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Utilisation of concentrated whey in the production of multigrain bread: optimisation of solid levels in concentrated whey and temperatures of baking

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Abstract

An attempt was made to utilise paneer whey, a major by-product of the dairy industry, as a diluent in the production of multigrain bread. The paneer whey, having a TS content of about 6%, was concentrated to three levels: 15, 20 and 25% TS, and was used to fully replace water in the dough formulation containing wheat flour supplemented with 5% each of sorghum, oats, flaxseed and maize flour; 3% yeast, 2% salt, 10% sugar and 15% oil (all on flour basis). The dough samples made by incorporating the different levels of whey were baked at three different temperatures: 160, 185 and 210°C, and the effect of the incorporation of whey as well as the baking temperatures on the sensory and textural attributes and crust colour of the bread was studied in a single experimental model. Based on the overall acceptability scores it was observed that the use of 15%TS whey as diluent resulted in multigrain bread with the highest acceptability. The rheological studies indicated increasing trends in hardness and SRT and decreasing trends in cohesiveness and springiness with increasing TS whey. The crust colour, measured by reflectance values, indicated an increase in darkness with increasing TS whey and baking temperature. The mean overall acceptability scores indicated that 185°C was the best baking temperature. The hardness of the bread increased with increasing baking temperature, and the springiness was maximum at 185°C. Therefore, it was henceforth recommended to use concentrated whey having 15%TS as diluent in the dough of multigrain bread and 185°C baking temperature.

Introduction

Whey is one of the major by-products of the dairy industry all over the world. A large part of whey, however, is left unutilised and disposed off which results in significant loss of potential nutrients and also leads to serious environmental pollution due to the high BOD of whey (30,000 to 50,000 mg/L). The composition of whey varies marginally depending on the type of milk coagulation (Khamrui and Rajorhia, 1998). In India, large quantities of whey are produced during the production of *chhana* and paneer in the traditional dairy sector. This whey needs to be utilised in an appropriate manner to prevent pollution and also to prevent loss of valuable milk solids having functional properties. The techno-economic problems associated with the utilisation of whey have been receiving considerable attention, and remarkable achievements have been made in this regard (Gupta and Singh, 2007). There are reports of utilisation of whey in many products such as beverages, soups, *lassi*, roti (Kumar, 2010), *idli* and *dosa* (Papinwar, 2010). However, the utilisation of whey in products of mass consumption is still lagging behind. In this context, its use in bakery products produced by small- and medium-scale bakers can be an appropriate avenue for the utilisation of whey solids in a growing product of mass consumption.

In India, both traditional and modern bakery industry have grown considerably. The bakery industry in India is the third largest sector of food processing industry accounting for over EUR 3.2 bil (≈INR 210 bil) and is growing at a rate of 13-15% per annum (Anonymous, 2013). The bakery businesses are operating on small- and medium-scales, and these processors are constantly on the lookout for newer products, cost reduction and value addition. There is an immense potential for the utilisation of whey solids in bakery products as a means of enhanced nutritive value, functional value,

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and reduction of production cost. Bread is one of the most widely consumed processed foods all over the world. The total market size of the bread industry is approximately 4 mil tonnes in India (Anonymous, 2017). Because of changing lifestyles, a large number of consumers, especially professionals are adopting bread as regular food and are willing to pay a price for the quality. As a result, many new food chains have sprung up specialising just in bread production and offer up to 100 varieties for sale at one time (Rao, 2005). In this context, bread would provide tremendous potential for effective utilisation of whey solids for desirable enhancement of nutritional and functional values. Multigrain bread can be made out of different grains either in whole or ground form. It is nutritionally superior to normal bread because the nutrients are drawn from multiple sources rather than a single source. With an increase in urbanisation and industrialisation there is an increased demand for convenience as well as nutritious products. Even though people have become health conscious due to the changing lifestyles, they do not have the time to consume every single type of grain one at a time. The use of whey solids in appropriate manner is likely to provide low cost solids to bread manufacturers besides resulting in newer and highly nutritional products. Studies have been reported earlier on utilisation of whey in bread (Divya and Rao, 2009; Jayalakshmi, 2011). The incorporation of whey solids results in changes in bread quality like porosity (Silagadze, 1980) and flavour (Preller, 1978). However it provides value addition in terms of enhanced nutritional value (Silagadze, 1980). Process parameters, especially dough formation and baking conditions need to be optimised for whey-incorporated bread (Divya and Rao, 2009). No such study has been described on the use of whey in multigrain bread. In the present work, the effect of concentrated whey and baking temperatures on multigrain bread quality is being reported.

