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Research Article

Effect of different coagulants on compositional, physico-chemical and sensory properties of medium fat paneer

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Abstract

Paneer is an Indian cottage cheese made by acid and heat coagulation of milk. Various souring agents like lemon juice, vinegar, etc. are employed for coagulation of milk. Dairy plants use permitted coagulants like citric acid, lactic acid, Glucono-delta-lactone (GDL), etc. Medium-fat paneer was prepared from mixed milk (3.0% fat and 8.5% SNF) using four different coagulants, viz., citric acid (1%), lactic acid (1%), calcium lactate (4%), and glucono-delta-lactone (2%). The moisture content and yield were found to be highest in paneer made with calcium lactate. Paneer prepared using citric acid had the highest amount of fat (20.82%), followed by GDL (19.5%), lactic acid (18.6%), and calcium lactate (17.67%). The protein content of paneer samples ranged from 17.84 to 20.3%. The pH of paneer prepared with calcium lactate was highest to that prepared using other coagulants. This might be due to its mild acidification and the role of calcium ions in coagulation. The pH of whey obtained during coagulation of milk by different coagulants ranged from 4.71 to 5.34. Paneer prepared with citric acid was most acceptable with highest scores for flavour and body & texture, and it was statistically comparable to that with calcium lactate ($p<0.05$). In context to colour characteristics, the whiteness index of paneer prepared with calcium lactate was higher followed by GDL, lactic acid and citric acid. However, the yellowness index was higher in paneer made with citric acid.

Keywords: Coagulants, Colour, Composition, Paneer, Sensory

Highlights

- The effects of coagulants on composition, physico-chemical properties and sensory properties were evaluated.
- The maximum yield was found in paneer prepared using calcium lactate.
- The highest pH was observed in paneer prepared using calcium lactate.
- The paneer prepared using citric acid showed maximum acceptability.

INTRODUCTION

Milk and milk products are important suppliers of various nutrients like high-quality protein, fat, carbohydrate, minerals, various important fat soluble and water-soluble vitamins like vitamin B_{12} and due to this it is often referred as a complete food in the diet. India is the largest milk-producing country and according to the Department of Animal Husbandry and Dairying [DAHD] (2025), the country's overall milk production reached 247.87 million tons in 2024-25. India is regarded as an agrarian nation with a considerable vegetarian population and due to this milk and its products like paneer and cheese play an important role in the diet as a source of animal protein (Kumar et al., 2014). According to IMARC Group (2025), the market size of paneer in India was valued at INR 731.4 billion. It is further estimated to reach INR 2,149.6 billion by 2034, exhibiting a CAGR of 12.34% from 2026-2034.

Paneer is an Indian cottage cheese and widely used in the preparation in various curries and other traditional dishes (Praveena & Anu, 2024). Traditionally, paneer is made from various acidic agents like lemon juice, vinegar and nowadays it is prepared from various permitted coagulants like citric acid, lactic acid, glucono-delta-lactone etc. A range of coagulants (sour milk, lactic acid, ascorbic acid, alum, calcium lactate, citric acid, etc.), different thermal and non-thermal treatments, and milk sources (such as cow, buffalo and goat milk) individually or in combination, have a major impact on the quality of paneer (Alam et al., 2024). Generally, paneer is reported to contain about 20% protein, 25% fat, 1.8% ash and 2% lactose (Varalakshmi & Leysen, 2020).

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As per FSSAI, paneer has three categories: low-fat paneer (60% maximum moisture and maximum 20% milk fat on dry matter basis), medium-fat paneer (60% maximum moisture and milk fat not more than 50% and less than 20% on dry matter basis), and regular paneer (60% maximum moisture and minimum 50% milk fat on dry matter basis) (Food Safety and Standards Authority of India [FSSAI], 2020). Consumers are now vigilant towards the quality and conscious for health benefits of their food choices. Owing to the presence of easily digestible and nutritionally superior protein, demand for paneer is increasing in the sections of vegetarians (Varalakshmi & Leysen, 2020; Kapoor et al., 2021a, 2021b). In general, there is a lack of data pertaining to the composition of medium-fat paneer and the effect of coagulants on its physicochemical characteristics; therefore, the present study was undertaken with the objective to evaluate the effect of coagulants on compositional, colour and sensory characteristics of medium-fat paneer.

