Optimization of processing parameters and ingredients for development of low-fat fibre-supplemented *paneer*

G. Singh · A. Kumar · B. K. Kumbhar · B. N. Dar

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Abstract Increasing demand of low calorie and high fibre containing products give impetus to dairy industry for development of a well palatable low calorie dairy products like *paneer*. The objective of the present study was to develop low-fat fibre-supplemented *paneer*. The ingredients were chosen for low-fat fibre-supplemented *paneer* to reduce the cost and calorie content besides providing the functional benefits. Optimization of ingredients was carried out in terms of independent variables viz wheat bran (0.4–0.8 %), maltodextrin (1–5 %), coagulation temperature (60–80 °C) and amount of citric acid solution (150–210 ml). Response Surface Methodology (RSM) was used to design the experiments and to select the optimum levels of ingredients. *Paneer* was made by using different levels of ingredients by coagulating hot milk using citric acid solution followed by pressing and dipping in chilled water for texturization. These parameters were evaluated in terms of physico-chemical parameters viz water activity, pH and acidity. Instrumental texture profile analysis (TPA) of *paneer* during optimization trials was done using TAXT 2i Texture Analyzer. The textural responses namely hardness, adhesiveness, springiness, cohesiveness, gumminess and chewiness were measured via

Texture Analyzer. The sensory properties namely flavor, appearance, body and texture, mouth feel and overall acceptability of *paneer* samples were evaluated by a semi-trained panel of judges using 9-point hedonic scale. Full second order polynomial was developed to predict each response. All the textural and sensory responses were statistically analysed.

Keywords Fibre · Low calorie · *Paneer* · Sensory properties · Texture · RSM

Introduction

Paneer is a popular heat and acid-coagulated Indian milk product analogous to the western cottage cheese. It is prepared by coagulating milk with citric acid and pressing the resulting curd into blocks or cubes. The product has a shelf life of 6 days at 10 °C (Jagannath et al 2001). *Paneer* consists usually of the protein and nearly all the, insoluble salts and colloidal materials, together with part of the moisture of serum of the original milk in which are contained lactose, whey proteins, soluble fats, vitamins and other milk components. It contains approximately 53–55 % moisture, 23–26 % fat, 17–18 % protein, 2–2.5 % carbohydrate and 1.5–2.0 % minerals (Kanawjia and Singh 2000). Traditionally, buffalo milk is boiled in a suitable vessel. The coagulant (usually sour whey) from previous batch is added to the hot milk and stirred with a ladle till coagulation is complete as evident from separation of clear greenish yellow whey. The contents of the vessel are emptied over a piece of coarse cloth (to collect coagulum) held over another bigger vessel (to collect whey). The curd, collected by draining the whey, is pressed further to remove more whey and to provide textural properties is finally washed with cold tap water (Anantakrishnan and Srinivasan 1964). However, at pilot plant the *paneer* was manufactured from buffalo milk with 6 % fat which was

G. Singh · A. Kumar
Department of Food Science and Technology, GBPUAT Pant Nagar, Pantnagar, Uttarakhand 263145, India

G. Singh
e-mail: gitanjali2112@gmail.com

A. Kumar
e-mail: lina_k5@yahoo.co.in

B. K. Kumbhar
Department of Post Harvest Process and Food Engineering, GBPUAT Pant Nagar, Pantnagar, Uttarakhand 263145, India

B. N. Dar (✉)
Department of Food Science & Technology, PAU, Ludhiana, Punjab 191141, India
e-mail: darnabi@gmail.com

heated at 82 °C for 5 min in a jacketed vat (Bhattacharya et al 1971). One per cent hot citric acid solution was added at 70 °C. The mixture was stirred continuously till coagulation is complete. The *paneer* thus formed was separated and pressed (Rao et al. 1992). The conventional *paneer* is quite rich in fat content, which not only pushes up the price of *paneer* but also makes it unsuitable to those consumers who are conscious of high fat as milk fat increases the risk of coronary heart disease. Recent research has shown that quite good quality *paneer* could be manufactured from milk with fat content as low as 3.0 % (Kanawjia and Singh 2000).

