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Quality of Paneer Made from High Solid Reconstituted Milk as Influenced by Calcium Phosphate Incorporation

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Abstract: A study was conducted to evaluate the quality characteristics of paneer, a directly acidified non-rennet fresh variety of cheese, made from reconstituted milk of higher total solid content so as to produce larger quantities of paneer per batch of milk taken for economical production of paneer. The paneer made from reconstituted milk of higher total solids content is known to produce quality wise inferior paneer. In an attempt to improve the quality of paneer from high solid reconstituted milk calcium phosphate was incorporated at different levels with a view to aid coagulation and improves the texture, cohesiveness and overall acceptability. It was found that the incorporation of different levels of calcium phosphate viz., 1, 1.5 and 2% to the reconstituted milk prior to acidification brought about significant improvement in the yield, total solids recovery, fat recovery, protein recovery and in sensory parameters like appearance, body and texture and overall acceptability scores at all levels of incorporation compared to control. Within the three calcium phosphate levels, 1.5% showed numerical superiority over the other two levels. In order to improve the quality characteristics of paneer from reconstituted milk it is suggested that calcium phosphate at the rate of 1.5% may be added prior to its manufacture.

Key words: Paneer, white cheese, reconstituted milk, whole milk powder, calcium phosphate, incorporation, susperiority

INTRODUCTION

Paneer represents a South Asian variety of soft cheese obtained by acid and heat coagulation of milk. It is non-fermentative, non rennet, non-melting and unripened type of cheese similar to the white cheese found throughout South and Central America, Mexico and Caribbean islands (Chandan, 2007). The unique feature of paneer is that it not only includes casein but most of the whey proteins also get recovered during its manufacture unlike other types of cheese wherein whey proteins are mostly lost in the whey. The recovery of whey proteins occur due to the use of high temperature along with direct acidification which results in co-precipitation of casein and whey proteins (Hill *et al*., 1982; Dalgleish, 1990). It is primarily used for the preparation of a number of highly nutritious culinary preparations, snacks and serves as a base for various South Asian sweetmeats like rasogolla, rasamalai, sandesh etc. which are extremely popular within and to a fair extent outside Asia (Shrivastava and Goyal, 2007). Due to the variation in milk production in different seasons, the milk in high production season is converted to milk powder to be used during the lean periods. It, at times becomes unavoidable to use milk powder during lean periods for the manufacture of cheese or paneer. The present study was undertaken to manufacture paneer of acceptable quality from high solid reconstituted milk as the use of high solid reconstituted milk has advantages that it helps in reducing the water, energy, time and labour for the production of paneer and larger quantity of paneer can be made per batch of milk taken.

However, preliminary trials and previous studies conducted by Singh and Kanawjia (1992), Zahar *et al*. (1997), Spadoti and Oliveira (1999), Solorza and Bell (2007) showed that paneer or cheese produced from high solid reconstituted milk resulted in quality wise compromisable product. In order to improve the quality characteristics of paneer made from high solid reconstituted milk calcium phosphate was added at various levels to reconstituted milk which is known to improve the quality characteristics of cheese as it improves bonding between casein micelles by creating additional reaction sites by virtue of cross linkages by divalent calcium ions thus resulting in cheese or paneer with compact, firm and cohesive body and

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smooth and closely knit texture (Dalgleish and Parker, 1980; Lucey and Fox, 1993; Pastorino *et al*., 2003; Abdel-Kader, 2003; Solorza and Bell, 2007).

MATERIALS AND METHODS

Locally manufactured, low heat spray dried Whole Milk Powder (WMP) was utilized for pursuing this study. About 5 Kg of WMP (fat 26%, protein 25%, lactose 37%, minerals 7%) was reconstituted with 10 L of warm water (-50°C) to obtain reconstituted milk with a solids to water ratio of 1:2. The reconstituted milk thus obtained was allowed to stand undisturbed for half an hour for complete hydration of milk powder and finally converted into paneer.