Materials and methods

Wheat, oat, maize, sorghum and flaxseed were procured from the local market and used for the preparation of composite flour. Baker's yeast, sugar, refined oil and salt were also procured from the local market. Paneer whey was obtained from the National Dairy Research Institute, Bangalore.

Concentration of whey

Concentration of whey was done by a pilot scale batch type APV vacuum evaporator (40 L capacity). The condenser was first cleaned using 1% sodium hydroxide at 70°C for 15-20 min followed by circulation of a 0.25% nitric acid at 55-60°C for 15 min, after which the evaporator was thoroughly rinsed with potable water. Next, 20 L paneer whey was heated to 55-60°C, and fed into the evaporator; care was taken to avoid foaming of whey in the evaporator and its escape along with the condensate. The whey was condensed at 55°C under vacuum for approximately 30 min. Steam under 10 lb pressure was passed through the calandria to heat the whey and maintain a temperature of 55°C. A product of approximately 25% total solids was obtained, which was roughly estimated by refractometer. The condensed whey was drawn into a clean container and TS % (total solids) was adjusted to desired level by addition of distilled water. The final TS content of the concentrated whey was accurately assessed by gravimetric method. The TS of whey was adjusted to 15, 20 and 25%TS by addition of calculated amount of water.

Preparation of bread

For the preparation of bread, 7.5 g baker's yeast was dissolved in 50 g lukewarm water for control and in 15%, 20% and 25% TS containing whey for experimental samples, with about 2 g sugar, and allowed to set for 10 min. Next, 23 g sugar was mixed to the water containing the yeast. Then, 200 g wheat flour was sieved and supplemented with 12.5 g each of maize, flaxseed, oat and sorghum flour. Then, 2 g salt was added to the multigrain flour mixture and thoroughly mixed before adding the water containing yeast and sugar. A good mixing of salt was ensured to avoid the deactivation of yeast during fermentation. Next, 37.5 g refined oil was used for kneading the dough into a smooth texture. The ingredients were taken in a Hobart mixer and kneaded for 4-5 min into smooth dough during which the remaining amount of warm water (15, 20 and 25% TS concentrated whey in case of experimental samples) was slowly added to the dough. The dough was divided in equal portions of 400 g. The divided dough was rounded to realign gluten fibrils and to facilitate CO2 retention and to give it a smooth surface. The rounded doughs were kept for intermediate proofing for 10-15 min for better machinability. The dough was then moulded by the operations of sheeting, curling, and seaming to redistribute gas cells and give it a final crumb structure. The moulded doughs were then placed in rectangular tin moulds (3 in × 7 in). The moulds were maintained at 28-30°C, covered with a cloth until the dough rose to full height and then baked at three different temperatures (160, 185, 210°C).

Optimisation of whey concentration to replace water as diluent, and selection of best baking temperature

The effect of the incorporation of concentrated whey and also the temperatures of baking on the physico-chemical and sensory characteristics of multigrain bread was studied, and the optimisation of whey concentration and baking temperatures was done based on the sensory scores, supported by instrumental values of texture profile analysis (TPA), stress relaxation time (SRT) and reflectance values.

Sensory evaluation of bread

The evaluation of the quality characteristics of baked bread was carried out following cooling to room temperature. Sensory evaluation was performed by five panellists who were graduate students and staff members of the Dairy Technology Section, National Dairy Research Institute, Bangalore. Breads were randomly assigned to each panellist. The panellists were asked to evaluate each bread formulation for colour and appearance (appearance and crust colour), body and texture (crumb texture and crumb grain), flavour (taste and odour) and overall acceptability. A 9-point Hedonic scale was used wherein 9 was 'extremely like' and 1 was 'extremely dislike'. The sensory evaluation sessions were carried out under well illuminated environment (BIS, 2012).

Texture profile analysis

The texture profile analysis (TPA) of the bread samples was carried out using a texture analyser (TA-XT plus, Stable Micro Systems, England) under the following test conditions:

> Mode: Measure Force in Compression; Pre-Test Speed: 1.0 mm/sec; Test Speed: 0.5 mm/sec; Post-Test Speed: 10.0 mm/sec; Target mode: Distance; Distance: 5 mm; Time: 5 sec; Trigger Type: Auto – 5 g
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> Procedure: The probe (P/75, circular disc of 75 mm diameter) was calibrated to a distance of 50 mm from the surface of platform. The sample of bread tempered to about 25°C was cut into pieces of 40 mm × 40 mm × 10 mm. The sample was positioned centrally over the platform and the computer was allowed to execute the program by activating 'run a test' option, then the sample was compressed by the plunger twice in a gap of 5 sec to yield a force – time curve. The height of the force peak on the first compression cycle (first bite) is the value of hardness (F). The ratio of the positive force under the second and first compressions is cohesiveness, while the ratio of the time difference between the ascending parts of two peaks is springiness.