Milk and milk products appear to be almost perfect foods, but provide none of the 25–30 g of dietary fibre required daily for adults. The ‘low residue’ nature of milk and milk products render them attributable to the absence of dietary fibre. This attribute of milk products become particularly relevant when the overall diet does not contain adequate amounts of dietary fibre as, again, is the case in much of the wealthy populations. In this context, milk and milk products considered as a vehicle for dietary fibre would not only take care of their own role in human health but could also enhance the healthfulness of the diet as a whole (Patel and Arora 2005). Adding fibre to milk or its derived products in the form of cereal-bran would make them edible and dairy products enriched with fibres. In addition, these vehicles contain electrolytes and trace elements which restore the imbalance created by the mineral faecal loss due to the cation-exchange properties of fibre. The addition of dietary fibre to dairy products is also desirable as it enhances nutritive status and adds value to the products. In recent years, dietary-fibre-rich milk and milk products are becoming increasingly important to the dairy industry from marketing point of view. They have been accepted by consumers due to low cost, low energy and low fat products which are likely to improve the public health in several ways (Nayak et al. 2000).

Dietary fibre is the edible part of plants or analogous carbohydrates that are resistant to digestion and absorption in the human small intestine with complete or partial fermentation in the large intestine. Dietary fibre includes polysaccharides, oligosaccharides, lignin and associated plant substances (AACC 1999). Since the mid 1980s, dietary fibre has been added to some functional as well as medical foods to improve functional properties of the products and to improve gastrointestinal functions by regulating transit time and facilitating absorption of fluid and electrolytes from the gut lumen (Schmidl and Labuza 1994). It is believed that a fibre intake of 30 g per day is desirable, half derived from cereal bran and half from fruits and vegetables. Most of the dietary fibres show good water holding capacity and few of them are readily soluble in water. Upon hydration, majority of them undergo swelling. Dietary fibres have been shown to bind nutritionally important minerals and therefore, they may influence electrolyte and mineral absorption, heavy metal toxicity, etc. Many organic molecules including bile acids,

cholesterol, steroid hormones and toxic compounds also get adsorbed by dietary fibres so dietary fibres are beneficial for human health (Stody et al 1982).

Dietary fiber incorporation in dairy products, particularly *paneer*, may influence sensory and textural properties of the product. Further, *paneer* quality could also be affected by various factors like composition of milk, type and amount of coagulant, heat treatment given to milk, temperature and pH of coagulation, etc. The present work deals with the development of low-fat fibre-supplemented *paneer* by optimizing ingredients and parameters using response surface methodology (RSM). The aim of this research was to use the RSM technique as a statistical technique and methodological approach to develop low-fat fibre-enriched *paneer* with maximum consumer acceptability. By using RSM, it should be possible to select the optimum composition and processing conditions.

Materials and methods

Materials

Fresh buffalo milk used for preparation of *paneer* was procured from Livestock Research Centre, G. B. Pant University of Agriculture and Technology, Pantnagar, Uttarakhand (India). All the chemical reagents used in the investigation were of analytical reagent (AR) grade. Stabilized wheat bran of superfine grade was procured from Guru Nanak Flour Mill Pvt. Ltd., Kichha, Distt. Udham Singh Nagar, Uttarakhand (India). Rice bran was procured from Uma Rice Mill, Kichha, Distt. Udham Singh Nagar, Uttarakhand (India). Psyllium husk of SAT-ISABGOL brand and Quaker White Oats were bought from local market. PARAS Premium spray dried skimmed milk powder was bought from local market for standardization of milk.

Preparation of low-fat fibre-supplemented *paneer*

Milk used for preparation of *paneer* was analyzed for fat by Gerber's method and solids-not-fat (SNF) by standard method of AOAC (1993). Low-fat fibre-supplemented *paneer* was prepared from fresh buffalo milk after filtration through a double layered muslin cloth to remove dirt and dust particles and other foreign impurities and then standardized to 3 % fat and 8.5 % SNF using water and skimmed milk powder. Maltodextrin and wheat bran were used at various levels as fat replacer and source of dietary fibre, respectively. A slurry of dietary fiber was prepared by meshing it with hot water and ground in mixer and grinder. Then it was added to milk and milk was stirred slowly and constantly for mixing the contents. The content was then heated to 90 °C for 5 min and then cooled to different coagulation temperatures followed by coagulation

by 1 % aqueous solution of citric acid by slowly adding to milk with continuous stirring till a complete coagulation occurred and clear transparent greenish yellow whey was separated out. The range of wheat bran, maltodextrin, coagulation temperature and amount of citric acid solution is given in Table 1. After coagulation of milk, the contents were left undisturbed for about 5 min and then filtered through a double layered muslin cloth in order to remove whey. The hot coagulum was transferred into a circular stainless steel hoops and a pressure of 1.22 psi was applied for 7 min. The coagulum after pressing was immediately transferred to chilled water for development of proper body and texture. Prepared *paneer* blocks were cut into cubes (1.5×1.5×1.5) cm and packed in polyethylene bags and stored at refrigeration temperature (5 °C) for further analysis.

