Impact of addition of salts on sensory, rheological properties and yield of Paneer

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Abstract
The objective of the present experiment was to arrive at a method of manufacture for Paneer by altering the process parameters such as coagulation temperature (°C), level of CaCl$_2$ (% w/w) and level of NaCl (% w/w) addition and its impact on sensory and yield of paneer. These parameters were standardized by using the Central Composite Rotatable Design (CCRD) of Response Surface Methodology (RSM), an advanced statistical software programme named Design Expert 9.0.3.1. Quadratic model fitted well to the sensory score for flavour, body and texture, colour and appearance score, moisture (%), yield (%) and Chewiness (Nmm) of Paneer manufactured and their $R^2$ values were 0.875, 0.811, 0.844, 0.855, 0.792, 0.817 respectively. A significant ($P<0.01$) negative effect of coagulation temperature for milk and non-significant positive effect of concentration of CaCl$_2$ addition and significant ($P<0.01$) positive effect of concentration of NaCl addition was observed. The values of moisture of Paneer ranged from 49.46 to 62.09 per cent. A significant ($P<0.01$) negative linear effect of coagulation temperature, non-significant positive effect of CaCl$_2$ addition and significant ($<0.01$) positive effect of concentration of NaCl addition on moisture of Paneer was observed. The values of yield of Paneer ranged from 15.46 to 20.55 per cent. At linear level, a significant ($P<0.01$) negative effect of coagulation temperature, non-significant ($P<0.01$) negative effect of CaCl$_2$ addition and significant ($P<0.01$) positive effect of concentration of NaCl addition on yield of Paneer was observed. The values of chewiness of Paneer ranged from 11.90 to 52.10 Nmm. At linear level a significant ($P<0.01$) positive effect of coagulation temperature, non-significant positive effect of concentration of CaCl$_2$ addition and significant ($P<0.01$) negative effect of concentration of NaCl addition on chewiness of Paneer was observed. The optimized process suggested by statistical package consisted of coagulation temperature of 77°C, 0.05 %, w/w of CaCl$_2$ and 0.5 %, w/w of NaCl addition. The yield of Paneer obtained employing this standardized process is 18.37 percent. While that of control Paneer prepared by same procedure without addition of salt is 16.3 percent.

Keywords: Paneer, NaCl, CaCl$_2$, Yield, Rheology of Paneer, Coagulation temperature

Introduction
Paneer is a South Asian variety of soft cheese obtained by acid and heat coagulation of milk. It is a non-fermentative, non-renneted, non-melting and unripened type of cheese. Paneer is having approximately 53-55 % moisture, 23-25 % milk fat, 17-18 % protein, 2.0-2.5 % lactose and 1.5-2.0 % minerals (Kanjwia and Singh, 1996) [16]. The yield of Paneer is dictated by the composition of milk used which changes with the seasons of the year had profound effect on the yield of Paneer. Milk obtained during winter season had highest yield (15.5 %) while rainy season had least yield of 14.79 %. Type of milk, standardization for fat or fat and SNF, heat treatment given to milk, type and strength of coagulant, losses incurred after coagulation (based on pH and temperature of coagulation) and moisture content of resultant paneer were standardized by several researchers. Chawla et al. (1987) [4] and Yadav et al. (1994) [31] reported incorporation of sodium chloride @ 0.5 % improved the yield of Paneer. Sanyal and Yadav (2000) [24] found that addition of 0.25 % common salt along with 2.5 % cultured skim milk increased the yield of reduced-fat Paneer. Sanyal et al. (2004) [26] observed that the addition of common salt @ 0.75 % to milk increased the yield of reduced-fat Paneer by 19.59 %. Addition of CaCl$_2$ alone alters flavour of Paneer and NaCl as only additive in milk for Paneer making have a tendency to give soft body that causes frying problem and also not liked by consumers.
Keeping the above facts an attempt is made to use combination of both CaCl$_2$ and NaCl for manufacturing of Paneer in order to get benefits of increasing yield without altering sensory and rheological properties of Paneer.