Preparation of paneer: The reconstituted milk was heated up to 90°C without holding, cooled to 70°C and coagulated using 2% citric acid as coagulating agent at 70°C with continuous but gentle stirring. During heating process different amount of calcium phosphate (viz., 1, 1.5 or 2% w/v of reconstituted milk) was added. The coagulum thus obtained was left undisturbed for approximately 5 min and the temperature of the contents was not allowed to drop below 60°C at this stage. Whey was drained by filtering contents through a fine muslin cloth.

The coagulum was then filled in wooden hoops with holes on the all sides and bottom to facilitate quick and efficient expulsion of whey. The hoops were lined with strong and clean muslin cloth from inside and the whole mass was then pressed in hoops by applying pressure of 230 kg m^{-2} on the lid of the hoop for approximately 15 min. The pressed block of curd was weighed to obtain green paneer yield, cut into pieces of suitable size (7.5×7.5×7.5 cm^3) and immersed in chilled water (4°C) for 1 h. The paneer was then taken out of water and drained well, wiped clean and weighed again to obtain final paneer yield and per cent moisture absorption.

Analysis

Physico-chemical analysis: The reconstituted milk and whey was analyzed for various physico-chemical characteristics such as Moisture by Gravimetric method, total proteins by micro-kjeldahl method, ash by incineration method, fat by ether extraction and titratable acidity as per AOAC (2003), pH by combined electrode digital pH meter and SNF by difference. Paneer was evaluated for moisture, fat, protein and ash as per AOAC (2003) guidelines for cheese. The pH of paneer was determined by the method of O'Keeffe *et al.* (1976). Fat on dry matter basis, total solids recovery and yield was calculated. Moisture absorption was estimated on the basis of the difference between green weight and weight of paneer after immersion in chilled water.

Sensory analysis: A panel of 10-15 semi-trained judges evaluated different sensory parameters of the paneer by 9-point Hedonic scale (Peryam and Pilgrim, 1957). The evaluation was carried out on the same day of sample preparation.

Statistical analysis: The data generated was analyzed by one way ANOVA using SPSS® software package and means were compared by using Duncans multiple range test (Snedecor and Cochran, 1980).

RESULTS AND DISCUSSION

Physicochemical characteristics of paneer: The physico-chemical characteristics of the paneer evaluated in present study is shown in Table 1. The moisture content of control and all other samples fortified with varying levels of calcium phosphate did not differ (α = 0.05) from one another however, all the calcium phosphate fortified samples had numerically higher values than the control. The increase in the moisture retention in the paneer with the addition of calcium compound as additive has also been reported by Singh and Kanawjia

Table 1: Effect of different levels of calcium phosphate addition on physico-chemical quality of reconstituted milk paneer

	Calcium phosphate levels			
Parameters	Control (0%)	1%	1.5%	2%
Moisture (%)	56.63±0.78	57.15±0.52	57.25±0.67	56.92±0.52
Fat (%)	19.80±0.31	19.42±0.16	19.41±0.25	19.39±0.23
Protein (%)	17.89±0.09^{a}	18.45±0.06^{b}	18.47±0.07^{b}	18.43±0.11^{b}
Ash (%)	2.38±0.04^{a}	3.10±0.02^{b}	3.39±0.02^{c}	3.80±0.03^{d}
TS recovery (%)	54.91±0.23^{a}	57.38±0.25^{b}	57.49±0.14^{b}	56.56±0.10^{b}
Fat recovery (%)	90.77±0.46^{a}	94.35±0.53^{b}	94.43±0.84^{b}	93.70±0.41^{b}
Protein recovery (%)	84.83±0.20^{a}	92.60±0.80^{b}	92.72±0.43^{b}	91.23±0.42^{b}
FDM (%)	45.66±0.48	45.33±0.18	45.40±0.13	45.02±0.10
Yield (kg/100 kg WMP)	119.50±1.73^{a}	127.67±1.67^{b}	127.83±2.42^{b}	126.00±2.18^{b}
Moisture absorption (% Green weight.)	4.82±0.19	5.37±0.07	5.36±0.27	5.14±0.07
pH	5.85±0.03^{a}	5.97±0.05^{b}	5.94±0.04^{b}	5.93±0.02^{b}
Coagulant amount (L/100 kg WMP)	55.83±0.83^{a}	50.83±0.83^{b}	50.67±2.33^{b}	51.67±3.00^{b}

