Effect of different coagulants at varying strengths on the quality of paneer made from reconstituted milk

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Abstract A study was conducted to determine the effect of different types of acids viz., citric acid, tartaric acid and malic acid each at 2, 3 and 5% concentrations on the quality of paneer made using reconstituted milk. The moisture, total solid recovery and yield and sensory scores for flavour, body and texture and overall acceptability of paneer decreased with the increasing strength of acid. However, these parameters for paneer made using coagulants at 2 and 3% levels were statistically comparable ($P>0.05$). Fat and protein per cent increased with the increase in the concentration of the acid. No difference was observed in the levels of ash and fat on dry matter basis and pH and appearance scores at all the three concentrations of the coagulants. The type of coagulant also elicited variations in most of the constituents of paneer. The paneer samples made with citric acid and tartaric acid had significantly higher ($P\leq 0.05$) values for fat, protein, ash, total solids recovery, fat on dry matter basis, body and texture and overall acceptability scores than paneer made with malic acid at all concentrations. No significant difference was seen in appearance and flavour scores among all the samples. In order to produce paneer with the most desirable characteristics from reconstituted milk, it is suggested citric acid and tartaric acid at 2% concentration can be utilized as coagulants.

Keywords Paneer · Reconstituted milk · Whole milk powder · Citric acid · Tartaric acid · Malic acid

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 (Torres and Chandan 1981; Chandan 2007). The unique feature of paneer is that it not only includes casein but also most of the whey proteins which get recovered during its manufacture while they are mostly lost in whey in the case of other types of cheeses. The recovery of whey proteins occurs due to the use of high temperature along with direct acidification which results in co-precipitation of casein and whey proteins (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 Indian sweetmeats like *rasogolla*, *rasamalai*, *sandesh* etc. which are extremely popular within and to a fair extent outside Asia (Wikipedia 2010). It is estimated that about 50% of total milk produced in India is converted into various milk products like ghee, butter, paneer, chhana, khoa etc. Among these paneer is one of the major milk products produced in India, especially in the north. According to an estimate about 5% of milk produced in India is converted into paneer (Chandan 2007). Good quality paneer is characterized by a marble white color, sweetish, mildly acidic taste, nutty flavour, spongy body and closely knit smooth texture. 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 paneer. But it has been seen that the use of dried milk mostly results in inferior product than the fresh milk (Singh and Kanawjia 1991, 1992). In

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order to improve the quality characteristics of paneer from reconstituted milk, different types of coagulants at different concentrations were used for its preparation, as a number of coagulants in various strengths and proportions are reported to have been used which have profound effect on the compositional, functional, physico-chemical and sensory characteristics of paneer (Sachdeva and Singh 1987; Pal et al. 1999; Kumar et al. 2007, 2008). So, the present study was undertaken to evaluate the effect of different types of food grade coagulants viz. citric acid, tartaric acid and malic acid at varying strengths on the quality of paneer made from reconstituted milk to determine the coagulant type and strength better suited for paneer manufacture from reconstituted milk.

Materials and methods

Materials Locally manufactured, low heat spray dried whole milk powder (WMP) was utilized for pursuing this study. About 4,000 g of WMP (fat 26%, protein 25%, lactose 35%, minerals 7%) was reconstituted with 20,000 ml of warm water (~50 °C) to obtain reconstituted milk with 17% (w/v) total solids. This level was selected on the basis of preliminary trial in which different total solid levels (14.5% to 34% TS) were used for paneer manufacture. The reconstituted milk thus obtained was allowed to stand undisturbed for 1/2 h for complete hydration of milk powder.

Preparation of paneer The reconstituted milk was heated up to 90 °C without holding, cooled to 70 °C and coagulated using three different types of coagulants viz., citric acid, malic acid and tartaric acid each at three different strengths viz., 2, 3 and 5% concentration with continuous but gentle stirring till clear greenish yellow whey was separated from the coagulated mass. Acid was added till the end point reached. 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 cut into pieces of suitable size (7.5×7.5×7.5 cm) and the pieces were immersed in chilled water (4 °C) for 1 h. The paneer was then taken out of water, drained well, wiped clean and weighed to obtain final paneer yield.