Materials and methods

Materials used

The milk used for manufacturing Paneer was procured from Department of Dairy Processing and Operations (Anubhav Dairy) of Anand Agricultural University, Anand. Citric acid as coagulant and calcium chloride, both Loba-chemical Pvt. Ltd., and good quality non iodized edible sodium chloride salt (Tata brand) was used for Paneer manufacture.

Basic process for Paneer preparation

20 kg milk was heated up to 90°C for 5 min. Thereafter, the temperature of milk was lowered to coagulation temperature (65 to 90°C). At this stage, CaCl$_2$ (0.00 to 0.15% by weight of milk) dissolved in 200 ml distilled water was added to milk. The milk was then coagulated with citric acid as a coagulant. After that NaCl (0.00 to 1%) was added in coagulated milk and kept for 10 min. The coagulated curd was strained and whey was separated. The curd was transferred in to the S.S. Paneer hoop for pressing by putting weight of about 2 kg on the hoop lid. The Paneer block was separated from the hoop and was dipped in chilled water (2-4°C) for 2 h. Thereafter, the Paneer block was weighed and cut into required size packed.

Experimental design

The central composite rotatable design was used for designing the experimental combinations (Modha and Pal, 2011) [20]. The experiment was designed using software Design Expert version 8.0.3. The variables used were coagulation temperature of milk, rate of CaCl$_2$ and NaCl addition level of these variables along with experimental plan consisting of three variables at five levels has been shown in Table 1. The variables were standardized to simplify computation and to deduce the relative effect of variables on response. The magnitude of the coefficients in second order polynomial shows the effect of that variable on the response.

Compositional analysis

The moisture of the Paneer samples were determined as per the procedure described in Indian Standard: 2785 (1979) [15] using Mojonnier Milk Tester Model-D. Fat extraction of Paneer was determined as per the procedure described in Indian Standard: 2311 (1963) [14]. Total nitrogen/protein of Paneer was determined by semi-micro kjeldahl method (Indian Standard: 1479-Part-II, 1961) [11], using Kjel-plus Digestion System (Model-KPS 006 L, M/s. Pelican Instruments, Chennai) and Kjel-plus Semi-Automatic Distillation System (Model-Distil M, M/s. Pelican Instruments, Chennai). Ash content of the samples was determined by procedure described in Indian Standard: 1547 (1985) [13]. Salt content of Paneer was carried out by procedure described in Indian Standard SP:18 Part XI (1981).

Physico-chemical quality analysis

Titratable acidity of Paneer was determined by the procedure as described by Boghara and Rajorhia (1982) [2]. The pH of Paneer was measured using Systronic digital pH meter, Model 335. The method described by Franklin and Sharpe (1963) [7] for cheese. The water activity of Paneer samples, tempered at 25°C temperature, was measured using Rotronic Hygroskop Model: Hygrolab-3 (M/s. Rotronic ag, Switzerland) (Hirpara et al., 2013) [10]. The method prescribed by Deeth et al. (1975) [16] was used to estimate the FFA content of Paneer.

Texture profile analysis

Four samples of each experimental Paneer were tempered to 23±1°C and then subjected to uniaxial compression to 40% of the initial sample height, using a Food Texture Analyzer of Lloyd Instruments LRX Plus material testing machine, England; fitted with 0–5 kN load cell. The force distance curve was obtained for a two-bite deformation cycle employing a Cross Head speed of 50 mm/min, Trigger 10 gf and 40 % compression.

Sensory evaluation

For the organoleptic evaluation of Paneer, 8 judges were selected (on the basis of duo-trio test). The Paneer samples were evaluated using 100 point scale as described in Indian Standards (IS: 15346, 2003) [12]. The judges were also requested to give criticism for each attribute of the samples.

