the *paneer* samples had hardness values that was significantly ($P<0.05$) different from each other (considering pressure P2). The values of hardness in decreasing order were for samples CP > CHP > BMP4.1 > BMP4.3 > BMP4.5 (Table 3).
Paneer with higher fat content was softer than lower fat *paneer* [7]. Barring for *paneer* BMP4.1, an increase in homogenization pressure from P1 to P2 led to products having significantly ($P\leq0.05$) lower hardness (Table 3). Usually, homogenization of milk leads to soft bodied milk product (i.e. *paneer*, soft cheese). However, surprisingly *panee*r obtained from completely homogenized milk (i.e. CHP) had the maximum hardness (P1 pressure); such value was significantly ($P<0.05$) greater than the hardness associated with *panee*r CP. The reason for the observed difference in hardness was possibly due to incorporation of $CaCl_2$ to the homogenized milk and the lower moisture content of such *paneer* (Table 1). *Paneer* prepared using milk subjected to P1 pressure were associated with significantly ($P<0.05$) higher values of hardness as compared to counterpart prepared using pressure P2 (Table 3). The softening of the texture of soft cheeses upon milk homogenization is an established fact [32]**.** The hardness values reported for buffalo milk *paneer* (unhomogenized) was 13.2 N by Kanawjia and Singh (1996) [33].
In terms of cohesiveness (considering pressure P1), *paneer* samples CHP and BMP4.1 had similar values. However, *paneer* CP had cohesiveness value (i.e. 0.386) which was significantly ($P<0.05$) higher than the values associated with rest of the *panee*r samples (i.e. consideration of both P1 and P2 pressure) (Table 3). However, the cohesiveness values of *panee*r samples BMP4.1, BMP4.3 and CHP were at par with each other in consideration of pressure P2 (Table 3). In case of *paneer* samples BMP4.1 and BMP4.5, those containing milk homogenized at P1 pressure had significantly ($P<0.05$) higher values of cohesiveness as compared to products containing milk homogenized at P2 pressure (Table 3). In general, homogenization of milk is deterrent to the cohesiveness of soft acidified milk cheeses [34].
Considering pressure P1, the springiness values of *panee*r samples CP, BMP4.1 and CHP were at par with each other. In a similar fashion, the springiness values of *panee*r BMP4.1, BMP4.3 and CHP were also similar to each other (Table 3). When considering pressure P2, *paneer* CP had springiness value that was at par with the values associated with samples BMP4.1 and CHP. Even springiness values of *panee*r samples BMP4.3 and BMP4.5 were similar; minimum value (i.e. 5.36) was associated with *paneer* BMP4.5 (Table 3). Since there was difference in the moisture content and protein recoveries (Table 1 and 2) of the *paneer* samples, the resultant protein content in product did not make much difference on the springiness values of such pertinent products. There was no significant effect of homogenization pressure (P1 vs. P2) on the springiness values of *paneer* (Table 3).
CP had the highest gumminess value (623.13 N) sharing its value with *paneer* CHP; the value of gumminess of these *panee*r was significantly ($P<0.05$) greater than rest of the *paneer* samples (i.e. BMP4.1, BMP4.3, BMP4.5 – considering pressure P1). However, *paneer* samples BMP4.3 (423.78N) and BMP4.5 (467.53N) had gumminess values that was at par with each other; both considered at pressure P1. Unlike the trend observed with pressure P1, at pressure P2, control *panee*r CP had significantly ($P<0.05$) greater gumminess value as compared to rest of the four *pan*eer

samples. However, in this case (pressure P2), *paneer* samples BMP4.1 (441.92N) and CHP (450.33N) had gumminess values that was at par with each other (Table 3). The gumminess values associated with *paneer* samples BMP4.3, BMP4.5 and CHP (subjected to P1 pressure) were significantly (P<0.05) higher than the counterpart products prepared using pressure P2 (Table 3). Such trend was similar to the trend observed for hardness of product; gumminess being a derivative of hardness.

The chewiness of *paneer* samples exhibited the same trend that was noticed for gumminess of the product; even considering each homogenization pressure. The chewiness of control *paneer* CP was highest (i.e. 35.02 N-mm) which was markedly (P<0.05) greater than the values associated with any of the other four *panee*r samples. Further, at P1 pressure, chewiness value of CP and CHP was similar; at P2 pressure, the relevant values of BMP4.1 and CHP was at par with each other (Table 3). The chewiness of *paneer* samples (i.e. BMP4.3, BMP4.5 and CHP) treated with pressure P1 also were significantly (P<0.05) higher than those treated using pressure P2; as was the case with gumminess. The values of chewiness reported for unhomogenized milk *paneer* were 72.0 Nmm by Kanawjia and Singh (1996) [33] was also noted.

Since, gumminess and chewiness are the derivatives of primary textural attributes (i.e. hardness, springiness, cohesiveness), the trend shown by hardness is usually reflected for the gumminess and chewiness values of such product too.