Physico-chemical analysis The reconstituted milk and whey were analyzed for various physico-chemical characteristics such as moisture by gravimetric method, total proteins by micro-Kjeldahl method, ash by incineration method (AOAC 2003), fat by Gerber method (IS 1977), titratable acidity by AOAC (2003), pH by combined electrode digital pH meter and SNF by difference. Paneer was evaluated for moisture, fat, protein ash and pH as per AOAC (2003) guidelines for cheese. Fat on dry matter basis, total solids recovery and yield were calculated.

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 the sample preparation.

Statistical analysis The data generated was analyzed by two way ANOVA using SPSS® software package with all possible interactions. The analysis of variance of group mean was computed and significance of means tested by using Least Significant Difference test at 5% level of significance. The nested means were compared when the interaction was found to be significant. In the absence of such significance the overall means, wherever significant were compared (Snedecor and Cochran 1980).

Results and discussion

Physico-chemical characteristics of paneer The physico-chemical characteristics of the paneer evaluated in present study are shown in Table 1. The interaction between the type and strength of coagulants was found to be non-significant in all the parameters studied. So only overall means were compared and results interpreted. The moisture content of paneer decreased progressively with the increase in the strength of coagulant from 2 to 5% irrespective of the type of the coagulant. These results are in agreement with those of Sachdeva and Singh (1988). They have reported that the concentration of coagulant was inversely related to moisture in paneer. So the coagulant concentration can be used to increase or decrease the moisture of paneer as per the requirement or to meet legal standards. However, higher concentrations of coagulants were found to be detrimental for paneer quality. On the other hand, the moisture content exhibited significant variation ($P \leq 0.05$) with the type of coagulant as well. The moisture content was the highest in case of malic acid paneer followed by tartaric acid and least in case of citric acid paneer. The higher moisture content in malic acid paneer could be the result of milder effect of malic acid on milk protein as malic acid has higher pK_a values which resulted in release of lower amount of H⁺ ions

Table 1 Effect of different types of coagulants at various concentrations on the physico-chemical quality of reconstituted milk paneer