Statistical analysis

The experiment was designed and responses were analyzed using software Design Expert version 8.0.3. All physicochemical determinations were average of three replicates, whereas sensory data were average of eight replicates. Table 2 shows the treatments to be experimented with reference to the Central Composite Rotatable Design for three independent variables: Coagulation temperature (°C), Rate of addition (%) of CaCl$_2$ and NaCl in actual values.

| Run order | Coagulation temperature (°C) (X$_1$) | CaCl$_2$ (%) (X$_2$) | NaCl (%) (X$_3$) |
|-----------|-------------------------------------|---------------------|-----------------|
| 1         | 78                                  | 0.15                | 0.50            |
| 2         | 78                                  | 0.08                | 0.50            |
| 3         | 78                                  | 0.08                | 1.00            |
| 4         | 78                                  | 0.08                | 0.50            |
| 5         | 65                                  | 0.08                | 0.50            |
| 6         | 78                                  | 0.08                | 0.50            |
| 7         | 90                                  | 0.08                | 0.50            |
| 8         | 78                                  | 0.08                | 0.50            |
| 9         | 70                                  | 0.12                | 0.80            |
| 10        | 85                                  | 0.03                | 0.80            |
Results and discussion

Effect on variables on properties of paneer

A second order polynomial was fitted into the data for all responses and the actual values observed are reported in Table 3.

\[ Y = \beta_0 + \sum_{i=1}^{3} \beta_i X_i + \sum_{i=1}^{3} \beta_{ii} X_i^2 + \sum_{i,j=1,i\neq j}^{3} \beta_{ij} X_i X_j \]

Where \( \beta_0, \beta_i, \beta_{ii}, \beta_{ij} = \) Regression coefficients, \( X_i, X_j = \) independent variables, \( Y = \) dependent variable.

\( R^2 \geq 0.80 \) for sensory attributes is statistically adequate for developing a model or equation (Henika 1982) [8]. Presently \( R^2 \) was > 0.80 for all the sensory responses. The probability value (p) showed the adequacy of the models so used to describe the effect of variables on different responses. The effect of temperature of coagulation and rates of addition of CaCl\(_2\) and NaCl on the responses is shown in equations below. The sign and magnitude of coefficients indicate the effect of the variable on the responses. The models thus developed with actual variables are as follows:

- Flavour = 27.45 + 0.41X1 + 49.65X2 + 16.36X3 + 0.041X12 + 0.087X13 - 55.91X23 - 0.0041X32 - 277.424X23 - 11.302X32
- Body & Texture = 74.59 - 1.039X1 - 2.336X2 + 3.021X3 + 0.613X12 + 0.0224X13 - 54.117X23 + 0.0053X32 + 4.88X23 + 1.25X32
- Colour and Appearance = 21.48 - 0.32X1 + 39.32X2 - 4.10X3 - 0.388X12 + 0.069X13 - 2.262X23 + 0.0017X32 - 41.26X32 - 0.0084X32

Total Sensory Score = 200.763 - 2.964X1 + 221.867X2 + 35.574X3 - 1.644X12 - 0.107X13 - 0.016X23 - 0.333X365X2 - 10.510X32

Moisture (%) = 129.095 - 1.906X1 + 142.668X2 + 22.859X3 - 1.057X12 - 0.068X13 - 41.200X33 + 0.0109X32 - 214.316X32 - 6.762X32

Yield (%) = 54.365 - 0.933X1 + 48.395X2 + 9.727X3 - 0.109X12 - 0.058X13 - 19.733X23 + 0.005X32 - 234.882X2 - 1.004X32