Row-wise group means with different superscripts differ significantly (α = 0.05); Mean±SE; N = 6; FDM: Fat on Dry Matter basis

(1988). The relatively higher moisture content in calcium phosphate fortified samples can be attributed to comparatively higher protein content in these samples, since proteins are hydrophilic in nature so increase in its percentage resulted in concomitant increase in the water content in paneer. Similar results were also reported by Pal and Yadav (1991), Prince *et al.* (2007) and Kumar *et al.* (2008). They observed an increasing trend of moisture retention with the increase in the protein content of paneer. The fat content of all the samples including the control samples were comparable with one another. It was observed that the calcium phosphate addition had a significant effect ($\alpha = 0.05$) on the protein content of the paneer in that the protein content of all the calcium phosphate fortified samples had significantly higher ($\alpha = 0.05$) values than the control samples while within they were noticed to be comparable. The increase in protein content with the addition of calcium compound as additive is also reported by Sachdeva *et al.* (1991) and Wolfschoon-Pombo (1997). The increase in protein content could be due to the adherence of Ca^{2+} ions on the α_{s1}-casein particles which results in reduction of negative electric charge and creates additional reaction sites through which aggregation may take place between casein micelles by virtue of cross linkages by divalent calcium ions thus leads to more protein retention in the coagulum (Dalgleish and Parker, 1980; Sachdeva *et al.*, 1991; Lucey and Fox, 1993; Joshi *et al.*, 2004) and also due to increased recovery of whey protein by the addition of calcium phosphate as it also induces the precipitation of whey protein thus they are recovered along with casein (Dybing and Smith, 1998; Guo *et al.*, 2003). The ash content of paneer increased significantly ($\alpha = 0.05$) in the progressive fashion with the increase in the amount of calcium phosphate addition. The reason for this consistent increase is undoubtedly due to an increase in the inorganic salt content of the paneer as a consequence of the addition of a proportionately increasing calcium phosphate levels. The TS recovery of all the test samples fortified with calcium phosphate had significantly higher ($\alpha = 0.05$) values than the control samples while the calcium phosphate fortified samples did not differ significantly from one another. These results corroborate the findings of (Sachdeva *et al.*, 1991; Arora *et al.*, 1996; Wolfschoon-Pombo, 1997) who noted comparatively higher transfer of milk solids into the curd by the addition of $CaCl_2$. This is probably because calcium ions helps in binding various component fractions of casein micelles to form a compact network, thus reducing the loss of TS of paneer in the form of fines into the whey and the phosphate promotes protein protein interaction and helps in precipitation of whey proteins, thus reduces their loss in whey (Pastorino *et al.*, 2003). The fat recovery was also significantly affected ($\alpha = 0.05$) by the calcium phosphate addition. It was found that the additive increased the per cent fat recovery significantly compared to the control samples (no additive). All the samples with varying levels of calcium phosphate were comparable to one another. A similar result was also noted by Wolfschoon-Pombo (1997) in cheese who found an increase in recovery of fat by addition of $CaCl_2$. This may be due to the effective entrapment of fat in the compact network between casein micelles formed by addition of calcium phosphate which prevents loss of free fat into the whey. The protein recovery followed the same trend as that of TS recovery. The addition of calcium phosphate caused significantly higher ($\alpha = 0.05$) protein recovery compared to control samples however, all the three samples with added calcium phosphate were comparable with one another. Among these three samples, 1 and 1.5% calcium phosphate added samples exhibited slightly higher value than 2% calcium phosphate added sample. The higher recovery in calcium phosphate added samples could be discussed on the same lines as for TS recoveries above in that the Ca^{2+} ions not only helped reduce negative charge on the casein micelle but also created additional reaction sites for cross linkages leading to integration of protein micelles in firm and compact coagulum with reduced loss of proteins in the form of fines into the whey (Dalgleish and Parker, 1980; Sachdeva *et al.*, 1991; Famelart *et al.*, 2009) and also due to enhanced recovery of whey protein by the addition of phosphate (Dybing and Smith, 1998; Guo *et al.*, 2003). However, lower recovery in 2% calcium phosphate added samples could be due to higher amount of Ca^{2+} ions adherence on casein particles which instead of creating bonds between different casein particles resulted in higher amount of positive charge on casein particles which caused repulsion among the casein particles thus affecting their aggregation to form compact paneer. The addition of varying levels of calcium phosphate did not elicit any significant variation ($\alpha = 0.05$) in Fat in Dry Matter (FDM) values irrespective of the treatments. All the samples including the control were comparable with one another with an overall mean value of 45.35±0.16. The findings were in the range of the reported values in literature (Pal *et al.*, 1991; Singh and Kanawjia, 1992; Chandan, 2007) for low fat paneer.