Stress relaxation test

The stress relaxation test of the bread samples was determined using a texture analyser (TA-XT plus, Stable Micro Systems, England) under the following test conditions:

> Mode: Measure Force in Compression; Pre-Test Speed: 1.0 mm/sec; Test Speed: 0.5 mm/sec; Post-Test Speed: 10.0 mm/sec; Target mode: Distance; Distance: 8 mm; Hold time: 180 sec; Trigger Type: Auto – 5 g; Accessory: P/ 75 plunger probe.
>
> Procedure: The probe was calibrated to a distance of 50 mm, above the top of the container or the sample surface. The bread sample was cut into pieces of 40 mm × 40 mm × 10 mm. The sample was positioned centrally over the platform and the computer was allowed to execute the program by activating 'run a test' option, then the sample was compressed by the plunger to about 80% of its original height and the compression held for a period of 180 sec to yield a force – time curve. The maximum value obtained on the force time curve (F) was multiplied with a factor 0.367 to obtain the F/e, the corresponding value of which on the time axis yielded the stress relaxation time of the bread.

Measurement of crust colour

Reflectance meter (ELICO Brand, Hyderabad, India) which measures surface glossiness of bread crust as well as crumb in terms of percent reflectance was used to measure the extent of lightness or darkness of colour during baking. The reading on the reflectance scale was adjusted to zero using completely opaque plate (black) under colour mode. Thereafter, percent reflectance values were adjusted to the specified values using standard colour plates under 450 nm filter plate. The sample was placed under the lamp of the reflectance meter and the percent reflectance as shown by the pointer was recorded.

Statistical analysis

The scores obtained from the sensory evaluation as well as the instrumental values were subjected to two-way ANOVA (F-test) followed by Tukey's Honest Significant Difference (HSD) parametric test (at $\alpha = 0.05$), using the SPSS 2007 package in order to determine the overall significance for the major effects ($n = 12$), experimental errors and panellists ($n = 5$) (Neto *et al*., 2007). Standard deviations of data of treatment effects were also computed to know the extent of variations in the data.

Results and discussion

Effect of incorporation of whey and temperature of baking on sensory attributes of multigrain bread

The effect of whey incorporation and baking temperatures was studied simultaneously because of probable interaction effect between them. Due to the contents of proteins and lactose, whey was expected to influence the baking time of the bread. It was observed that the sensory and textural quality of multigrain bread was affected by replacing water in the bread formulation with concentrated whey, depending upon the total solids content in the whey. As TS level in concentrated whey was increased, the appearance of bread improved because of creamy colour of the product, as indicated by the mean colour and appearance (C&A) scores of the bread baked at 160 and 185°C. However, this was not the case at 210°C. It was observed that the mean C&A scores gradually increased from 7.32 ± 0.28 for control to 7.58 ± 0.33 and 7.74 ± 0.3 when 15% TS whey and 20% TS whey was used, respectively. However, the score was observed to decrease to 7.67 ± 0.42 when 25% TS whey was used. Since whey contains lactose, Maillard reaction might have imparted the creamy colour to the bread. The use of high baking temperature might have resulted in more reactions thereby adversely affecting the C&A. With regard to textural quality, there was not much advantage from the incorporation of whey. At 160°C, there was a slight improvement in B&T of bread with 15% TS whey, but otherwise B&T remained the same. Similar trend was also obtained at other baking temperatures of 185 and 210°C (Table 1). The whey-incorporated bread was found to be slightly more brittle than normal multigrain bread. Although the addition of whey proteins is not expected to result in brittleness because of their good water binding ability, lactose addition might have contributed to such textural attribute. Similar observation was made by Divya and Rao (2009) in wheat bread. The whey incorporation in the present work was observed to impart slight sweet taste to the bread. The concentrated whey possessed slight sweet taste because of 5.05% lactose and was slightly salty. Because of these taste characteristics of concentrated whey, bread flavour was also affected. Statistically however, 15% TS whey incorporation did not affect the flavour of bread, but thereafter the flavour score decreased. For example, at 185°C the flavour score of control sample was 7.61 and those of 15% and 20% TS whey were 7.64 and 7.47, respectively, which were statistically similar ($p > 0.05$). However, the flavour score significantly decreased to 7.28 by the incorporation of 25% TS whey which could be attributed to sweeter and salty tastes. Overall, it was noticed that the use of 15% TS whey had little effect on bread quality. Therefore this could be utilised for dough preparation without any adverse effect on multigrain bread quality. The mean overall acceptance scores of 20% and 25% TS whey breads were 6.88 and 6.78, which were significantly lower than those of control (7.37) and 15% TS whey bread (7.47). The use of concentrated whey of more than 15% TS adversely affected the bread quality, though still within the acceptable limits. Higher level of incorporation of whey solids contributed to slightly sour taste. A similar observation was reported earlier by Poonam (2007) during the preparation of buns and soup sticks, which indicated that the whey solids could be incorporated only up to a certain level, and in the present work above 15% TS whey contributed to negative acceptability with decreased sensory scores (Table 1).