| Run order | Flavour | B & T | C & A | Total sensory score | Moisture (%) | Yield (%) | Chewingness (Nmm) |
|-----------|---------|-------|-------|--------------------|--------------|-----------|-------------------|
| 1         | 40.83   | 30.20 | 8.15  | 84.18              | 54.13        | 15.46     | 30.50             |
| 2         | 43.99   | 29.02 | 8.44  | 86.45              | 55.59        | 18.40     | 23.30             |
| 3         | 44.83   | 29.94 | 9.20  | 88.97              | 57.21        | 18.94     | 23.90             |
| 4         | 43.35   | 28.57 | 8.26  | 85.18              | 54.77        | 18.13     | 39.10             |
| 5         | 46.50   | 31.02 | 9.55  | 91.87              | 62.09        | 20.55     | 19.20             |
| 6         | 42.77   | 29.98 | 8.38  | 86.13              | 55.38        | 18.33     | 27.60             |
| 7         | 39.19   | 29.04 | 7.78  | 81.01              | 52.09        | 17.24     | 45.30             |
| 8         | 42.25   | 29.59 | 8.26  | 85.10              | 54.72        | 18.11     | 23.30             |
| 9         | 43.20   | 33.59 | 8.92  | 90.71              | 61.61        | 20.39     | 11.90             |
| 10        | 45.07   | 29.79 | 8.66  | 88.52              | 56.92        | 18.84     | 14.20             |
| 11        | 42.23   | 29.43 | 8.24  | 84.90              | 54.59        | 18.07     | 28.70             |
| 12        | 36.32   | 29.06 | 7.57  | 77.95              | 50.12        | 16.59     | 47.00             |
| 13        | 41.18   | 30.45 | 8.24  | 84.87              | 54.57        | 18.06     | 27.60             |
| 14        | 41.10   | 30.39 | 8.22  | 84.71              | 54.47        | 18.03     | 41.10             |
| 15        | 38.88   | 30.53 | 7.94  | 82.35              | 52.95        | 17.53     | 49.20             |
| 16        | 42.85   | 28.23 | 8.16  | 84.24              | 54.17        | 17.93     | 34.00             |
| 17        | 38.25   | 26.23 | 7.44  | 76.92              | 49.46        | 16.37     | 52.10             |
| 18        | 45.59   | 32.98 | 8.02  | 91.59              | 58.89        | 20.13     | 16.50             |
| 19        | 40.12   | 33.10 | 8.44  | 86.66              | 55.72        | 18.44     | 33.00             |
| 20        | 46.02   | 33.28 | 8.12  | 92.42              | 59.42        | 19.67     | 28.40             |

\( R^2 \) = 0.875

| 0.811 | 0.844 | 0.855 | 0.855 | 0.792 | 0.817 |

The manufacture of Paneer is dependent on the very important stage of heat coagulation which decides its quality and functionality. The study was undertaken with the main aim of evaluating effect of coagulation temperature, concentration of CaCl\(_2\) and NaCl on sensory attributes, moisture content, yield as well as rheological properties (chewiness) of Paneer.

In this experiment, different levels of concentration of CaCl\(_2\), concentration of NaCl and coagulation temperature during manufacturing of Paneer was evaluated. These parameters were decided on the basis of preliminary trials undertaken. The levels for concentration of CaCl\(_2\) (@ 0.00 to 0.15 %), concentration of NaCl (@ 0.00 to 1 %) as well as coagulation temperature (65 to 90°C) were selected on the basis of preliminary trials taking into consideration the sensory attributes.

The Paneer prepared with varying temperatures of coagulation, concentration of CaCl\(_2\) and NaCl which were tried out for coagulation of milk and their responses are shown in design matrix of three factors CCRD deign consisting of 20 experiments. These treatment samples were
evaluated for various sensory, rheological and compositional characteristics.

The most important criteria for evaluating the quality of any traditional Indian dairy products is sensory characteristics which include flavour, body and texture, colour and appearance and total sensory score which in turn determines its acceptability. The sensory score data along with formulations as per their run order is shown in Table 3.

Sensory scores of Paneer for Flavour varied from 36.32 to 46.30, Body and Texture 26.23 to 33.59, Colour and Appearance 7.44 to 9.55 and Total sensory score of Paneer as depicted in Table 3 ranged from 76.92 to 92.42 (total out of 100). Coagulation temperature has profoundly significant effect on all sensory attributes and they all were affected with change in temperature of coagulation.

Flavour of the Paneer was significantly affected and was linearly negatively correlated with coagulation temperature. Addition of sodium chloride at linear level had shown significantly positive correlations for flavour but significantly reverse trend was noted at quadratic level, which might be because of more salty taste prevailed at higher level of addition. Yadav et al. (1994) [31] and Kaur et al. (2003) [17] also reported addition of NaCl increased flavour score of the experimental Paneer.

Body and texture score of the Paneer was significantly affected with temperature of coagulation. Increase in coagulation temperature resulted in decrease in body and texture score of Paneer. Upon addition of CaCl₂, a non-significant increase in body and texture score was observed. Arora et al. (1996) [1] when added CaCl₂ @ 0.05% in milk, resulted in improvement of Body and Texture score. Similar trend was reported by Singh and Kanawjia (1988) [30] upon addition of CaCl₂ @ 0.1% to milk prior to coagulation.