Conc. (%)	Coagulants			Mean
	Citric acid	Tartaric acid	Malic acid	
Moisture (%)				
2%	57.4±0.49	58.3±0.45	60.6±0.40	58.8±0.53 ¹
3%	57.1±0.23	57.9±0.43	60.4±0.47	58.4±0.54 ¹
5%	56.1±0.33	56.9±0.49	59.0±0.09	57.3±0.47 ²
Mean	56.9±0.27 ^a	57.7±0.30 ^b	60.0±0.31 ^c	
Fat (%)				
2%	19.1±0.13	18.5±0.10	17.2±0.19	18.2±0.30 ¹
3%	19.2±0.09	18.6±0.21	17.3±0.20	18.3±0.29 ¹
5%	19.4±0.11	18.8±0.10	17.8±0.17	18.7±0.24 ²
Mean	19.2±0.07 ^a	18.6±0.09 ^b	17.4±0.13 ^c	
Protein (%)				
2%	18.1±0.18	17.9±0.12	16.6±0.15	17.5±0.24 ¹
3%	18.2±0.21	18.0±0.19	16.6±0.21	17.6±0.27 ¹
5%	18.7±0.26	18.5±0.13	17.3±0.12	18.1±0.24 ²
Mean	18.3±0.14 ^a	18.1±0.12 ^a	16.8±0.14 ^b	
Ash (%)				
2%	1.9±0.04	1.9±0.02	1.8±0.05	1.9±0.03
3%	1.9±0.03	1.9±0.01	1.8±0.10	1.9±0.04
5%	2.0±0.02	2.0±0.03	1.8±0.03	1.9±0.03
Mean	1.9±0.02 ^a	1.9±0.01 ^a	1.8±0.03 ^b	
Total solids recovery (%)				
2%	58.7±0.31	58.0±0.47	56.9±0.13	57.8±0.31 ¹
3%	58.4±0.42	57.7±0.12	56.6±0.44	57.5±0.31 ¹
5%	57.1±0.39	56.6±0.54	55.6±0.36	56.4±0.31 ²
Mean	58.1±0.30 ^a	57.4±0.30 ^a	56.4±0.26 ^b	
Fat recovery (%)				
2%	95.2±0.28	94.1±0.05	92.0±0.24	93.8±0.37 ¹
3%	94.7±0.33	93.5±0.27	91.0±0.24	93.1±0.56 ¹
5%	92.2±0.78	90.6±0.27	88.9±0.19	90.6±0.43 ²
Mean	94.1±0.53 ^a	92.7±0.55 ^a	90.7±0.47 ^b	
Protein recovery (%)				
2%	93.4±0.13	93.1±0.18	90.2±0.19	92.2±0.47 ¹
3%	92.8±0.14	92.3±0.08	89.5±0.14	91.6±0.51 ¹
5%	91.1±0.18	91.0±0.39	88.0±0.34	90.0±0.52 ²
Mean	92.4±0.36 ^a	92.1±0.95 ^a	89.3±0.35 ^b	
FDM (%)				
2%	44.8±0.33	44.2±0.29	43.8±0.10	44.2±0.13
3%	44.7±0.31	44.2±0.16	43.7±0.38	44.1±0.21
5%	44.2±0.14	43.8±0.34	43.5±0.35	43.8±0.18
Mean	44.5±0.17 ^a	44.0±0.15 ^b	43.6±0.16 ^b	
Yield (kg/100 kg milk powder)				
2%	130.4±0.94	131.5±1.04	137.0±1.53	133.0±1.18 ¹
3%	128.7±1.36	129.7±1.48	135.2±1.66	131.2±1.27 ¹
5%	123.3±1.67	124.3±0.73	128.3±1.01	125.3±0.97 ²
Mean	127.5±1.26 ^a	128.5±1.21 ^a	133.5±1.50 ^b	

Row-wise group means (alphabets) and column-wise (numerals) with different superscripts differ significantly ($P \leq 0.05$); Mean $\pm$ S.E; $N=3$

per unit weight of acid and slower rate of release of H^+ ions from the acid solution which could have resulted in milder level of denaturation of milk proteins thus retaining higher hydration capabilities compared to citric acid or tartaric acid (Pal et al. 1999). The higher moisture retention by the use of tartaric acid as coagulant than citric acid was also reported by Joshi et al. (1991) in *chhana*. It was found that all the samples had moisture content that was well within the range prescribed by IS (1983) and PFA (2010). The fat content in paneer increased gradually with the increase in the concentration of coagulant. However, when fat content in paneer was compared on the basis of type of coagulant the highest fat content was noticed in citric acid paneer ($P \leq 0.05$) followed in order by tartaric acid and malic acid paneer. The decrease in the fat content was due to the decrease in fat recovery from citric acid through tartaric acid to malic acid paneer. The protein content in the paneer prepared with 5% acid had significantly higher ($P \leq 0.05$) values than either 2% or 3% coagulant paneer. The increase in the protein content could be due to the increase in the TS of the paneer which resulted in concomitant increase in the protein content of paneer. However, it was found that the protein content of paneer made using citric acid and tartaric acid were comparable and both had significantly higher ($P \leq 0.05$) values than malic acid paneer. The lower value in malic acid paneer could be explained on the basis of poor recovery of milk solids as well as higher moisture content which resulted in decrease in protein contents proportionately per unit mass of paneer. The ash content did not show any variation ($P > 0.05$) among the three concentrations of coagulants. However, citric acid and tartaric acid resulted in significantly higher ($P \leq 0.05$) ash content than malic acid paneer. Analysis of data revealed that the TS recoveries were inversely related to the concentration of coagulants, so with the increase in concentration from 2 to 5%, the TS recovery decreased, although 2 and 3% paneer samples were comparable statistically at 5% level of significance. But moisture level also decreased with increase in coagulant concentration. Results are in agreement with those reported earlier by Sachdeva and Singh (1987, 1988) who also found that TS recovery varied inversely with the concentration of the coagulant solution. The higher concentration of coagulant might result in higher degree of denaturation of paneer milk proteins thus appreciably affecting the bonding between them and consequently loss of these milk proteins in the form of fines into the whey. Thus it is suggested to use lower concentration of coagulants to maximize the recovery of milk solids in the paneer. However, when overall means for TS recovery were analyzed on the basis of coagulant types, it was revealed that TS recovery for citric acid paneer and tartaric acid paneer had significantly higher ($P \leq 0.05$) values than malic acid paneer samples. This might be due to the fact that the