With regard to baking temperature, it was noticed that 160-185°C temperature resulted in maximum C&A scores and 185°C yielded the maximum C&A score on 15%TS whey incorporated bread. As baking temperature increased, more chemical reactions occurred, including charring reactions, which affected the appearance of bread (Zanoni *et al*., 1995). Baking temperature has influence on the BT attribute by effecting the moisture evaporation and starch-water interactions (Therdthai *et al*., 2002). It can be noticed from BT scores (Table 1) that 185°C resulted in maximum BT scores because the bread possessed optimum firmness and chewiness. At high temperature, the bread was firm from the outside and soggy from the inside. Similarly, flavour score was maximum at 185°C due to the production of optimum flavour compounds. In bread, the flavour was reported to be due to compounds which are volatile in nature (Cauvain, 2012). For the same reason, the overall acceptability of bread prepared at 185°C was statistically higher than the other tested temperatures (Table 1).

Effects of whey incorporation and baking temperatures on instrumentally measured textural attributes

TPA characteristics

The mean hardness value of bread samples gradually increased with increasing levels of whey solids. The mean hardness values among all treatments significantly differed except for between control and 15% TS whey. This could be attributed to the slightly high TS content in the bread samples. Further, this could also be attributed to increased water binding properties especially due to whey

Table 1. The effect of incorporation of concentrated paneer whey and baking temperatures on colour and appearance scores of multigrain bread

Baking Temperature (°C)	Control	15% TS whey	20% TS whey	25% TS whey	Mean scores due to baking temperature
(i) Colour and appearance					
160	$7.20^{aA} \pm 0.33$	$7.38^{bA} \pm 0.37$	$7.87^{cB} \pm 0.29$	$7.93^{cB} \pm 0.34$	$7.60^{B} \pm 0.31$
185	$7.27^{aB} \pm 0.23$	$7.82^{bC} \pm 0.19$	$7.83^{bB} \pm 0.21$	$7.84^{bB} \pm 0.24$	$7.69^{C} \pm 0.24$
210	$7.50^{bB} \pm 0.14$	$7.55^{bB} \pm 0.22$	$7.51^{bA} \pm 0.23$	$7.23^{aA} \pm 0.25$	$7.48^{A} \pm 0.13$
Mean scores due to Whey TS	$7.32^{a} \pm 0.28$	$7.58^{b} \pm 0.33$	$7.74^{c} \pm 0.30$	$7.67^{bc} \pm 0.42$	
(ii) Body and Texture					
160	$7.45^{cB} \pm 0.42$	$7.70^{bB} \pm 0.32$	$6.90^{aB} \pm 0.30$	$6.85^{aB} \pm 0.37$	$7.22^{B} \pm 0.36$
185	$7.70^{bC} \pm 0.20$	$7.71^{bB} \pm 0.19$	$7.13^{aC} \pm 0.27$	$6.94^{aB} \pm 0.27$	$7.37^{C} \pm 0.34$
210	$6.93^{bA} \pm 0.39$	$6.84^{bA} \pm 0.31$	$6.30^{aA} \pm 0.35$	$6.23^{aA} \pm 0.42$	$6.57^{A} \pm 0.31$
Mean scores due to Whey TS	$7.36^{b} \pm 0.48$	$7.41^{b} \pm 0.50$	$6.77^{a} \pm 0.47$	$6.67^{a} \pm 0.48$	
(iii) Flavour					
160	$7.44^{bA} \pm 0.37$	$7.55^{bA} \pm 0.29$	$7.34^{abB} \pm 0.26$	$7.18^{aAB} \pm 0.28$	$7.38^{A} \pm 0.14$
185	$7.61^{bA} \pm 0.22$	$7.64^{bA} \pm 0.22$	$7.47^{bB} \pm 0.22$	$7.28^{aB} \pm 0.31$	$7.50^{B} \pm 0.14$
210	$7.53^{bA} \pm 0.17$	$7.49^{bA} \pm 0.28$	$7.15^{aA} \pm 0.45$	$7.08^{aA} \pm 0.47$	$7.31^{A} \pm 0.2$
Mean scores due to Whey TS	$7.53^{c} \pm 0.28$	$7.56^{c} \pm 0.27$	$7.32^{b} \pm 0.35$	$7.18^{a} \pm 0.38$	
(iv) Overall Acceptability					
160	$7.52^{bB} \pm 0.39$	$7.70^{bB} \pm 0.32$	$7.06^{aB} \pm 0.36$	$6.89^{aB} \pm 0.43$	$7.29^{B} \pm 0.33$
185	$7.50^{cB} \pm 0.31$	$7.77^{bB} \pm 0.26$	$7.10^{aB} \pm 0.22$	$7.03^{aB} \pm 0.29$	$7.35^{B} \pm 0.30$
210	$7.10^{bA} \pm 0.30$	$6.95^{bA} \pm 0.43$	$6.49^{aA} \pm 0.47$	$6.40^{aA} \pm 0.52$	$6.73^{A} \pm 0.30$
Mean scores due to Whey TS	$7.37^{b} \pm 0.39$	$7.47^{b} \pm 0.51$	$6.88^{a} \pm 0.46$	$6.78^{a} \pm 0.51$	