Optimization of the formulation for low-fat fibre-supplemented paneer

Based on preliminary trials and review of literature, the constant parameters and independent variables with their ranges and the dependent variables were selected for the final experiments. Central Composite Rotatable Design (CCRD) was chosen because, it is the most popular response surface design, and it gives very good predictions in the middle of design space.

RSM was used to determine the effect of the independent variables on the dependent variables statistically. A full second order mathematical model of the following form was fitted to all the response data.

$$Y = \beta_0 + \sum_{i=1}^k \beta_i X_i + \sum_{i=1}^k \beta_{ii} X_i^2 + \sum_{i=1}^{k-1} \sum_{j=i+1}^k \beta_{ij} X_i X_j \quad (1)$$

where,

β_0 , β_i , β_{ii} , β_{ij} , are regression coefficients, X_i and X_j are independent variables in coded form, k is the number of independent variables and Y is a response.

Before optimization, goals were set for each independent variable and two responses. The criteria for allotment of the goals were based on the calorie content, product's sensory characteristics and health benefits conferred by maximum amount of fiber incorporation. All the independent variables

and hardness were kept in range on the basis of results of preliminary trials so that an optimum product could be obtained with respect to its composition, sensory and textural properties. Overall acceptability was set for maximum goal setting so that an acceptable product be made from consumer point of view.

Evaluation of texture

Texture profile analysis (TPA) test was performed on *paneer* samples using Texture Analyzer (Model TAXT2i, Exponent Stable Micro Systems, United Kingdom, Software Texture Expert Exceed version 7.1.6). The specifications of the Texture Analyzer were: load cell capacity-25 kg, displacement-0.1–524 mm and speed-20–0.01 mm/s. To place the sample for analysis heavy duty platform (HDP/90) was used. This platform was a base from which many attachments were fitted to the texture analyzer. It ensured the precision alignment of probes and product samples. Compression platen (P/75) made of stainless steel with 75 mm diameter, was used throughout the experiments. For TPA analysis *paneer* was uniformly cut into cubes of (1.5×1.5×1.5) cm dimensions. *Paneer* cubes were subjected to TPA test by positioning samples centrally on the heavy duty platform under the probe. Then compression test was commenced. When a 5 g surface trigger force attained, the probe proceeded to compress the *paneer* cubes to 65 % strain. After the end of compression at which the force was maximum, the probe returned to its original position at constant speed (5 mm/s). Peak force at the end of compression indicated hardness of the sample. The negative region of the graph produced on probe return, was an indication of the adhesive property of the sample. The texture profile curve was interpreted in terms of six textural parameters viz., hardness, adhesiveness, springiness, cohesiveness, gumminess and chewiness. All tests were replicated thrice.

Sensory evaluation

The sensory quality of *paneer* was evaluated using 9-point hedonic scale where 9 and 1 represented liked extremely and disliked extremely, respectively. A trained panel consisting of 5 members drawn from the faculty of department of Food Science and Technology, G.B.P.U.A. & T., Pantnagar, evaluated the

Table 1 Values of independent variables in coded and uncoded form

Independent variables Name	Code	Coded levels				
		−2	−1	0	1	2
		Actual levels				
Wheat bran (%)	X1	0.4	0.5	0.6	0.7	0.8
Maltodextrin (%)	X2	1	2	3	4	5
Coagulation temperature (°C)	X3	65	70	75	80	85
Amount of citric acid solution (ml)	X4	150	165	180	195	210

samples for sensory quality. The samples were served to the panelists and they were asked to evaluate the *paneer* on 9-point hedonic rating for appearance, taste/flavor, body and texture, mouthfeel and overall acceptability.