Colour and Appearance score of Paneer was significantly affected by temperature of coagulation and sodium chloride. Colour and appearance score decreased significantly with linear rise in coagulation temperature; however, it increased with increase in rate of addition of sodium chloride.

Overall acceptability is the indicative parameter of sensory quality of product in totality and consists of appearance, flavour, body and textural characteristics. The increase in coagulation temperature (X₁) decreases the sensory score significantly (<0.01) whereas increasing concentration of CaCl₂ (X₂) increased the sensory score at linear level but non-significantly. NaCl concentration (X₃) showed its negative significance in quadratic terms due to unacceptable saltiness in Paneer at higher concentrations of NaCl.

A non-significant negative interactive effect on sensory properties was observed with varying coagulation temperature and concentration of CaCl₂ and concentration of NaCl. The response surface for total sensory score in relation to coagulation temperature, rate of addition of calcium chloride and sodium chloride are shown in Fig. 1. Sachdeva et al. (1991) [23] observed that incorporation of 0.08% CaCl₂ in manufacture of Paneer at coagulation pH of 5.20 – 5.25, had maximum sensory score. Singh and Kanawjia (1988) [30] also observed that use of CaCl₂ @ 0.1% to milk prior to coagulation increases all the sensory characteristics. When Paneer was dipped in 3% brine, Kaur et al. (2003) [17] obtained a good sensory score. Similarly, Yadav et al. (1994) [31] found that use of common salt @ 0.5% in milk led to an improvement in the total sensory score.

The Paneer prepared by using 78°C coagulation temperature, 0.08 % (w/w) CaCl₂ and 0.50 % (w/w) NaCl was rated the best for its total sensory score (Table 3).
Fig 1: Effect of Coagulation temperature, rate of addition of calcium chloride and sodium chloride on sensory score of Paneer (design expert plots).

Table 4: P values and partial coefficient of regression equations of suggested model for Sensory properties of Paneer

| Factors       | Flavour        | Body & Texture | Colour & Appearance | Total Sensory Score |
|---------------|----------------|----------------|---------------------|---------------------|
|               | P Value | Partial Coefficient | P Value | Partial Coefficient | P Value | Partial Coefficient | P Value | Partial Coefficient | P Value | Partial Coefficient |
| Model         | 125.170 | 40.049           | 3.552              | 421.536              | 421.536 |
| Linear Level  |          |                  |                    |                      |          |
| X1            | 0.0035*  | -1.373           | 0.019*             | -1.209              | 0.007*   | -0.317              | 0.0003*  | -3.850              |
| X2            | 0.066    | -0.746           | 0.086              | 0.840               | 0.397    | 0.084               | 0.4622   | 0.551               |
| X3            | 0.0001*  | 2.258            | 0.209              | 0.580               | 0.006*   | 0.330               | 0.0006*  | 3.542               |
| Interactive Effect |      |                  |                    |                      |          |
| X1 x X2       | 0.977    | 0.014            | 0.724              | 0.205               | 0.317    | -0.13               | 0.5724   | -0.55               |
| X1 x X3       | 0.690    | 0.194            | 0.931              | 0.050               | 0.238    | 0.155               | 0.8041   | -0.24               |
| X1 x X4       | 0.148    | -0.741           | 0.232              | -0.718              | 0.813    | -0.03               | 0.3883   | -0.85               |
Table 5: P values and partial coefficient of regression equations of suggested model for composition and rheological properties of Paneer