*Capital superscripts show variations due to baking temperature and smaller superscripts show variations due to variation in levels of whey solids.
**Scores on 9-point hedonic scale

protein denaturation, which generally results in better water binding properties as reported by Hutton and Campbell (1981). The water binding property of denatured whey protein was also reported by Kulkarni *et al*. (1990). Cohesiveness of the crumb decreased with the addition of whey as diluent. The results were negatively correlated indicating that as the TS content in whey increased the cohesiveness decreased, and the decrease at all levels was statistically significant. Springiness is an important characteristic of the bread which reflects the softness and also its ability to get back to its original condition when subjected to different handling conditions. The springiness values for control samples was 0.702 ± 0.074 and for the experimental samples the values were 0.667 ± 0.131, 0.568 ± 0.09 and 0.541 ± 0.084 for breads with 15, 20 and 25% TS whey, respectively. The decrease in springiness values was gradual and significant. The values were observed to be non-significant between control and 15% TS whey, and also between 20 and 25% TS whey.

The baking temperature was observed to have statistically significant effect on the hardness value with positive correlation (Table 2). The hardness of bread was observed to be 28.377 ± 9.651 N at 160°C, 31.056 ± 9.657 at 185°C and 32.255 ± 10.626 at 210°C (Table 2). The baking temperature was also observed to have significant effect on the cohesiveness (Table 2). However, the trend was observed to be non-uniform. The results indicated that cohesiveness increased with increasing baking temperature up to 185°C and then decreased at 210°C. Similar to cohesiveness, the change in springiness due to baking temperature was observed to be non-uniform. The springiness value at 160°C was 0.659 ± 0.052, which increased to 0.674 ± 0.076 at 185°C and decreased to 0.525 ± 0.084 at 210°C.The springiness values were observed to be non-significant between 160 and 185°C, but differed significantly between 185 and 210°C. The variations in springiness could be attributed to the textural characteristic variations due to the denaturation of whey proteins (Collado, 2003) and also marginal increase in the total solid contents in the final product (Divya and Rao, 2009). Bread, being foamy in structure, its firmness to a large extent depends on the number of air cells which depend on the baking characteristics of the dough (Walstra, 1999). It was also observed that as the water binding properties increased the hardness of bread also increased but at the same time resulted in

Table 2. The ANOVA analysis on the incorporation of concentrated paneer whey and baking temperatures on sensory scores of multigrain bread

Factors affecting sensory characteristics	Df	*F*-value				Significance			
		C&A	B&T	FL	OA	C&A	B&T	FL	OA
Temperature of baking	2	20.27*	155.6*	9.25*	79.4*	0.000	0.000	0.000	0.000
Whey solids level	3	33.42*	97.29*	23.58*	61.9*	0.000	0.000	0.000	0.000
Interaction (Temperature × Whey solids level)	6	22.12*	1.40	0.96	1.55	0.000	0.214	0.454	0.161
Within groups	276								
Total	287								

*Significant $p < 0.05$; C&A: colour and appearance; B&T: body and texture; FL: flavour; OA: Overall acceptance

a decrease in cohesiveness implying that the product was becoming crumbly in body and texture. This was also reflected in decreased body and texture scores at higher levels of incorporation of whey solids.