Results and discussion

The parameters optimized using DESIGN EXPERT software is given in Table 1. The data obtained for textural properties viz. hardness, adhesiveness, springiness, cohesiveness, gumminess and chewiness of *paneer* determined by Texture Analyzer are given in Table 2 along with the experiment number. The average value of hardness of *paneer* varied from 792.49 g to 2992.47 g. It can be seen from Table 3 that

effect of maltodextrin on hardness was found significant ($P<0.1$) at linear level, whereas coagulation temperature was found significant ($p<0.05$), whereas interactive effect of wheat bran and amount of citric acid solution was found significant ($p<0.1$) on hardness of *paneer*. Figure 1 describes that as amount of citric acid solution was increased hardness increased linearly with it but as amount of wheat bran increased hardness first decreased then increased. Wheat bran had highly significant effect on hardness at quadratic level ($P<0.01$). Positive coefficient of quadratic term of wheat bran indicated that hardness was minimum at centre point. The average adhesiveness of *paneer* varied from -46.625 g.sec to -4.774 g.sec. It can be seen from Table 3 that interaction of maltodextrin with amount of citric acid solution had significant ($P<0.1$) effect on adhesiveness. From Fig. 2 it is evident

Table 2 Instrumental textural quality of low-fat fiber-supplemented paneer

Experiment No.	Textural responses					
	Hardness (g)	Adhesiveness (g.sec)	Springiness	Cohesiveness	Gumminess	Chewiness
1	921.7±171.5	-24.6±21.1	0.58±0.038	0.51±0.027##	465.7±83.0	272.5±61.7
2	1315.2±68.5	-23.9±15.8	0.75±0.023	0.45±0.036	586.7±35.2	441.0±32.8
3	1814±132.9	-19.7±4.9	0.62±0.028	0.42±0.014	767.2±75.3	471.4±25.9
4	1094.94±89.0	-17.1±3.8	0.66±0.024	0.35±0.021	381.1±13.8	251.2±10.5
5	1211.3±122.6	-27.3±12.6	0.67±0.046	0.37±0.028	453.5±64.1	302.7±43.2
6	1837.3±59.9	-9.4±3.5	0.71±0.024	0.46±0.01	843.5±39.4	597.5±9.1
7	1863.2±125.4	-27.9±17.4	0.70±0.05	0.43±0.014	802.6±27.0	561.4±58.9
8	1302.3±32.5	-45.1±21.4	0.70±0.05	0.39±0.022	502.7±9.2	346.4±18.1
9	1859.8±113.4	-13.9±1.0	0.69±0.009	0.45±0.014	838.0±37.3	574.3±18.3
10	911.9±22.3	-32.2±1.0	0.60±0.04	0.48±0.009	432.4±2.0	258.4±16.5
11	1817.8±86.3	-12.9±0.6	0.71±0.007	0.42±0.019	756.5±57.8	539.9±41.3
12	1665.1±141.1	-14.1±4.03	0.67±0.046	0.44±0.03	735.9±113.8	487.5±57.0
13	1866.9±59.8	-30.0±3.7	0.69±0.019	0.47±0.012	877.2±33.1	609.3±32.7
14	1077.9±98.0	-46.6±4.1#	0.72±0.027	0.37±0.023	396.5±17.1	285.3±19.1
15	2992.5±5.5##	-31.5±14.3	0.75±0.036	0.38±0.034	1127.3±98.9##	847.3±35.9##
16	1989.7±38.7	-13.3±18.6	0.76±0.083	0.34±0.025#	683.6±39.9	519.3±53.0
17	1697.9±130.7	-14.2±15.4	0.63±0.023	0.44±0.047	740.1±109.1	463.1±63.4
18	2317.7±159.3	-20.1±5.3	0.70±0.007	0.35±0.019	804.4±64.6	560.9±49.7
19	1212.2±118.0	-27.9±16.9	0.70±0.011	0.44±0.017	526.3±40.2	365.8±22.3
20	1356.1±68.1	-22.2±7.5	0.66±0.022	0.42±0.013	568.2±15.8	373.6±9.0
21	792.5±75.4#	-21.8±3.9	0.69±0.024	0.39±0.019	310.6±43.4#	213.8±34.2
22	1802.7±87.9	-4.8±2.6##	0.76±0.01##	0.38±0.015	684.0±8.8	522.5±11.4
23	808.9±67.2	-24.0±1.2	0.55±0.022#	0.44±0.024	358.9±33.8	198.1±17.0#
24	978.9±103.2	-24.7±10.6	0.69±0.096	0.41±0.031	403.4±28.7	275.1±32.2
25	827.2±103.4	-22.2±5.2	0.64±0.107	0.48±0.023	394.7±31.2	252.5±59.3
26	1115.9±154.8	-22.8±14.5	0.64±0.068	0.43±0.031	476.8±79.5	306.1±82.2
27	925.6±82.2	-28.6±20.3	0.65±0.027	0.41±0.019	382.4±52.5	248.5±44.7
28	1075.9±22.3	-29.5±13.0	0.73±0.04	0.35±0.009	380.8±2.0	278.9±16.5
29	1008.4±51.3	-18.4±1.4	0.66±0.025	0.39±0.013	388.8±15.1	258.2±6.4
30	1344.9±106.5	-16.3±13.2	0.706±0.02	0.36±0.018	487.5±60.4	343.4±34.0