MATERIALS AND METHODS

For the preparation of medium-fat paneer, unhomogenized toned milk containing 3.0% fat and 8.5% SNF was procured from a dairy plant. Four different coagulants of varying strengths, viz. citric acid (1%, 177 mL/L), lactic acid (1%, 200 mL/L), calcium lactate (4%, 200 mL/L), and glucono-delta-lactone (2%, 213 mL/L) - were used for paneer preparation.

Preparation of paneer: A standard method was used for the manufacturing of paneer on a pilot scale as given by Hussain et al. (2025) with some modifications (Fig. 1). The standardized milk (3% fat and 8.5% SNF) was heated to 90°C for 10 minutes, cooled to 75°C and coagulated. The coagulum was allowed to settle down for 5 min, and the whey was drained off. The coagulated mass was transferred into pressing hoops and pressed for 15-20 min (~2.5 kg/cm^2) to remove excess moisture. The pressed paneer block was kept in chilled water at 4-6°C for 45 minutes and then packaged and stored below 5°C.

Analysis of paneer for physico-chemical characteristics: The paneer samples were prepared for analysis purpose (FSSAI 01.042:2022). The samples were analysed for moisture and fat content according to the methods prescribed for cheese by the FSSAI (2022). Fat on dry matter basis and yield were also calculated. Protein content of paneer was analysed by the Kjeldahl method (ISO, 2014). Various physico-chemical parameters for whey were also

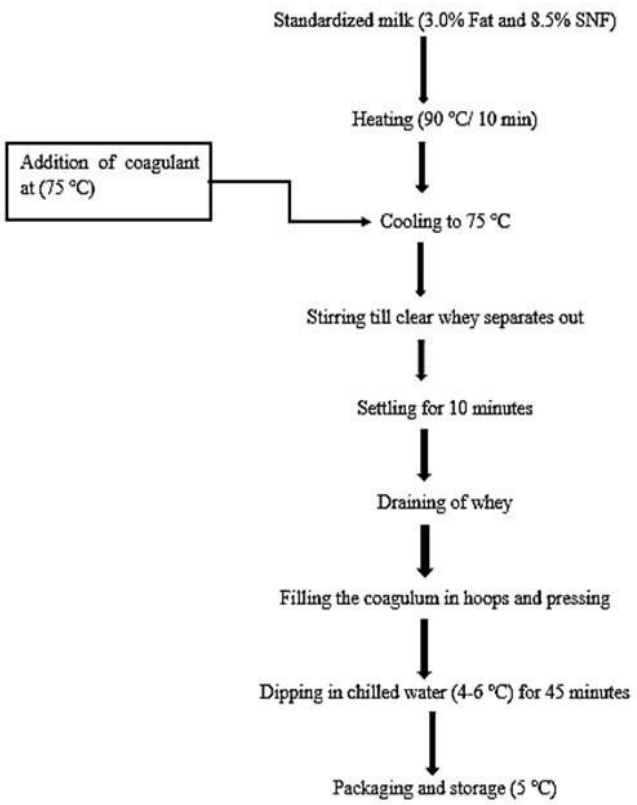


Fig. 1. Flow diagram for manufacture of medium fat paneer

analysed, such as total solids by the gravimetric method (FSSAI, 2022), lactose content (FSSAI, 2022) and pH by a digital pH meter.

Sensory analysis: The paneer was evaluated sensorially using a 100-point BIS scorecard BIS (2003) by a panel of semi-trained judges for various sensory attributes.

Colour analysis: Various colour attributes like L*, a*, b* values of paneer were measured using Konica Minolta Chromameter CR-400 (Japan). The yellowness index was determined by using the formula, while the whiteness index was calculated using the formula given by Rhim et al. (1999).

Yellowness index = (142.86xb*) / L*, and

Whiteness index = $100 - [(100 - L^*)^2 + (a^*)^2 + (b^*)^2]^{1/2}$

Statistical analysis: The data were analysed using a Completely Randomized Design (CRD).

RESULTS

The results for compositional parameters of paneer are presented in Table 1.