| Factors | Moisture (%) | Yield (%) | Chewiness (Nmm) |
|---------|--------------|-----------|-----------------|
|         | P Value      | Partial Coefficient | P Value | Partial Coefficient | P Value | Partial Coefficient |
| Model   |             |            |               |                |         |                    |
| Linear Level |             |            |               |                |         |                    |
| X₁      | 0.0003*     | -2.475     | 0.002*        | -0.865         | 0.001*  | 8.164              |
| X₂      | 0.462       | 0.354      | 0.319         | -0.231         | 0.476   | 1.384              |
| X₃      | 0.0006*     | 2.278      | 0.004*        | 0.801          | 0.001*  | -8.570             |
| Interactive Effect |             |            |               |                |         |                    |
| X₁X₂    | 0.572       | -0.353     | 0.901         | -0.036         | 0.263   | 2.900              |
| X₁X₃    | 0.804       | -0.153     | 0.660         | -0.130         | 0.496   | -1.725             |
| X₂X₃    | 0.388       | -0.546     | 0.386         | -0.261         | 0.335   | 2.475              |
| Quadratic Level |             |            |               |                |         |                    |
| X₁²     | 0.204       | 0.613      | 0.179         | 0.310          | 0.690   | 0.746              |
| X₂²     | 0.367       | -0.426     | 0.055         | -0.047         | 0.690   | 0.746              |
| X₃²     | 0.215       | -0.597     | 0.688         | -0.088         | 0.327   | 1.877              |

Effect of variables on compositional and textural responses Moisture (%)
The values of moisture of Paneer shown in Table 3 ranged from 49.46 to 62.09 %. The Paneer prepared by using coagulation temperature 65°C, 0.08% of CaCl₂ and 0.50% of NaCl had the highest value of moisture in paneer. The paneer prepared by using coagulation temperature 85°C, 0.03% of CaCl₂ and 0.2 % of NaCl had lowest value of moisture. The P value for coagulation temperature showed its significance in quadratic terms (Table 5). This indicates that the increase in coagulation temperature (X₁) decreases the moisture significantly (P<0.01) while increasing concentration of CaCl₂ (X₂) increases the moisture at linear level non-significantly. While at linear level concentration of NaCl (X₃) showed a significant positive effect stating that upon increasing concentration of NaCl, the moisture content of resultant paneer increases significantly. The P value for all the three parameters showed that they have non-significant effect at quadratic terms (Table 5). The negative sign indicates the negative effect of concentration of CaCl₂ and NaCl on moisture content of paneer. In quadratic term a non-significant positive effect on moisture was found with the varying coagulation temperature (X₁²). Use of coagulation temperature greater than 70 °C resulted in hard and dry paneer while free surface moisture was evident when coagulated at lower (<70°C) temperatures (Sachdeva and Singh 1988a) [23]. Masud (2002) [19] recommended use of higher (85°C) coagulation temperature for buffalo milk paneer.

Yield (%)
The yield of the product aims at quantifying objectively the solids recovered during product manufacture to the maximum extent possible into the finished product. The values of yield of Paneer shown in Table 3 ranged from 15.46 to 20.55 %. The Paneer prepared by using coagulation temperature 65°C, 0.08% of CaCl₂ and 0.50% of NaCl had the highest value of yield in Paneer. The Paneer prepared by using coagulation temperature 78°C, 0.15% of CaCl₂ and 0.50% of NaCl had lowest value of yield. The tabulated values in Table 5 indicates that the increase in coagulation temperature (X₁) decreases the yield significantly (P<0.01) while increasing concentration of CaCl₂ (X₂) decreased the yield at linear level but non-significantly. For different concentration of NaCl (X₃) indicates the significant positive effect on yield of Paneer. A non-significant negative interactive effect on yield was observed with varying coagulation temperature and concentration of CaCl₂, varying coagulation temperature and concentration of NaCl and varying concentration of CaCl₂ and NaCl. A non-significant positive effect on yield was found with the varying coagulation temperature (X₁). A non-significant negative effect on yield was found with concentration of CaCl₂ (X₂) and concentration of NaCl (X₃). Hill et al. (1982) [19] recommended use of high temperature and CaCl₂ for getting better yield through co-precipitation of casein and whey proteins. Singh and Kanawjia (1988) [30] when added CaCl₂ @ 0.1% to milk prior to coagulation observed increased total solids recovery and yield of Paneer. Arora et al. (1996) [1] observed that addition of CaCl₂ increased fat, protein, TS, pH and TS recovery and thus yield of Paneer made from diluted milk. Makhal and Kanawjia (2005) [18] obtained enhanced yield of Paneer during co-precipitation of casein and whey protein through acidification in presence of calcium chloride added @ 0.15%. The yield of Paneer from buffalo milk was found to decrease with an increase in coagulation temperature as observed by Sachdeva and Singh (1988b) [22], while for cow milk it increased as reported by Singh and Kanawjia (1988) [30]. Chawla et al. (1987) [3] observed that the incorporation of sodium chloride @ 0.5% and NFDM dramatically helped in increasing the moisture content of low fat Paneer and thereby improved the yield of Paneer. Sanyal and Yadav (2000) [25] found that addition of common salt @ 0.25% along with 2.5% cultured skim milk increased the yield of reduced-fat Paneer. Sanyal et al. (2004) [27] observed that the addition of common salt @ 0.75% to milk increased the yield of reduced-fat Paneer by 19.59% above that of control.