Stress relaxation time

The stress relaxation time (SRT) is an important parameter which indirectly reflects the softness of the bread or non-crumbly characteristics. Generally, bread becomes crumbly during storage and SRT values can be used as an index of freshness of the bread. The SRT values obtained in the present work were observed to increase with the replacement of water by concentrated whey as a diluent, and as the TS content of whey increased, the SRT values also increased. The SRT values were 24.169 ± 3.42 sec for control while the values were 26.933 ± 4.55. 31.451 ± 5.45 and 35.372 ± 5.91 for bread prepared with 15, 20 and 25% TS whey, respectively (Table 3). Similarly, it was also observed that SRT values increased with increasing baking temperature. The statistical analysis of the data indicated that the SRT values varied significantly both due to the TS content of whey and also due to the temperature of baking (Table 4). The values were observed to vary significantly for all the levels of treatments. Divya and Rao (2009) also reported that stress relaxation time increased with increasing baking temperature which could also be taken as an indicator for increased hardness.

Table 3. Effect of incorporation of concentrated paneer whey and baking temperature on textural values of multigrain bread

Temperature of baking (°C)	Control	15% TS whey	20% TS whey	25% TS whey	Mean scores due to baking temperature
(i) Hardness (N)					
160	$19.93^{aA} \pm 2.73$	$18.09^{aA} \pm 3.91$	$34.55^{bA} \pm 6.19$	$40.93^{cA} \pm 2.64$	$28.38^{A} \pm 9.65$
185	$22.10^{aA} \pm 2.93$	$22.02^{aB} \pm 3.99$	$35.07^{bA} \pm 3.55$	$45.03^{cB} \pm 1.81$	$31.06^{B} \pm 9.66$
210	$24.91^{aB} \pm 3.57$	$24.94^{aB} \pm 2.69$	$42.05^{bB} \pm 3.41$	$49.11^{cC} \pm 2.24$	$32.26^{C} \pm 10.6$
Mean scores due to Whey TS	$22.31^{a} \pm 3.78$	$21.69^{a} \pm 4.64$	$37.22^{b} \pm 5.82$	$45.02^{c} \pm 4.11$	
(ii) Cohesiveness					
160	$0.519^{cA} \pm 0.062$	$0.477^{bcB} \pm 0.077$	$0.442^{bB} \pm 0.029$	$0.377^{aAB} \pm 0.062$	$0.454^{B} \pm .052$
185	$0.574^{cB} \pm 0.063$	$0.533^{bcC} \pm 0.024$	$0.484^{bB} \pm 0.060$	$0.425^{aB} \pm 0.057$	$0.504^{C} \pm .056$
210	$0.475^{cA} \pm 0.045$	$0.410^{bA} \pm 0.049$	$0.361^{abA} \pm 0.040$	$0.335^{aA} \pm 0.090$	$0.395^{A} \pm .053$
Mean scores due to Whey TS	$0.523^{d} \pm 0.071$	$0.473^{c} \pm 0.076$	$0.429^{b} \pm 0.069$	$0.379^{a} \pm .0660$	
(iii) Springiness					
160	$0.701^{bB} \pm 0.020$	$0.718^{bB} \pm 0.067$	$0.63^{abB} \pm 0.031$	$0.590^{aB} \pm 0.009$	$0.659^{B} \pm 0.052$
185	$0.756^{bB} \pm 0.094$	$0.746^{bB} \pm 0.116$	$0.605^{aB} \pm 0.065$	$0.592^{aB} \pm 0.044$	$0.674^{B} \pm 0.076$
210	$0.649^{cC} \pm 0.031$	$0.539^{bA} \pm 0.084$	$0.471^{aA} \pm 0.061$	$0.441^{aA} \pm 0.059$	$0.525^{A} \pm 0.080$
Mean scores due to Whey TS	$0.702^{b} \pm 0.074$	$0.667^{b} \pm 0.131$	$0.568^{a} \pm 0.090$	$0.541^{a} \pm 0.084$	
(iv) Stress Relaxation Time (sec)					
160	$20.68^{aA} \pm 0.57$	$22.32^{aA} \pm 0.61$	$25.47^{bA} \pm 1.12$	$29.06^{cA} \pm 2.14$	$24.381^{A} \pm 3.20$
185	$23.83^{aB} \pm 1.89$	$27.50^{bB} \pm 4.16$	$31.96^{cB} \pm 3.95$	$36.47^{dB} \pm 4.89$	$29.941^{B} \pm 4.74$
210	$27.99^{aC} \pm 1.72$	$30.98^{bC} \pm 2.03$	$36.92^{cC} \pm 1.74$	$40.59^{dC} \pm 2.04$	$34.122^{C} \pm 4.98$
Mean scores due to Whey TS	$24.17^{a} \pm 3.42$	$26.93^{b} \pm 4.55$	$31.45^{c} \pm 5.45$	$35.37^{d} \pm 5.91$	