malic acid resulted in paneer with protein bound in a loose network giving rise to softer and weaker curd, which was comparatively less efficient to retain paneer proteins as well as entrapped fat in it. The comparable values for TS recoveries between citric acid and tartaric acid paneer are also reported in the literature (Sachdeva and Singh 1987; Joshi et al. 1991). So, different acids can be used for obtaining paneer with different composition and quality as per the requirements of the market. The fat and protein recoveries on the basis of concentration as well as type of coagulant showed a similar trend like TS recoveries. The possible reason for this is that fat and protein are the main two components which makeup the total solids of paneer thus their recoveries showed almost similar trend as that of TS recoveries. Fat on dry matter (FDM) values did not show much variation between the samples by use of various concentrations of coagulants. However, the values were significantly higher ($P \leq 0.05$) in citric acid paneer than those for tartaric acid and malic acid paneer. The trend in the FDM values was almost proportional to that in the fat content of paneer. Yield of paneer obtained with 2 and 3% coagulants had significantly higher ($P \leq 0.05$) values than paneer made using 5% coagulant. The decrease in yield with the increase in concentration of coagulant may be partly due to decrease in moisture retention and partly due to decrease in TS recoveries as suggested by Sachdeva and Singh (1987, 1988) and Wolfschoon-Pombo (1997), whereas statistical analysis revealed that irrespective of the strength of coagulants, highest yield was found when malic acid was used as coagulant, the rest of the two were comparable. The higher yield in malic acid paneer was probably because of higher moisture content in it and not due to the higher TS recovery. A similar result was also obtained by Pal et al. (1999). However, the yield of citric acid and tartaric acid paneer was found to be comparable. Thus different acids at different strengths could be employed for the paneer preparation as per the requirements. If higher yield was goal without consideration of quality then lower concentration of malic acid could be used. In case there was demand for good quality paneer with good TS in the market then lower concentrations of citric acids could be utilized for paneer manufacture.

Sensory quality Sensory characteristics of paneer are presented in Table 2. It can be seen that the appearance scores from all the treatments were comparable ($P > 0.05$) with an overall mean of 7.65 ± 0.04 . The score for appearance is in agreement with that reported by Singh and Kanawjia (1991) for recombined milk paneer. The flavour scores decreased with the increase in the concentration of coagulants. Paneer made with 5% coagulant scored less as it was criticized for having comparatively

Table 2 Sensory quality of paneer made from reconstituted milk using different types of coagulants at various strengths