Chewiness (Nmm)
Chewiness (Nmm) is the amount of effort that goes into preparing a solid product ready for swallowing. Paneer ideally requires some chewiness to exhibit its functionality for frying and cooking purposes. The values of chewiness (Nmm) of Paneer shown in Table 3 ranged from 11.90 to 52.10 Nmm. Increase in coagulation temperature (X₁) increased the chewiness significantly (P<0.01) while increasing concentration of CaCl₂ (X₂) increased the chewiness at linear level but non-significantly. The P value for concentration of NaCl (X₃) (Table 5) showed its significance in linear terms and indicates the negative effect of concentration of NaCl (X₃) on chewiness of Paneer. A non-significant positive interactive effect on chewiness was observed with varying coagulation temperature and concentration of CaCl₂ and varying concentration of CaCl₂ and NaCl (Fig. 2). A non-
significant negative interactive effect on chewiness was observed with varying Coagulation temperature and concentration of NaCl. The square of factor indicates the effect of factor at highest level used in the product standardization. A non-significant positive effect on chewiness was found with the varying Coagulation temperature ($X_1^2$), varying level of concentration of CaCl$_2$ ($X_2^2$) and concentration of NaCl ($X_3^2$).

Sindhu (1996) attributed higher hardness and chewiness in buffalo milk Paneer to the higher concentration of casein in the micellar state and higher content of total and colloidal calcium. In the present study Paneer prepared by employing 85°C coagulation temperature, addition of CaCl$_2$ @ 0.03% (w/w) and NaCl @ 0.20% (w/w) resulted in to the highest value of chewiness (Nmm) in Paneer which is desirable for its better functionality for the culinary purposes. Both the coagulation temperature as well as addition of CaCl$_2$ has positive effect on chewiness (Nmm) property of Paneer, the former being statistically significant ($P<0.01$). The response surface plots as shown in Fig. 2 are based on the above model.
Optimization of independent variables

Process optimization for the manufacture of Paneer was carried out with the objective of determining the best possible combination(s) of different levels of factors viz. coagulation temperature (°C) (X₁), addition of CaCl₂ % (w/w) (X₂) and NaCl % (w/w) (X₃) that would lead to the most acceptable product in terms of sensory scores, composition attributes and rheological characteristics.

The optimum levels suggested by the software Design expert 8.0.3 for Coagulation temperature, rate of calcium chloride and sodium chloride addition were 77°C, 0.05 % and 0.5 % with the desirability of 0.781. The predicted and actual response values (obtained after making the product using the optimum level of ingredients) have been presented in Table 6 from which it can be observed that both the values were statistically at par, hence, the above levels of ingredients were recommended. The Schematic Flow Diagram Standardized for the manufacture of Paneer is shown in Fig. 3. This standardized process yielded standardized Paneer having the proximate composition as depicted in Table 7. The detailed analysis of the compositional, physico-chemical, textural, sensory as well microbial attributes obtained from the three replications employing the optimized processing factors was performed and their average values are tabulated here under in Table 7.