*Capital superscripts show variations due to baking temperatures and smaller superscripts show variations due to variation in levels of whey solids.
**Scores on 9-point hedonic scale

Table 4. The ANOVA analysis on the incorporation of concentrated paneer whey and baking temperatures on textural scores of multigrain bread

Factors affecting Textural Characteristics	Df	F-value				Significance			
		H, N	Co	Sp	SRT, sec	H, N	Co	Sp	SRT, sec
Temperature of baking	2	20.27*	155.6*	9.25*	79.4*	0.000	0.000	0.000	0.000
Whey solids level	3	33.42*	97.29*	23.58*	61.9*	0.000	0.000	0.000	0.000
Interaction (Temperature × Whey solids level)	6	22.12*	1.40	0.96	1.55	0.471	0.918	0.070	0.151
Within groups	276								
Total	287								

*Significant p < 0.05; H: hardness; N: Newton; Co: cohesiveness; SRT: stress relaxation time; sec: seconds

Effects of whey incorporation and baking temperatures on crust colour

Reflectance is an important parameter which indicates the ‘brownness’ of the crust. Lower value of reflectance indicates more brown crust. The reflectance in the present work was observed to decrease with increasing TS whey. The reflectance values were 54.43 ± 2.96% for control and 50.27 ± 2.71, 48.08 ± 4.38 and 47.00 ± 4.52% for breads made with 15, 20 and 25% TS whey, respectively. Similarly, the mean reflectance value showed a negative correlation with baking temperatures indicating that higher temperature led to more brown crust colour.

The statistical analysis on the values showed that reflectance values differed significantly due to both the solid content of the concentrated whey and also the temperature used for baking (*F*-value = 486.14 and 1333.18 respectively) (Table 5). The mean values of all the treatments using whey as diluent were significantly different from each other. The temperature of baking was also shown to have significant effect on the reflectance of the bread. The reflectance values at all the three temperatures were also observed to differ significantly from each other. It is also evident that the interaction between temperature of baking and the TS of whey used as diluent (*F*-value = 18.95) had a significant effect (Table 5), indicating that the browning of the crust was a result of the synergistic effect of both the TS of whey as well as the temperature of baking.

The trend of variation of reflectance values could be used to explain the variation shown in colour and appearance scores. The mean colour and appearance scores were maximum for bread made using 20% TS whey. Reflectance values indicated that the bread crust became more brown as the TS of whey increased. This could be attributed to the presence of lactose in the whey which is available in a more concentrated level as TS of whey increases. Lactose contributes to Maillard browning thereby adding to the colour of the crust. The Maillard browning in bakery products due to enhanced solid level of the whey incorporated as diluent was earlier reported by Jarita and Kulkarni (2009) and Divya and Rao (2009). The increase in baking temperature led to more browning of crust, hence the negative trend seen in reflectance scores. The bread crust appeared to be most brown at 210°C. However, subjective analysis indicated that the bread baked at 185°C had the highest sensory scores for colour and appearance. This clearly indicates that intense brown colour of the bread crust was not preferred by the panellists. Optimum development of brown colour of the crust was observed at 185°C when using 20% TS whey as diluent.