Table1. Compositional parameters of paneer prepared using different coagulants

Coagulants	Parameter						
	Moisture (%)	Fat (%)	Protein (%)	FDM (%)	pH	Ash (%)	Yield (%)
CA	55.82[a]	20.82	20.33[b]	45.34	5.53[a]	1.44[a]	15.37[a]
LA	59.50[bc]	18.6	19.06[ab]	46	5.75[b]	1.40[a]	17.22[b]
CL	61.91[c]	17.67	17.84[a]	46.61	6.07[c]	2.08[b]	19.48[c]
GDL	58.34[ab]	19.5	19.36[ab]	46.83	5.66[b]	1.49[a]	16.69[ab]
SEm±	0.97	0.73	0.51	1.75	0.03	0.1	0.52
CD (0.05)	2.99	NS	1.59	NS	0.09	0.32	1.6
CV %	3.29	7.64	5.39	7.58	1.09	13.18	6.05

*The values are mean of four replications. *a-c: values with different letters within a different column are significantly different at 5% (i.e., $p<0.05$). *CA: Citric acid; LA: Lactic acid; CL: Calcium Lactate; GDL: Glucono Delta Lactone

Compositional parameters of paneer prepared using different coagulants: The moisture content of paneer prepared using different coagulants, viz. citric acid, lactic acid, calcium lactate and GDL varied from 54.98-56.66, 57.25-61.75, 59.84-63.98 and 57.59-59.09% respectively with corresponding mean values of 55.82, 59.50, 61.91 and 58.34. Moisture content of paneer prepared using lactic acid and GDL did not differ significantly; however, it significantly differs from that of paneer made from citric acid and calcium lactate ($p<0.05$).

The fat content of paneer prepared using different coagulants, viz. citric acid, lactic acid, calcium lactate, and GDL were 20.19–21.45, 18.5–18.7, 17.01–18.3, and 19.25–19.75%, respectively, with a mean value of 20.82, 18.6, 17.67, and 19.5%. The fat-on-dry-matter (FDM) ranged from 41.34–49.34, 43.41–48.59, 44.84–48.39, and 46.37–47.29%, with mean values of 45.34, 46.00, 46.61, and 46.83%, respectively. Although the fat content of paneer prepared with different coagulants differed significantly, no significant difference was observed in FDM content.

The protein content of paneer made with different coagulants-citric acid, lactic acid, calcium lactate, and GDL-ranged from 19.94–20.72, 17.63–20.49, 16.98–18.7, and 18.58–20.14%, respectively, with corresponding mean values of 20.33, 19.06, 17.84, and 19.36%. While no significant difference in protein content was observed between GDL and lactic acid, both differed significantly from paneer coagulated with citric acid and calcium lactate ($p<0.05$)

The pH of paneer prepared using various coagulants, viz., citric acid, lactic acid, calcium lactate, and GDL, ranged from 5.45–5.61, 5.69–5.81, 6.03–6.11, and 5.62–5.70, respectively with mean values of 5.53, 5.75, 6.07, and 5.66, respectively. No significant difference in pH was observed between GDL and lactic acid; however, it differed significantly from paneer made using citric acid and calcium lactate ($p<0.05$).

Paneer made using various coagulants, such as citric acid, lactic acid, calcium lactate, and GDL, had an ash content in the range of 1.04-1.84, 1.18-1.62, 1.77-2.39 and 1.3-1.68, respectively, with a mean values of 1.44, 1.40, 2.08 and 1.49. Significant difference did not found in the ash content of paneer with citric acid, GDL and lactic acid. It differed significantly from paneer made using calcium lactate ($p<0.05$).

The yield of paneer made with citric acid, lactic acid, calcium lactate, and GDL ranged between 14.8-15.94, 15.86-18.75, 18.51-20.45 and 15.35-18.03, respectively, with a mean value of 15.37, 17.22, 19.48 and 16.69. Significant difference in yield of paneer was not found between citric acid and GDL, however, it differed significantly from paneer made using lactic acid and calcium lactate ($p<0.05$).

Physico-chemical parameters of whey prepared using different coagulants: The results obtained for compositional parameters of whey prepared using different coagulants are depicted in Table 2. The total solids (TS) of paneer whey prepared using different coagulants, viz. citric acid, lactic acid, calcium lactate and GDL varied from 5.89-5.99, 5.60-5.76, 5.71-5.91 and 5.61-5.81%, respectively, with a corresponding mean value of 5.94, 5.63, 5.81 and 5.71%. The lactose content observed was 4.97-5.87, 4.85-5.53, 4.56-5.14 and 4.6-5.12%, with the mean values of 5.42, 5.19, 4.85 and 4.86%, respectively (Table2).