Paneer having least adhesiveness is desirable. The adhesiveness of *paneer* samples CP, BMP4.3, BMP4.5 and CHP were found to be at par with each other; however, control *paneer* CP had significantly (P<0.05) greater (i.e. 1.66 N-mm) adhesiveness as compared to *paneer* BMP4.1 (i.e. 1.33 N-mm), considering pressure P1. Considering pressure P2, none of the *paneer* samples could be differentiated from each other with regard to their adhesiveness (Table 3). *Paneer* from blended milks, treated at lower pressure (P1) were associated with significantly (P<0.05) lower adhesiveness values as compared to the counterpart made employing higher pressure (P2). The adhesiveness of *paneer* CHP was unaffected by the homogenization pressure used (Table 3). Such effect was possibly due to higher FDM content associated with product prepared from milk subjected to higher homogenization pressure (i.e. P2 vs. P1) (Table 1). In general, we can observe that *panee*r sample containing higher fat content were associated with somewhat greater adhesiveness value. The relation between fat content and adhesiveness of product has been established [35, 36].

Dongare *et al*. (2019) [37] reported hardness, cohesiveness, springiness and chewiness of *paneer* to be 4.56 Kg, 0.480, 1.11 m and 6.52 Kg-m respectively. Shashikumar and Puranik (2011) [38] reported hardness, cohesiveness, springiness and chewiness of cow milk *paneer* to be 17.42 Kg, 0.645, 0.767 m and 8.62 Kg-m respectively.

Sensory scores of *paneer*

Sensory evaluation of *paneer* is an important aspect for acceptance of the product by the consumers. *Paneer* should ideally be white in colour. The flavour arising from acidic and heated milk taste, along with pleasant and nutty note is the ideal characteristic of *paneer*. The body and texture of *paneer* should be compact, smooth, spongy and close-knit; it should be firm enough to hold its shape during cutting/slicing/dicing operations [39]. *Paneer* was judged and scored using BIS score card [21].

It is clearly evident from the tabulated values (Table 4) that control *paneer* (CP) had superior score for each and every sensory attribute studied. This reveals that homogenization of milk or incorporating homogenized milk in the milk blend led to some impairment in the sensory score of the resultant *paneer*.

There was no marked influence of the treatment (fat content of milk, homogenization) on the colour and appearance score of *paneer* samples. Somewhat improved appearance was especially noted with *paneer* BMP4.5 when using P2 pressure (Table 4).

Considering the flavour scores, control product CP had significantly (P<0.05) higher score (i.e. 44.38 out of 50.00) as compared to rest of the *paneer* samples (i.e. BMP4.1, BMP4.3, BMP4.5 and CHP – considering P1 pressure only); the latter four *paneer* samples had flavour scores that was at par with each other. A marked improvement in the flavour score of product made from homogenized milk or milk blend containing such treated milk was noted, when higher pressure (i.e. P2) was used. Such an improvement in flavour when employing pressure P2 led to all the *paneer* products containing such treated (homogenized) milk or prepared from homogenized milk having flavour scores that was at par with the score assigned to control *paneer* CP. Even comparing amongst the products prepared from blended milk or from homogenized milk, the scores of *paneer* samples were similar (Table 4).

Table 4: Effect of milk fat content and homogenization condition on the sensory score of *paneer*

Parameters	Pressure	CP	BMP4.1	BMP4.3	BMP4.5	CHP	SEm	CD (0.05)	%CV
Flavour (50)	P1	44.38±0.78^{a}	42.63±0.85^{b}	42.00±0.57^{b}	43.00±0.91^{b}	43.00±0.73^{b}	0.39	1.18	1.81
	P2		43.50±0.94^{a}	43.00±0.91^{a}	43.38±0.85^{a}	43.50±0.79^{a}	0.43	NS	1.97
Body and texture (35)	P1	31.75±0.96^{a}	30.50±0.91^{ab}	30.75±0.86^{abA}	29.31±1.08^{bA}	31.50±0.91^{a}	0.48	1.43	3.09
	P2		29.00±0.91^{b}	28.56±0.85^{bB}	27.69±0.85^{bB}	31.06±0.77^{a}	0.44	1.31	2.94
Colour and appearance (10)	P1	9.06±0.63^{a}	8.94±0.43^{aA}	8.88±0.32^{a}	8.75±0.35^{a}	9.13±0.59^{a}	0.24	NS	5.37
	P2		8.31±0.24^{aB}	8.38±0.43^{a}	9.06±0.42^{a}	9.00±0.45^{a}	0.23	NS	5.17
Total score (100)*	P1	90.19±0.65^{a}	87.06±0.77^{bcA}	86.62±1.61^{c}	86.06±0.83^{c}	88.62±1.75^{ab}	0.61	1.83	1.39
	P2		85.81±0.43^{bB}	84.94±1.25^{b}	85.12±1.45^{b}	88.56±1.49^{a}	0.57	1.72	1.31

Figures placed after ± indicates standard deviation; Duncun value in small case indicate significant difference (P<0.05) viewed horizontally; Duncan value in capital letters indicate significant difference (P<0.05) viewed vertically. * Total score of 100 includes score of 5.0 for packaged given to all *paneer* samples.