#Minimum value ##Maximum value (Mean ± S.D.)

Table 3 Regression analysis of textural properties of low-fat fiber-supplemented paneer

	Hardness		Adhesiveness		Springiness		Cohesiveness		Gumminess		Chewiness	
	Coefficients	P	Coefficients	P	Coefficients	P	Coefficients	P	Coefficients	P	Coefficients	P
Constant	1049.7	0.047**	-22.9	0.826	0.67	0.065*	0.4	0.657	418.5	0.102*	281.3	0.055*
X1	-79.7	0.339	-1.07	0.618	0.012	0.182	-0.015	0.136	-58.2	0.112	-33.2	0.199
X2	159.4	0.067*	1.58	0.464	0.003	0.714	-0.017	0.08*	39.5	0.27	29.1	0.256
X3	198.4	0.027**	-1.61	0.454	0.024	0.012**	-0.013	0.177	61.2	0.096*	57.9	0.03**
X4	131.7	0.124	-0.04	0.986	0.02	0.03**	-0.004	0.685	47.2	0.191	42.9	0.102*
X1X2	-107.3	0.295	1.16	0.659	-0.01	0.36	-0.006	0.689	-48.4	0.27	-39.9	0.206
X1X3	-18.7	0.852	1.14	0.664	-0.001	0.938	-0.0005	0.962	-8.9	0.835	-9.5	0.757
X1X4	-164.5	0.104*	-1.36	0.605	-0.022	0.050*	0.0004	0.970	-73.5	0.102*	-65.5	0.047**
X2X3	48.2	0.633	-2.21	0.403	0.005	0.663	0.007	0.527	14.2	0.740	17.2	0.577
X2X4	122.5	0.234	4.73	0.086*	0.015	0.156	0.0007	0.953	40.9	0.347	40.6	0.199
X3X4	37.7	0.708	-1.49	0.570	0.007	0.524	-0.0092	0.436	-4.9	0.907	1.8	0.953
X1 ²	277.1	0.002***	0.72	0.719	0.0004	0.964	-0.001	0.899	107.8	0.004***	72.5	0.007***
X2 ²	96.2	0.222	-1.27	0.529	0.004	0.607	0.008	0.384	51.5	0.131	36.8	0.131
X3 ²	99.5	0.207	1.69	0.403	0.016	0.054*	-0.003	0.779	39.0	0.244	36.5	0.134
X4 ²	-1.35	0.986	-1.09	0.588	-0.01	0.204	0.008	0.355	10.0	0.760	3.6	0.878
R ² (%)	69.74		35.96		67.83		42.84		64.83		68.74	
F value	2.47		0.6		2.26		0.8		1.97		2.36	
LOF	s		s		ns		ns		s		s	

***, **, * Significant at 1, 5 and 10 % level of significance respectively

ns non-significant, s significant

X1- Wheat bran, X2- Maltodextrin, X3- Coagulation temperature, X4- Amount of citric acid solution

Fig. 1 Interactive effect of wheat bran (A) and amount of citric acid solution (D) on hardness of paneer