The TS of paneer whey made with GDL and calcium lactate did not differ significantly from that of whey made with lactic acid and citric acid ($p<0.05$). The lactose content of whey prepared using lactic acid, calcium lactate and GDL did not differ significantly; however, it differed significantly from that of whey made using citric acid ($p<0.05$).

The pH of paneer whey prepared using different coagulants viz. citric acid, lactic acid, calcium lactate and GDL varied from 4.88-5.06, 5.12-5.18, 5.31-5.37

and 4.70-4.7, respectively, while the mean values of 4.97, 5.15, 5.34 and 4.71.

Table 2. Compositional parameters of whey prepared using different coagulants

Coagulants	Parameter		
	Total solid (%)	pH	Lactose content (%)
CA	5.94[c]	4.97[b]	5.42[b]
LA	5.63[a]	5.15[c]	5.19[ab]
CL	5.81[bc]	5.34[d]	4.85[a]
GDL	5.71[ab]	4.71[a]	4.86[a]
SEm±	0.04	0.03	0.14
CD (0.05)	0.14	0.09	0.45
CV %	1.63	1.26	5.83

*The values are mean of four replications. *a-d: values with different letters within a different column are significantly different at 5% (i.e., p<0.05). *CA: Citric acid; LA: Lactic acid; CL: Calcium Lactate; GDL: Glucono Delta Lactone

Effect of different coagulants on colour attributes (L*, a*, b*) of paneer: The results pertaining to the effect of different coagulants on colour attributes (L*, a*, b*) of paneer are depicted in Table 3.

The L*, a*, and b* values of paneer prepared using different coagulants—viz. citric acid, lactic acid, calcium lactate, and GDL—ranged from 74.73–75.37, –3.95 to –4.03, 8.66–8.76; 75.25–76.51, –3.96 to –4.00, 8.31–8.41; 77.64–77.72, –3.95 to –4.01, 7.30–7.54 and 75.42–76.54, –3.93 to –3.99, 8.06–8.72, respectively. The corresponding mean L*, a*, b* values were 75.05, –3.99, 8.71; 75.88, –3.98, 8.36; 77.68, –3.98, 7.42 and 75.98, –3.96, 8.39, respectively.

The yellowness index and whiteness index of paneer prepared using citric acid, lactic acid, calcium lactate, and GDL ranged from 16.68–17.02, 72.96–73.58; 15.62–15.88, 73.58–74.74; 13.43–13.85, 76.12–76.16 and 15.34–15.94, 73.81–74.71, respectively. The corresponding mean values were 16.85, 15.74, 13.64, and 15.64 for the yellowness index, and 73.27, 74.16, 76.14, and 74.26 for the whiteness index, respectively. While no significant difference in yellowness index and whiteness index was found between paneer prepared using GDL and lactic acid, both indices significantly differed from that of paneer prepared using citric acid and calcium lactate (p<0.05).

Table 3. Effect of different coagulants on colour attributes (L*, a*, b*) of paneer

Coagulants	Parameters				
	L*	a*	b*	Yellowness index	Whiteness index
CA	75.05[a]	-3.99	8.71[b]	16.85[c]	73.27[a]
LA	75.88[a]	-3.98	8.36[b]	15.74[b]	74.16[b]
CL	77.68[b]	-3.98	7.42[a]	13.64[a]	76.14[c]
GDL	75.98[a]	-3.96	8.39[b]	15.64[b]	74.26[b]
SEm±	0.3	-1.23	0.13	0.22	0.28
CD (0.05)	0.92	NS	0.4	0.7	0.88
CV %	0.79	0.02	3.17	2.95	0.77

*The values are mean of four replications. *a-c: values with different letters within a different column are significantly different at 5% (i.e., p<0.05). *CA: Citric acid; LA: Lactic acid; CL: Calcium Lactate; GDL: Glucono Delta Lactone

Table 4. Sensory attributes of paneer prepared using different coagulants

Coagulants	Parameters			
	Colour and appearance	Body and texture	Flavour	Overall acceptability
CA	7.65[a]	31.24[b]	44.21[c]	88.11[b]
LA	7.96[ab]	30.28[a]	43.37[b]	86.62[ab]
CL	8.57[b]	30.29[a]	43.43[b]	87.04[b]
GDL	8.12[ab]	29.85[a]	42.55[a]	85.52[a]
SEm±	0.2	0.3	0.24	0.48
CD (0.05)	0.62	0.93	0.74	1.5
CV %	5.06	1.98	1.11	1.12