According to BIS (2003) [21], *paneer* scoring ≥ 84.0 % (i.e. ≥ 42.0 out of 50.0) is considered to be of 'Good' quality; all the *paneer* samples (control and experimental) were in this category only. It is interesting to note that lower-fat (i.e. 23.90 % fat of BMP4.1) *paneer* had flavour score as good as the ones noted with full-fat (i.e. 25.65 % fat of CHP) *paneer*

(Table 4), indicating that homogenization treatment helped in improving the flavour, especially of low-fat products. Possibly, the superior fat recovery noted with low-fat *paneer* (i.e. BMP4.1) must have retained the richness and mouth feel contributed by fat, evident in such product.

Similar to the present finding, Vishweshwaraiah and Anantakrishnan [40] reported improved sensory score of *paneer* prepared from homogenized milk as compared to unhomogenized milk counterpart. Chawla *et al.* [12] did not notice any improvement in the flavour of *paneer* prepared from homogenized low-fat milk.

Paneer samples CP and CHP had body and texture (BT) score that was at par with each other. However, *paneer* CP had significantly ($P<0.05$) superior BT score (i.e. 31.75 out of 35.00) as compared to those prepared from blended milks (i.e. BMP4.1, BMP4.3 and BMP4.5; considering pressure P1) (Table 4). The latter three *paneer* samples had similar BT scores. When employing higher homogenization pressure (P2), the same trend of reduced BT scores amongst homogenized milk *panee*r samples was noted as was the case when employing pressure P1 (Table 4). The increase in the moisture content of *paneer* prepared from blended milks, plus the impact of homogenization on the coagulum, obviously led to reduced firmness of the product, affecting their BT scores.

Since literature pertaining to *paneer* made from homogenized milk is lacking, such relevant parameter pertaining to soft cheese has been included for discussion. El-Gawad and Abd [41] also noted inferior BT score (i.e. 22.0 out of 35.0) in Mozzarella cheese obtained from homogenized (2.45 MPa, 60ºC) milk as compared to such score (i.e. 24.0 out of 35.0) prepared from unhomogenized milk (3.0 % milk fat as starting material in both cases).

Since control *paneer* (CP) was associated with the maximum scores for each sensory attribute, it obviously had the maximum (i.e.90.19 out of 100.0) total sensory score. However, such appreciable score of CP was shared by *paneer* sample CHP, irrespective of the homogenization pressure (P1 or P2) used (Table 4). Considering pressure P1, *paneer* sample BMP4.1 had significantly ($P<0.05$) higher total sensory score as compared to BMP4.3 and BMP4.5. Considering pressure P2, all the *paneer* made from blended milks (i.e. BMP4.1, BMP4.3, and BMP4.5) had total sensory scores that was at par with each other (Table 4).

All the experimental *paneer* samples scored 'Good' grade as per BIS grading system, while control *paneer* CP scored 'Excellent' grade (BIS, 2003) [21]. BMP4.1 scored significantly ($P\leq0.05$) higher total score (i.e. 87.06 out of 100.0) when homogenization pressure was lower (i.e P1); the score for *paneer* prepared from P2 homogenized milk was 85.81 (out of 100.0). Among the *paneer* prepared from blended milks, BMP4.1 containing milk homogenized at P1 pressure had the highest total sensory score (i.e. 87.06 out of 100.0). Hence, P1 pressure is beneficial in obtaining product with desired characteristics as compared to pressure P1.

In absence of literature on *paneer*, pertinent literature on Mozzarella cheese has been used. Mozzarella cheese prepared from unhomogenized and homogenized (25.0 kg/cm^2 pressure, 60ºC) milk (both having 3.0% fat) had total sensory score of 71.0 and 73.0 (out of 100.0) respectively; homogenized milk cheese had slight upper hand [41].

Conclusion

Manufacture of *paneer* from blended milk containing homogenized milk (4:6, unhomogenized: homogenized, w/w) was beneficial with regard to recovery of milk constituents in product, especially fat and to some extent TS recovery, leading to enhanced cheese yield. Use of BMP4.1 (milk homogenized at P1 pressure [4.90 and 0.98 MPa] to be used in blend) enabled obtaining *paneer* to have FDM content complying with the FSSA requirements, with attendant higher recovery of fat and TS and yield, with cost benefit. Use of milk with lower fat (4.1 vs. 4.5 %) costs lower; 85.0 % of total cost is contributed by raw material – milk itself. Preparing *paneer* from exclusively homogenized milk is not recommended since there is no yield advantage.

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