Table 6: Comparison of predicted v/s actual values of responses used for process optimization for Paneer manufacture

| Response                          | P Value | Predicted Value * | Actual Value @ | Cal. t-Value # | Level of Significance |
|-----------------------------------|---------|-------------------|----------------|---------------|----------------------|
| Flavour (out of 50)               | 0.852   | 43.60             | 43.61          | 0.199         | NS                   |
| Body and Texture (out of 35)      | 0.276   | 29.56             | 29.63          | 1.263         | NS                   |
| Colour and appearance (out of 10)| 0.042   | 8.23              | 8.21           | 0.895         | NS                   |
| Total Sensory Score (out of 100)  | 0.906   | 86.38             | 86.40          | 0.127         | NS                   |
| Moisture (%)                      | 0.454   | 55.54             | 55.09          | 0.857         | NS                   |
| Yield (%)                         | 0.471   | 18.46             | 18.37          | 0.821         | NS                   |
| Chewiness (Nmm)                   | 0.354   | 27.51             | 28.10          | 1.092         | NS                   |

* Predicted values of Design Expert 9.0.3.1 package
@ Actual values are average of five trials for optimised product
# t-values found non-significant at 5 % level of significance
NS = Non Significant
Tabulated t-value = 2.776 (cal. t-value less than tabulated value)

Conclusion

The sensory scores of Paneer manufactured employing various coagulation temperature, concentration of CaCl₂ and concentration of NaCl were influenced markedly. The Paneer prepared by using 77°C coagulation temperature, 0.08%, w/w CaCl₂ and 0.50 %, w/w NaCl addition was rated the best. Thus, good quality Paneer can be prepared with improved Yield and rheological properties by employing coagulation temperature at 77°C along with 0.05%, w/w CaCl₂ and 0.50 %, w/w NaCl addition.
Table 7: Average proximate chemical composition, physicochemical properties, rheological properties, sensory attributes and microbiological quality of Paneer manufactured by standardized process

| Attributes                      | Value       | Attributes                      | Value       |
|---------------------------------|-------------|---------------------------------|-------------|
| **Composition Attributes**      |             | **Rheological Properties**      |             |
| Moisture (%)                    | 55.16±0.57  | Hardness (N)                    | 15.36±0.02  |
| Fat (%)                         | 23.75±0.65  | Cohesiveness                    | 0.38±0.01   |
| Total Protein (%)               | 17.84±0.15  | Springiness (mm)                | 4.81±0.06   |
| Lactose (%)                     | 2.57±0.17   | Gumminess (N)                   | 5.84±0.22   |
| Ash (%)                         | 1.33±0.02   | Chewiness (Nmm)                 | 28.10±1.14  |
| Salt (%)                        | 0.29±0.02   | Adhesiveness (Nmm)              | 1.33±0.01   |
| **Physico-Chemical Properties** |             | **Sensory Attributes**          |             |
| Acidity (% L.A.)                | 0.47±0.02   | Flavour (out of 50)             | 43.61±0.56  |
| pH                              | 6.13±0.01   | Body and Texture (out of 35)    | 29.63±0.58  |
| Water Activity (aw)             | 0.99±0.00   | Colour and Appearance (out of 10) | 8.21±0.50 |
| Free Fatty Acid (μ eq/g)        | 0.36±0.01   | Total score (out of 100)*       | 86.40±0.16  |
| **Microbial Count**             |             |                                 |             |
| Standard Plate count (log_{10}cfu/g) | 3.22±0.02   | Salmonella count                | Absent in 25 g |
| Yeast and Mold Count            | Absent in 1 g | Staphylococcus aureus count    | Absent in 1 g |
| Coliform Count                  | Absent in 1 g | Listeria monocytogenes count   | Absent in 1 g |

*Total score include 5 score (out of 5) given to package.

Fig 3: Standardized process for the manufacture of Paneer

Standardization of Milk
(Fat SNF=4.5/8.7)

Heat Treatment, (85°C, 5 min)

Adjusting to 77°C Coagulation Temp.

Coagulation with gentle stirring till clear whey separates out

Holding for 10 min.

Straining of curd

Transfer curd to Paneer hoops

Pressing

Opening the hoops

Immersion of Paneer blocks in Pasteurized chilled water (4°C, 2 h)

Packaging & Storage (7±2°C)

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