Conc. (%)	Coagulants			Mean
	Citric acid	Tartaric acid	Malic acid	
Appearance				
2%	7.7±0.09	7.8±0.11	7.6±0.12	7.7±0.06
3%	7.7±0.08	7.7±0.10	7.5±0.13	7.7±0.06
5%	7.6±0.09	7.7±0.08	7.5±0.18	7.6±0.07
Mean	7.7±0.05	7.7±0.06	7.6±0.08	
Flavour				
2%	7.6±0.09	7.5±0.12	7.7±0.17	7.6±0.07 ¹
3%	7.4±0.09	7.3±0.09	7.5±0.14	7.4±0.06 ¹
5%	7.2±0.09	7.1±0.12	7.2±0.16	7.2±0.07 ²
Mean	7.4±0.05	7.3±0.07	7.5±0.09	
Body and Texture				
2%	7.6±0.09	7.5±0.09	7.1±0.17	7.4±0.07 ¹
3%	7.4±0.09	7.3±0.09	7.0±0.15	7.3±0.07 ¹
5%	7.2±0.12	7.1±0.08	6.7±0.21	7.0±0.07 ²
Mean	7.4±0.06 ^a	7.3±0.05 ^a	6.9±0.07 ^b	
Overall Acceptability				
2%	7.6±0.09	7.5±0.10	7.3±0.13	7.5±0.06 ¹
3%	7.4±0.09	7.4±0.09	7.2±0.14	7.3±0.06 ¹
5%	7.1±0.08	7.1±0.08	6.8±0.18	7.0±0.07 ²
Mean	7.4±0.05 ^a	7.4±0.07 ^a	7.1±0.07 ^b	

Row-wise group means (alphabets) and column-wise (numerals) with different superscripts differ significantly ($P \leq 0.05$); 9-point Hedonic scale (9 = like extremely, 1 = dislike extremely); Mean $\pm$ S.E; $N=3$; Assessors = 11–13

more acidic taste. Sachdeva and Singh (1987, 1988) and Kumar et al. (2007, 2008) also observed decrease in the flavour scores with the increase in the concentration and level of acid. The acidic and lower flavour scores might be due to the use of higher amount of acids in 5% paneer as requirement of coagulant was comparatively higher at this level. At lower coagulant concentrations, coagulation was slower and more uniform due to more thorough action of coagulant throughout the milk lot, while at higher concentration coagulation was rapid and non-uniform with higher level of denaturation at various points in milk. These changes resulted in higher requirement of coagulant which subsequently resulted in more acidic taste. It was also observed that there were greater chances of inaccuracy in detecting the end point of coagulation with higher concentration of acids than the lower concentration. The flavour scores did not show any significant difference ($P > 0.05$) among citric acid, tartaric acid and malic acid paneer. However, malic acid paneer had slightly improved flavour. The body and texture score also exhibited decrease in score with the increase in concentration of coagulant. The lower score for paneer with higher coagulant concentration may

be due to higher level of denaturation of milk proteins on being exposed to higher concentration of acids thus affecting their subsequent interaction with each other and with water molecules thus resulted in comparatively harder and dryer paneer which had lower scores. A similar trend was also noted by Sachdeva and Singh (1987, 1988) and Kumar et al. (2007, 2008). The body and texture scores of malic acid paneer had significantly lower values than tartaric acid and citric acid paneer. The lower score in malic acid paneer was possibly due to higher moisture retention and comparatively soft and weak body and loose and open texture. Similar finding was also reported by Pal et al. (1999) in paneer made with malic acid. The overall acceptability of paneer decreased with increase in concentration of acid. The effect of type of coagulants on overall acceptability revealed that the citric acid and tartaric acid paneer were comparable with each other; however, both of them scored significantly higher ($P \leq 0.05$) values than malic acid paneer. The lower overall acceptability scores in malic acid paneer are in accordance with the findings of Pal et al. (1999) and were mainly due to the textural defects. Paneer samples made with citric acid and tartaric acid at 2% concentration were considered most desirable in terms of sensory quality. However, all the paneer samples were good enough to score in the range of like moderately (7) to like very much (8).