*The values are mean of four replications. *a-c: values with different letters within a different column are significantly different at 5% (i.e., p<0.05). *CA: Citric acid; LA: Lactic acid; CL: Calcium Lactate; GDL: Glucono Delta Lactone

Sensory attributes of paneer prepared using different coagulants: The scores for sensory attributes of paneer prepared using different coagulants are depicted in Table 4.

The colour and appearance of paneer prepared using different coagulants, viz. citric acid, lactic acid, calcium lactate and GDL ranged from 7.08-8.22, 7.91-8.01, 8.39-8.75 and 7.84-8.4, respectively, with a mean value of 7.65, 7.96, 8.57 and 8.12. The colour and appearance of paneer prepared using citric acid, lactic acid and GDL did not differ significantly and lactic acid and GDL showed intermediate values; however, these scores differed from those of paneer made with calcium lactate (p<0.05).

The body and texture score of paneer prepared using different coagulants

viz. citric acid, lactic acid, calcium lactate and GDL ranged from 30.62-31.86, 30.03-30.53, 30.26-30.32 and 29.35-30.35, respectively with a mean value of 31.24, 30.28, 30.29 and 29.85. The body and texture of paneer prepared using calcium lactate, lactic acid and GDL did not differ significantly; however, it significantly differed from that of paneer made with citric acid ($p<0.05$).

The flavour score of paneer prepared using different coagulants, viz. citric acid, lactic acid, calcium lactate and GDL ranges from 43.99-44.43, 43.09-43.65, 42.63-44.23 and 42.5-42.6 respectively with a mean value of 44.21, 43.37, 43.43 and 42.55. The flavour of paneer prepared using calcium lactate and lactic acid did not differ significantly; however, it significantly differs from paneer made by using citric acid and GDL ($p<0.05$).

The overall acceptability score of paneer prepared using different coagulants, viz. citric acid, lactic acid, calcium lactate and GDL ranged from 87.99-88.23, 80.52-80.72, 86.68-87.4 and 84.68-86.36, respectively, with a mean value of 88.11, 86.62, 87.04 and 85.52. The overall acceptability of paneer prepared using citric acid, calcium lactate and lactic acid did not differ significantly; however, it significantly differs from that of paneer made with GDL ($p<0.05$).

DISCUSSION

Compositional parameters of paneer prepared using different coagulants: The yield of paneer found in this study was highest (19.48%), when calcium lactate was used as a coagulant which was followed by lactic acid (17.22%), GDL (16.69%) and citric acid. Kumar et al. (2019) studied the effect of different coagulants (citric acid, malic acid, alum, calcium lactate, glucono-delta-lactone) on the yield, sensory, instrumental colour and textural characteristics of cow's milk paneer and observed the yield of paneer to be highest (206.34 g/L) when calcium lactate was used as a coagulant followed by alum (201.11 g/L), GDL (188.83 g/L), malic acid (183.71 g/L) and citric acid (158.09 g/L). Soleimani et al. (2024) has also reported higher yield in mineral salt coagulated soft cheese as compared with acetic acid and citric acid coagulated cheeses.

Sachdeva and Singh (1987, 1988) and Wolfschoon-Pombo (1997) have proposed that the decrease in yield may be partially attributed to reduced moisture retention and partially to decreased total solids (TS) recovery, as the concentration of coagulant increases. However, statistical analysis showed that using calcium lactate as a coagulant, irrespective of its strength, produced the maximum yield, followed by lactic acid, GDL and citric acid. When calcium lactate is used as coagulant, it upsets the mineral balance in milk, causing casein moieties to become unstable and precipitate. The adherence of Ca^{2+} ions on the alpha casein particles lowers the negative electric charge and produces more reaction sites for aggregation of casein micelles. Thus, the additional calcium from calcium lactate can result in greater casein retention in the coagulum with consequent less protein losses in whey (Dalgleish & Parker 1980; Sachdeva et al., 1991).