The yield of paneer made using different calcium phosphate fortification levels was comparable with one another but they had significantly higher ($\alpha = 0.05$) values than the control. The increase in the yield with the addition of $CaCl_2$ (source of calcium ions) has also been reported by (Wolfschoon-Pombo, 1997; Kanawjia and Rizvi, 2003). The increase in the yield of paneer was probably due to a significantly higher retention of milk fat and SNF into the curd and also to some extent by higher moisture retention in these samples and also higher recovery of whey proteins by phosphate (Dybing and Smith, 1998; Guo *et al*., 2003).

The moisture absorption was almost similar (α = 0.05) in all the samples under test with no significant difference. The values in the study fall within the range of the reported values (Sachdeva and Singh, 1988; Pal *et al.*, 1999). The pH of the control samples had significantly lower (α = 0.05) value compared to all other samples fortified with calcium phosphate. The latter in turn were comparable with one another. The lower pH in control samples could be attributed to higher amount of coagulant used in case of control samples compared to all calcium phosphate added samples. The requirement of coagulant for control samples was significantly higher (α = 0.05) than the rest of the samples. This is because calcium phosphate helps in the coagulation of the milk thus it decreases the requirement of coagulant (Dybing and Smith, 1998).

Sensory quality of paneer: The scores obtained from the sensory evaluation of the paneer samples prepared during this study are shown in Table 2. The appearance scores of paneer made from calcium phosphate added milk were significantly (α = 0.05) higher compared to control samples. However, all the calcium phosphate treated samples had comparable values. The improvement in the sensory score of paneer by the addition of calcium compound as additive has also been reported by Sachdeva *et al.* (1991) and Kanawjia and Rizvi (2003). The lower appearance score in control was attributed to dull surface and withered appearance compared to the treated samples which exhibited a glistening white marble like sheen upon evaluation. The sensory score for flavour in paneer was not significantly affected (α = 0.05) by the addition of calcium phosphate. All the treatments including the control were comparable. However, control samples had relatively lower scores and were criticized for being slightly acidic in flavour. This might have developed due to use of comparatively higher amount of coagulant in it. Among all the sensory characteristics the body and texture was appreciably affected than all other sensory parameters. The body and texture scores for all calcium phosphate groups were significantly higher (α = 0.05) than the control. The higher body and textural scores by the addition of calcium compound ($CaCl_2$) have also been reported in the literature (Sachdeva *et al.*, 1991; Kanawjia and Rizvi, 2003). The higher score was due to a better matting pattern within casein particles in paneer which resulted in compact, firm and cohesive body and smooth and closely knit texture whereas control samples were criticized for being hard, crumbly, dry and showed improper matting. However, within the calcium phosphate fortified samples, 1 and 1.5% added samples were comparable and they had significantly higher value than 2% calcium phosphate added samples. The lower scores in higher levels of calcium phosphate (i.e., 2% added sample was due to slightly hard body and granular texture as higher amount of calcium phosphate induced coagulation even before addition of coagulant (citric acid) which imparted some amount of granularity and slightly harder body characteristics which lowered its score, same phenomenon was also observed by Sachdeva *et al.* (1991) in cow milk paneer by the addition of 0.1% calcium chloride. The results are in agreement with the finding of Singh and Kanawjia (1988, 1991) and Sachdeva *et al.* (1991). Overall acceptability score was found to be lowest in control and it improved in all the calcium phosphate treated samples. Within the latter group, the 1 and 1.5% added samples were comparable (α = 0.05) to each other and both had significantly higher values than 2% added level. Control samples were rated like slightly while all the calcium phosphate treated samples were rated like moderately.