Whey characteristics Table 3 gives an understandable view of different whey characteristics studied. Perusal of the data elucidates that the TS losses in whey exhibited a direct relationship with the concentration of coagulants used and it increased significantly ($P \leq 0.05$) with the increase in the concentration of coagulants from 2 to 5%. Minimum loss of solids in whey was found when 2% coagulant was used while it was maximum when 5% coagulant was used. The increase in the losses of TS in whey with the increase in the concentration of coagulant was probably due to higher denaturation of milk solids which in turn resulted in less intimate bonding between paneer proteins at higher concentrations of coagulants resulting in higher losses into the whey. The analysis revealed that the coagulant type also had the significant ($P \leq 0.05$) effect on the TS of whey. The maximum losses were recorded in malic acid whey followed by tartaric acid whey and least in citric acid whey. The higher losses in tartaric acid and malic acid whey than citric acid whey was also reported by Sachdeva and Singh (1987) and Pal et al. (1999) respectively. The higher values in malic acid whey may be due to poor body and texture due to loose bonding between casein micelles treated with malic acid resulting in relatively higher losses of milk solids into the whey. The losses of fat in whey were found to increase significantly ($P \leq 0.05$) in value with the increase in the concentration of the coagulants. This could

Table 3 Effect of different types of coagulants in varying strengths on the physico-chemical quality of whey

Conc. (%)	Coagulants			Mean
	Citric acid	Tartaric acid	Malic acid	
Total solids (%)				
2%	8.9±0.15	9.1±0.10	9.3±0.05	9.1±0.08 ¹
3%	9.1±0.06	9.2±0.02	9.5±0.07	9.3±0.07 ²
5%	9.4±0.07	9.6±0.16	9.8±0.05	9.6±0.08 ³
Mean	9.1±0.10 ^a	9.3±0.09 ^b	9.5±0.08 ^c	
Fat (%)				
2%	0.28±0.02	0.35±0.00	0.47±0.03	0.37±0.03 ¹
3%	0.32±0.02	0.38±0.02	0.53±0.03	0.41±0.03 ²
5%	0.47±0.04	0.56±0.02	0.66±0.03	0.57±0.03 ³
Mean	0.36±0.03 ^a	0.43±0.03 ^b	0.56±0.10 ^c	
Protein (%)				
2%	0.38±0.01	0.39±0.00	0.56±0.01	0.45±0.03 ¹
3%	0.42±0.01	0.45±0.00	0.61±0.01	0.49±0.03 ²
5%	0.53±0.01	0.53±0.01	0.71±0.02	0.59±0.03 ³
Mean	0.44±0.02 ^a	0.46±0.02 ^a	0.63±0.02 ^b	
pH				
2%	5.4±0.07	5.3±0.03	5.4±0.03	5.4±0.02
3%	5.4±0.03	5.3±0.03	5.3±0.03	5.3±0.02
5%	5.4±0.09	5.3±0.03	5.3±0.03	5.3±0.03
Mean	5.4±0.03	5.3±0.02	5.4±0.02	

Row-wise group means (alphabets) and column-wise (numerals) with different superscripts differ significantly ($P \leq 0.05$); Mean ± S.E; $N=3$

be possibly because of comparatively stronger action of higher strengths of acids on the milk proteins which have consequently decreased their ability to retain fat. There were also higher values of fat losses in malic acid whey than tartaric and citric acid which may be due to comparatively soft and open texture attained in malic acid paneer which was not effective enough to retain higher amount of free fat in it compared to more compact body of paneer formed by other two acids and same seems to be true between tartaric acid and citric acid whey. The protein losses were significantly lower ($P \leq 0.05$) in whey when 2% coagulant was used compared to 3 and 5% coagulant. Malic acid whey had significantly higher ($P \leq 0.05$) value of protein losses than those of citric acid and tartaric acid whey. This is probably because malic acid resulted in the paneer with higher hydration capabilities with softer and weaker body which was not able to hold caseins particles firmly together thus there was comparatively higher loss of proteins in the form of fines into the whey. The pH values of all the treatments were comparable, although, tartaric acid whey showed noticeably lower value. It might be due to inherent capacity of tartaric acid than other acids due to its lower pK_a values.

Conclusion

It can be concluded that the use of citric acid and tartaric acid at 2% concentration can be utilized for the manufacture of paneer from reconstituted milk with good total solids recovery, yield and most desirable sensory characteristics.

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