Conclusion

Multigrain bread is a nutritional alternative to plain wheat bread. Its value could further be improved by using concentrated whey (15% TS) in dough preparation. Acceptable quality multigrain

Table 5. The ANOVA analysis on the incorporation of concentrated paneer whey and baking temperatures on the reflectance of multigrain bread

Factors affecting reflectance	Sum of squares	Df	Mean Square	*F*-value	Significance
Temperature of baking	2666.25	2	1333.175*	684.203*	0.000
Whey solids Level	1458.404	3	486.135*	249.491*	0.000
Interaction (Temperature × Whey solids level)	113.704	6	18.951*	9.726*	0.000
Within groups	327.349	168	1.949		
Total	4565.808	179			

*Significant $p < 0.05$

bread can be produced by replacing water in its dough formulation with whey having TS of 15% and baking it a temperature of about 185°C for about 30 minutes without affecting the sensory attributes. The addition of whey as diluent resulted in increased browning of the crust, which increased with increasing baking temperature, thus indicating a synergistic effect of TS of whey used as diluent with temperature of baking. The textural properties of bread made with 15% TS whey also did not differ significantly from that of the control multigrain bread.

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References

Anonymous. 2017. Bread industry in India, p. 4. Retrieved from website: https://vdocuments.site/bread-industry-in-india.html.

Anonymous. 2013. In revenue, bakery third among processed foods. Retrieved from website: http://www.fnbnews.com/article/detnews.asp?articleid=34630&sectionid=11.

BIS. 2012. IS:6273, Guide for sensory evaluation of foods, Part-II, methods and evaluation cards. New Delhi, India: Bureau of Indian Standards.

Cauvain, S. P. 2012. Bread making: improving quality, 2nd edition. United Kingdom: Woodhead Publishing Ltd.

Collado, M. 2003. Encyclopedia of Food Sciences and Nutrition. Benjamin, C. (ed), Bread making processes, p. 627–634, London: Elsevier.

Divya, N. and Rao, K. J. 2009. Studies on utilization of Indian cottage cheese whey in wheat bread manufacture. Journal of Food Processing and Preservation 34(6): 975–992.

Gupta, V. K. and Singh, S. 2007. Utilization of Whey. New Delhi: Monograph published by the Indian Dairy Association.

Hutton, C. W. and Campbell, A. M. 1981. Protein functionality in foods. Cherry, J. P. (ed.) In: Water and Fat Absorption, p. 177–200, Washington, D.C.: American Chemical Society.

Jarita, M. and Kulkarni, S. 2009. Incorporation of concentrated whey in the production of soup sticks. Indian Journal of Dairy Science 69(1): 14–19.

Jayalakshmi, K. 2011. Utilization of concentrated and lactose hydrolyzed whey in the preparation of bread. Karnal, India: National Dairy Research Institute, M. Tech Thesis.

Khamrui, K. and Rajorhia, G. S. 1998. Making profits from whey. Indian Dairyman 50(6):13.

Kulkarni, S., Huss, M., Kessler, H. G. and Plock, J. 1990. Einfluss Kasein/Molken protein Verhalthnisse under Trockenmasserhohung auf rheologische und sensorische Eigenschaften von Sahnejoghurt. Labensmittel Industrie and Milchwirtschaft 111: 1144.

Kumar, S. 2010. Incorporation of concentrated whey in the preparation of Chapatis. Karnal, India: National Dairy Research Institute, M. Tech Thesis.

Neto, B., Scarminio, I. S. and Bruns, R. E. 2007 Como fazer experimentos: pesquisa e desenvolvimento na ciência e na indústria 3. ed. Campinas: UNICAMP.

Papinwar, K. N. 2010. Utilization of concentrated whey in the preparation of *Idli* and *Dosa*. Karnal, India: National Dairy Research Institute, M. Tech Thesis.

Poonam, M. 2007. Incorporation of concentrated whey in the production of bun and pizza. Karnal, India: National Dairy Research Institute, M. Tech. Thesis.

Preller, W. 1978. Verwertung des Sekunddarrohstoffs Molke in der USSR. Milchforschung-Milchpraxis 20: 8–11.

Rao, R. 2005. Dough on the rise. Modern Food Processing 1(1): 30.

Silagadze, M.A. 1980. Khleb. Kondit, Promyshl. 7: 27–30.

Therdthai, N., Zhou, W., Adamczak, T. 2002. Optimization of the temperature profile in bread baking. Journal of Food Engineering 55(1): 41–48.

Walstra, P. 1999. Casein sub-micelles: do they exist? International Dairy Journal 9(3): 189–192.

Zanoni, B., Peri, C. and Bruno, D. 1995. Modeling of browning kinetics of bread crust during baking. Lebensmittel-Wissenschaf tund Technologie 28(6): 604–609.