Whey characteristics: Perusal of the data in Table 3 shows that the TS losses in whey were comparable among calcium phosphate added samples however, they were having significantly lower (α = 0.05) values from control samples. The possible reasons for comparatively lower losses of TS in whey of calcium phosphate added samples could be a better bonding between casein micelles in the curd through fortified cross linkages with the aid of

Table 2: Sensory quality of reconstituted milk paneer as influenced by the addition of various levels of calcium phosphate

	Calcium phosphate levels			
Parameters	Control (0%)	1%	1.5%	2%
Appearance	6.82±0.20[a]	7.46±0.08[b]	7.46±0.12[b]	7.46±0.10[b]
Flavour	6.95±0.15	7.15±0.11	7.15±0.11	7.03±0.11
Body and texture	6.59±0.13[a]	7.31±0.09[b]	7.38±0.09[b]	7.08±0.12[c]
Overall acceptability	6.82±0.13[a]	7.23±0.10[b]	7.38±0.09[b]	7.10±0.10[ab]

Row-wise group means with different superscripts differ significantly (α = 0.05); 9-point Hedonic scale (9 = like extremely, 1 = dislike extremely); Mean±SE; N = 6; Assessors =13

Table 3: Effect of different levels of calcium phosphate addition on the losses in whey

	Calcium phosphate levels			
Parameters	Control (0%)	1%	1.5%	2%
Total solids (%)	23.00±0.13[a]	22.36±0.11[b]	22.13±0.15[b]	22.83±0.09[a]
Fat (%)	1.30±0.06[a]	0.82±0.07[b]	0.80±0.11[b]	0.90±0.06[b]
Protein (%)	2.07±0.03[a]	1.03±0.10[b]	1.01±0.04[b]	1.22±0.06[c]
Yield (L/100 kg WMP)	185.00±0.00	181.67±0.83	182.50±1.44	182.50±0.00
pH	5.33±0.03[a]	5.40±0.00[b]	5.40±0.00[b]	5.40±0.00[b]

Row-wise group means with different superscripts differ significantly ($\alpha = 0.05$); Mean±SE; N = 6

divalent Ca^{2+} ions thus decreasing the escape of protein particles and the entrapped fat globules into the whey. The increased recovery of whey proteins brought about by added phosphate also contributes to lower loss of solids in whey in calcium phosphate fortified samples. However, within calcium phosphate treated groups, the higher values in 2% added samples than either 1 or 1.5% could be the result of poor recoveries of milk solids in the paneer due to excessive adherence of Ca^{2+} ions on casein particleswhich instead of creating bonds between different casein particles resulted in repulsion among the casein particles thus affecting in their aggregation.

The fat losses in whey were significantly higher ($\alpha = 0.05$) in control samples compared to the calcium phosphate added samples. Within the latter group, the fat losses in whey were not affected significantly by the level of fortification. These findings agree favorably with those of Wolfschoon-Pombo (1997) who noted a decrease in loss of milk fat into the whey by the addition of $CaCl_2$. The protein losses in whey were found to be significantly ($\alpha = 0.05$) higher in control samples compared to all other samples under study.

The reduction in the loss of proteins in whey by the addition of calcium compound as additive has also been reported by Wolfschoon-Pombo (1997). The lower protein losses in calcium phosphate fortified samples can be explained on the same lines as discussed in TS losses above. The yield of whey in all the samples including the control did not show any variation at 5% level of significance. The pH of whey in control samples had significantly lower ($\alpha = 0.05$) values than all the samples fortified with calcium phosphate. The latter were comparable to one another. The lower pH value in control sample could be attributed to higher requirement of coagulant in these samples compared to the rest of the samples.

CONCLUSION

It might be concluded that the addition of 1.5% calcium phosphate to the reconstituted milk prior to acidification would help in developing paneer with more desirable characteristics in terms of TS recovery, yield as well as sensory quality. It is suggested that calcium phosphate at above mentioned level may be incorporated for production of paneer from high solid reconstituted milk.

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