Design-Expert® Software

Hardness

- Design points above predicted value
- Design points below predicted value

2992.47
792.49

X1 = A: A
X2 = D: D

Actual Factors

B: B = 0.00
C: C = 0.00

that with increase in percentage of maltodextrin adhesiveness also increased in a linear fashion but adhesiveness increased slowly with increase in amount of citric acid solution. The average value of springiness for *paneer* varied from 0.553 to 0.764 (Table 2). It can be seen from Table 3 that effect of coagulation temperature and amount of citric acid solution on springiness were significant ($P < 0.05$) at linear level, whereas interactive effect of wheat bran and amount of citric acid

solution was found significant on springiness of *paneer* at 10 % level of significance. It is evident from Fig. 3 that with the increase in amounts of wheat bran and citric acid solution there was increase in springiness in a linear manner. Quadratic term of coagulation temperature was significantly affecting the springiness of *paneer* ($P < 0.1$). Positive coefficient of quadratic term of coagulation temperature indicated that the springiness was found minimum at centre point. The average

Fig. 2 Interactive effect of maltodextrin (B) and amount of citric acid solution (D) on adhesiveness of paneer

Design-Expert® Software

Adhesive

- Design points above predicted value
- Design points below predicted value

-4.774
-46.625

X1 = B: B
X2 = D: D

Actual Factors

A: A = 0.00
C: C = 0.00

Fig. 3 Interactive effect of wheat bran (A) and amount of citric acid solution (D) on springiness of paneer

Design-Expert® Software

Springiness

● Design points above predicted value

○ Design points below predicted value

0.764

0.553

X1 = A: A

X2 = D: D

Actual Factors

B: B = 0.00

C: C = 0.00

cohesiveness of *paneer* varied from 0.344 to 0.507. It is evident from Table 3 that maltodextrin had significant ($P < 0.1$) effect on cohesiveness at linear level that may be due to the binding effect of maltodextrin. The average value of gumminess for

paneer varied from 310.598 to 1127.278. It can be seen from Table 3 that coagulation temperature had significant ($P < 0.1$) effect on gumminess at linear level. Positive coefficient of coagulation temperature indicated that the gumminess increased

Fig. 4 Interactive effect of wheat bran (A) and amount of citric acid solution (D) on gumminess of paneer

Design-Expert® Software

Gumminess

● Design points above predicted value

○ Design points below predicted value

1127.28

310.598

X1 = A: A

X2 = D: D

Actual Factors

B: B = 0.00

C: C = 0.00

with the coagulation temperature. Wheat bran with amount of citric acid solution affected gumminess significantly ($P<0.1$) gumminess at interactive level. It can be seen from Fig. 4 that there is a linear relationship between amount of citric acid solution and gumminess but in case of wheat bran as its amount was increased gumminess first decreased then increased. Wheat bran had highly significant ($P<0.01$) effect on gumminess at quadratic level. Positive coefficient of quadratic term of wheat bran indicated that the gumminess was minimum at centre level. The average chewiness data ranged between 198.131 and 847.307. It was observed from Table 3 that coagulation temperature ($P<0.05$) and amount of citric acid solution ($P<0.1$) were significantly affecting chewiness at linear level while their positive coefficients suggested that chewiness was increased with the increase in coagulation temperature and amount of citric acid solution added to the milk for coagulation. The effect of interactive terms of wheat bran and amount of citric acid solution was found significant ($P<0.05$). Figure 5 showed that with the amount of citric acid solution increased chewiness also increased but as amount of wheat bran was chewiness first decreased then increased. Effect of wheat bran had highly significant effect on the chewiness of *paneer* ($P<0.01$) at quadratic level. Positive coefficient indicates minimum value of springiness at centre point of wheat bran.

The data obtained for sensory properties viz. flavor, appearance, body and texture, mouth feel and overall acceptability of *paneer* determined by semi-trained panel are given

in the Table 4. The average flavor scores for *paneer* ranged between 6.1 and 8.4. It can be seen from Table 5 that wheat bran, maltodextrin, coagulation temperature and amount of citric acid solution were not significantly affecting the flavor of *paneer* at linear and interactive levels. However, wheat bran was significantly affecting flavor at quadratic level ($P<0.05$). Negative coefficient of quadratic term of flavor indicated that maximum score for flavor could be obtained at centre point. Table 4 shows that the average appearance scores for *paneer* ranged between 5.8 and 8.4. From Table 5, it can be observed that the effect of wheat bran, maltodextrin, coagulation temperature and amount of citric acid solution was insignificant at linear level and interactive level, but at quadratic level, wheat bran had highly significant effect ($P<0.001$) on appearance of product. Negative coefficient of quadratic term of wheat bran indicated that maximum score for appearance could be obtained at centre point.