The chemical composition of paneer varies with various parameters like type of milk, coagulation temperature, type and strength of coagulant, pressing time and pressure, etc. Among the coagulants studied, the highest moisture content was observed in paneer with calcium lactate, followed by lactic acid, GDL and citric acid. Rathwa et al. (2025) has reported 53.26 per cent moisture in paneer prepared using 1% citric acid, which is in alignment with the moisture content of citric acid coagulated paneer in this study (Table 1). The higher moisture content in paneer prepared using calcium lactate may be due to the formation of a stronger calcium-casein protein network, which enhances water-holding capacity and reduces syneresis. Soleimani et al. (2024) have also indicated higher moisture content in soft cheese prepared using mineral salt as compared to cheese prepared using citric and acetic acid.

The fat content of paneer made with various coagulants varied greatly; paneer prepared using citric acid had the highest value (20.82%), followed by GDL (19.5%), lactic acid (18.6%), and calcium lactate (17.67%). Rapid coagulation, produces a strong and compact curd structure which reduces fat loss in whey, may be the cause of the greater fat content in paneer made with citric acid. On the other hand, calcium lactate exhibited lower fat content, possibly due to higher moisture retention. However, the type of coagulant did not significantly ($p>0.05$) affect the FDM content between the treatments.

The protein content of paneer samples ranged from 17.84 % to 20.3%. Singh et al. (2025) reported the protein content in paneer to be in the range of 18 to 20%. Among all the coagulants, paneer prepared using citric acid had the highest protein content, while lowest protein content was found in calcium lactate coagulated paneer, which might be correlated to the lowest and the highest moisture content in the respective paneer (Table 1).

The highest pH was observed in paneer prepared using calcium lactate may be due to its mild

acidification and the role of calcium ions in coagulation, which allows curd formation at a relatively higher pH compared to acid coagulants. In contrast, organic acid coagulants, such as citric acid and lactic acid, quickly promote acidification, which lowers pH levels. Soleimani et al. (2024) have reported pH of soft cheese prepared using acetic acid and citric acid in the range of 5.7 and 6.

Ash content in the paneer prepared using different coagulants in this study varied from 1.04 to 2.39 per cent which corroborated with those reported by Rajorhia et al. (1984) for ash in paneer from Karnal and Delhi, i.e. between 1.00 and 2.91 per cent. According to Naik et al. (2016), the ash in paneer collected from various regions of Odisha ranged from 1.00 to 2.67 per cent. Similarly, Bhandekar et al. (2018) stated that the ash in paneer sold in Nagpur city ranged from 1.81 to 2.02 per cent. Samples of paneer had mean ash contents ranging from 1.40 to 2.08 per cent. The notable variation was observed in the ash content of paneer ($p<0.05$) prepared using different coagulants. The paneer made with calcium lactate had the highest ash content (2.08 per cent).

Khan et al. (2014) studied the effect of coagulants, viz. citric acid, tartaric acid and malic acid on quality of paneer prepared from reconstituted milk. They observed that the paneer made with citric acid and tartaric acid had significantly higher ($p\leq0.05$) 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. The results of this study for the same are in general agreement with these findings.

Physico-chemical parameters of whey prepared using different coagulants: The highest mean TS (5.94%) in whey was observed when paneer was prepared using citric acid, followed by calcium lactate, GDL and lactic acid. The TS content of whey differed significantly when different coagulants were used. Khan et al. (2014) also observed the least TS losses when paneer was prepared using citric acid in comparison to tartaric acid and malic acid. Sen and De (1984) and Bandyopadhyay et al. (2005) noted that adding a 4% calcium lactate solution for cow's milk coagulation produced less fat loss in Chhana whey when compared to citric acid.

The pH of paneer whey made using different coagulants ranged from 4.71 to 5.34. According to Vishweshwaraiah and Anantakrishnan (1985), paneer prepared by coagulating cow's milk at pH 5.0, sensorially outperformed the one that was coagulated at pH 5.5. When making paneer from cow's milk, Sachdeva et al. (1991) recommended a coagulation pH of 5.2–5.25. In terms of TS recovery and product quality, Sachdeva and Singh (1988a) found that the ideal coagulation pH for paneer made from buffalo milk was 5.35.