Average values for body and texture varied from 5.9 to 8.6 (Table 4). Table 5 shows that wheat bran, maltodextrin, coagulation temperature and amount of citric acid solution were insignificant at linear and interactive levels. Only wheat bran was affecting body and texture significantly ($P<0.1$) at quadratic level and negative coefficient of quadratic term of wheat bran indicated that maximum score for body and texture could be obtained at centre point. Average mouth feel scores varied from 6.3 to 8.6. Table 5 shows that wheat bran, maltodextrin, coagulation temperature and amount of citric acid solution were

Fig. 5 Interactive effect of wheat bran (A) and amount of citric acid solution (D) on chewiness of paneer

Design-Expert® Software

Chewiness

● Design points above predicted value

○ Design points below predicted value

847.307

198.131

X1 = A: A

X2 = D: D

Actual Factors

B: B = 0.00

C: C = 0.00

Table 4 Sensory quality of low-fat fiber-supplemented paneer

Experiment No.	Sensory responses				
	Flavor	Appearance	Body and texture	Mouth feel	Overall acceptability
1	7.6±0.65	7.4±0.65	6.9±0.22	7.1±0.65	7.2±0.57
2	7.2±0.76	7.35±0.49	7.3±0.91	7.35±0.60	7.35±0.60
3	7.9±0.42	7.7±0.27	7.8±0.27	8.0±0.27	8.0±0.2
4	7.3±0.84	7.8±0.76	7.3±0.57	7.2±0.84	7.4±0.65
5	8.4±0.65**	8.4±0.42**	8.6±0.42**	8.6±0.42**	8.5±0.5**
6	7.1±0.74	7.1±1.02	6.5±1.58	6.7±0.67	6.9±0.65
7	6.9±0.74	7.2±1.25	6.9±1.75	7.1±0.89	6.9±1.14
8	7.6±0.65	7.9±0.42	8.3±0.27	7.9±0.22	8.0±0.37
9	7.4±0.42	7.7±0.67	7.4±0.22	7.3±0.27	7.4±0.22
10	6.7±0.57	6.8±0.57	6.3±0.76	6.5±0.87	6.5±0.87
11	7.7±0.67	7.5±0.5	7.5±0.5	7.5±0.5	7.5±0.5
12	7.2±0.84	7.3±0.27	7.3±1.1	7.3±0.67	7.3±0.67
13	7.7±0.45	7.5±0.37	7.8±0.27	7.8±0.27	7.7±0.25
14	7.6±0.42	7.5±0.71	7.35±0.86	7.2±0.76	7.5±0.35
15	7.5±1	7.6±0.82	7.7±0.67	7.5±1	7.5±1
16	7.1±0.55	7.3±0.45	7.0±0.35	7.1±0.42	7±0.35
17	6.1±1.2 *	5.8±1.3*	5.9±1.1*	6.3±1.48*	5.9±1.14*
18	7.0±0.79	7.0±0.71	7.4±0.89	7.2±0.76	7.1±0.65
19	7.6±0.55	7.9±0.55	7.9±0.74	7.7±0.67	7.9±0.55
20	7.2±0.45	7.0±0.61	7.4±0.27	7.0±0.71	7.0±1.35
21	7.2±0.42	7.7±0.45	7.2±0.5	7.0±0.45	6.6±0.55
22	7.4±0.45	7.7±0.67	7.5±0.57	7.3±0.22	7.5±0.37
23	7.2±0.76	7.0±0.57	6.7±0.71	7.1±0.72	7±0.35
24	7.3±0.42	7.2±0.27	7.5±0.94	6.9±0.72	7.3±0.7
25	7.6±0.83	8.2±0.57	7.5±0.76	7.5±0.72	8±0.5
26	8.2±0.45	7.7±0.71	7.9±0.74	8.0±0.5	8.0±0.72
27	7.3±0.79	7.5±0.82	7.1±0.91	7.5±0.94	7.3±0.45
28	8.0±1.5	7.9±1	7.7±0.96	7.5±0.84	7.8±0.74
29	7.8±0.76	8.1±0.42	7.9±0.65	7.9±0.65	8.0±0.71
30	7.1±1.2	7.6±0.55	7.8±0.57	7.6±0.65	7.7±0.57

*Minimum value **Maximum value (Mean ± S.D.)

found insignificant at linear and interactive levels. But wheat bran was affecting mouth feel significantly ($P<0.1$) at quadratic level and negative coefficient of quadratic term of wheat bran indicated that maximum score for mouth feel could be obtained at centre point. The average values of overall acceptability scores for *paneer* ranged between 5.9 and 8.5. It is noticed from Table 5 that wheat bran, maltodextrin, coagulation temperature and amount of citric acid solution were found insignificant at linear and interactive levels. But wheat bran was affecting overall acceptability significantly ($P<0.05$) at quadratic level. Negative coefficient of quadratic term of wheat bran indicated that maximum score for overall acceptability could be obtained at centre point.

Based on the above mentioned criteria the optimization was carried out. From optimization, 47 solutions were

obtained, out of which the one that suited the criteria most was selected. The most suitable optimum point was having wheat bran at 0.54 %, maltodextrin at 1 %, coagulation temperature of 80 °C, amount of citric acid solution 187.35 ml, overall acceptability with sensory score of 8.43 and hardness with 1779.8 g. The values for textural attributes viz. hardness, adhesiveness, springiness, cohesiveness, gumminess and chewiness obtained for fresh optimized *paneer* samples were 1270.75 g, −18.799 g.sec, 0.689, 0.374, 471.65, 325.12, respectively. Sensory quality of optimized fresh *paneer* samples was determined. The average scores for the flavor, general appearance, body and texture, mouth feel and overall acceptability obtained for fresh *paneer* samples were 7.6, 7.7, 7.9, 7.8 and 7.9 respectively.

Table 5 Regression analysis of sensory properties of low-fat fiber-supplemented paneer

	Flavor		Appearance		Body & Texture		Mouth Feel		Overall acceptability	
	Coefficients	P	Coefficients	P	Coefficients	P	Coefficients	P	Coefficients	P
Constant	7.68	0.623	7.83	0.362	7.66	0.848	7.68	0.786	7.82	0.600
X1	-0.063	0.526	0.017	0.864	-0.01	0.937	-0.079	0.470	-0.015	0.901
X2	-0.05	0.611	-0.054	0.580	0.027	0.838	-0.009	0.939	-0.048	0.683
X3	0.054	0.582	0.038	0.701	0.12	0.359	0.092	0.404	0.14	0.244
X4	-0.038	0.702	-0.054	0.580	0.015	0.912	-0.088	0.426	-0.048	0.683
X1X2	0.11	0.382	0.16	0.186	0.2	0.221	0.15	0.270	0.15	0.295
X1X3	0.069	0.568	0.006	0.958	-0.028	0.862	-0.031	0.815	0.022	0.879
X1X4	-0.006	0.958	-0.056	0.638	-0.1	0.527	-0.019	0.888	-0.059	0.680
X2X3	-0.18	0.145	-0.1	0.407	-0.15	0.371	-0.16	0.251	-0.18	0.211
X2X4	0.044	0.716	-0.013	0.917	-0.022	0.893	0.006	0.963	-0.016	0.913
X3X4	0.056	0.64	0.019	0.875	0.022	0.893	0.025	0.851	0.041	0.777
X1 ²	-0.23	0.021**	-0.3	0.004***	-0.22	0.087*	-0.18	0.09*	-0.27	0.025**
X2 ²	-0.012	0.891	-0.041	0.657	0.029	0.817	-0.025	0.807	-0.024	0.823
X3 ²	-0.044	0.634	0.028	0.758	-0.046	0.708	-0.081	0.429	-0.12	0.266
X4 ²	-0.056	0.541	-0.12	0.194	-0.11	0.385	-0.11	0.278	-0.099	0.370
R ² (%)	44.04		52.91		34.82		37.78		44.81	
F value	0.84		1.2		0.57		0.65		0.87	
LOF	ns		ns		s		s		s	

***, **, *Significant at 1, 5 and 10 % level of significance respectively

ns non-significant, s significant

X1- Wheat bran, X2- Maltodextrin, X3- Coagulation temperature, X4- Amount of citric acid solution

Conclusions

On the basis of above findings it may be concluded that an acceptable quality *paneer* can be prepared by addition of wheat bran as dietary fibre source and maltodextrin as a fat replacer. Being low in fat and supplemented with dietary fibre, the *paneer* may have tremendous market potential on account of low cost and the numerous health benefits.

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