The highest lactose content was observed in the case of whey obtained when citric acid was used as coagulant, followed by lactic acid, GDL and calcium lactate. The lactose content of whey obtained with citric acid and lactic acid, as well as GDL and calcium lactate was similar. Tripathi et al. (2015) reported lactose content of paneer whey ranging from 4.69 - 6.05%. In this study, lactose content of whey ranged from 4.85to 5.42%, which is close to these findings.

Effect of different coagulants on colour attributes (L, a*, b*) of paneer: Various colour parameters (L*, a*, b*) of paneer are shown in the Table 3. The whiter the paneer, the higher the L* value. A value of 100 denotes total white, while a value of zero denotes total dark (black) colour. In our study we obtained highest L* value for the paneer prepared using calcium lactate followed by GDL, lactic acid and citric acid. Kumar et al. (2019) has also reported highest L* value for paneer prepared using calcium lactate (96.6), followed by GDL, alum, malic acid and citric acid. This finding also corroborates with the highest whiteness index and lowest yellowness index obtained for calcium lactate-coagulated paneer. While, the citric acid coagulated paneer showed the highest yellowness and lowest whiteness index.

There are very few reports on the effects of coagulant on the colour and appearance of paneer. Thus, the data cannot be substantially compared with other researchers' finding in this respect.

Sensory attributes of paneer prepared using different coagulants: Sensory attributes of paneer were significantly influenced by the type of coagulant used. Due to its whiter appearance, the paneer made with calcium lactate received the highest colour and appearance score (8.57), whereas the paneer made with citric acid received the lowest score due to the yellowish-white surface. Kumar et al. (2019) reported the highest colour and appearance score of paneer when calcium lactate was used as a coagulant, followed by GDL, alum, malic acid and citric acid. Thus, paneer prepared using calcium lactate obtained the highest colour and appearance score (8.71) because of whiter appearance, whereas, that from citric acid secured the lowest score because of yellowish-white surface colour.

Khan et al. (2011) observed the highest appearance score for citric acid in comparison to malic acid and tartaric acid.

The body and texture score of paneer obtained using citric acid was highest (31.24), which was significantly different from that of paneer obtained using calcium lactate, lactic acid and GDL. According to Kumar et al. (2019), paneer made with citric acid had the best sponginess and smoothness for body and texture attributes. As a result, it received the highest score, which was significantly higher than that of other paneer samples prepared using GDL, malic acid and calcium lactate.

Due to increased moisture retention, chhana coagulated with calcium lactate had a poor body and texture score, resulting in a very weak but smooth texture. According to Sen and De (1984), cow milk chhana made using calcium lactate had a good flavour, a smooth texture, and a soft body.

In this study, the highest flavour score was obtained in citric acid coagulated paneer. Lactic acid and calcium lactate coagulated paneer received nearly identical flavour scores, which were statistically comparable ($p>0.05$).

The overall acceptability of paneer samples ranged from 85.52 to 88.11, with significant differences ($p<0.05$). The maximum acceptability (88.11) was shown by paneer made with citric acid, which was statistically comparable to calcium lactate (87.04). While lactic acid (86.62) showed intermediate values and was statistically comparable to both groups, GDL had the lowest acceptance (85.52). Khan et al. (2011) also reported paneer prepared using citric acid to be most acceptable in comparison to tartaric acid and malic acid. Overall, our findings are in alignment with the reported values.

The present study showed that the type of coagulant has a major impact on composition, sensory, colour and quality of paneer. According to sensory analysis, some coagulants resulted in paneer with good flavour, texture, and general acceptability, while others caused minor changes in hardness or sourness. Coagulants also affected whiteness and yellowness indices, according to colour analysis; calcium-based coagulants often gave a whiter result, whereas acidic coagulants contributed to a somewhat yellowish appearance. Although citric acid coagulated paneer had the lowest yield and lowest whiteness index, it was sensorially most acceptable. Use of calcium lactate as a coagulant led to the highest yield of paneer primarily due to higher moisture retention. Looking into the results of this study, it can be stated that choosing the right coagulant is essential to obtain paneer which can optimally meet compositional, sensory, yield and regulatory requirements.

Conflict of interest: Authors have no conflict of interest in this study.

Author's contribution: AAP, MVC: Investigation and data generation; AIS: Supervision of the study; AIS, CND: Preparation of manuscript; ACP, AKJ: Engaged in data curation.

Data availability statement: Data will be provided upon request to the corresponding author.

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