Effect of ingredients and processing parameters on the sensory, instrumental colour, texture and microstructure of *Pinni*

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Abstract: *Pinni* is an immensely popular traditional milk-cereal based sweet of northern states of India. Ingredients for production of *pinni* are ghee, wheat flour, sugar, pulses and *khoa*. In the production of *pinni*, slight variations in the processing parameters such as level of wheat flour, ghee, powdered sugar and roasting time can affect the quality significantly. Hence, these processing parameters were standardized using response surface methodology (RSM) and their effect on texture, microstructure, physico-chemical and sensory attributes of *pinni* was studied. The solution having maximum desirability of 0.773, corresponding to 44.99 parts of wheat flour, 35.62 parts of ghee, 24.99 parts sugar and 9.06 min roasting time was selected as optimized condition for *pinni* preparation. Scanning electron microscopy study effectively described the changes occurred in protein and starch particles of *pinni* during different stages of production.

Keywords: Instrumental colour, Microstructure, *Pinni*, Sensory, Texture analysis

Introduction

Pinni, is a traditional Indian milk based sweetmeat popular in Northern India. Wheat flour-*khoa pinni* is the most common *pinni* variant prepared in household as well as by small scale manufactures. It is prepared by roasting wheat flour with *khoa* and sugar (Talwar and Brar, 2015). Like many other traditional sweets, the practice of *pinni* making has largely remained a cottage scale operation by the local sweetmeat makers (*halwais*). Being prepared at small scale, the hygienic conditions are usually not maintained and thus inferior quality products are manufactured and marketed. At the same time due to lack of any prescribed standards laid down by the food standards authority, quality in terms of proximate composition, texture and microbiological counts varies a lot. Recently in order to tap the potential of traditional sweet markets, several dairies in organised sector have started their production. Also the changing economic scenario offers new opportunities to Indian dairy industry, particularly organized sector, for expanding their product profile. Many of these traditional milk products such as *gulab jamun*, *rasogolla*, *ras mamai*, *mishti doi*, *shrikhand*, *basundi* etc. which were manufactured at small scale in specific geographical locations, have been introduced in other parts of the Indian subcontinent. These products are also being exported to countries have large Indian ethnic population. Despite the fact that it is one of the common and popular traditional dairy products of northern India sporadic information is available regarding manufacturing process and chemical composition of *pinni*. Response Surface Methodology (RSM) is one of the popular optimization methods with vast application in optimizing food product production conditions because it can describe the combined effects of ingredients and processing parameters (independent variables) on the quality attributes (responses) of resultant product. Rathod and Khamrui (2015) used RSM to model instrumental texture profile of reduced calorie *peda* (a *khoa* based sweetmeat) as a function of ingredients and found that textural parameters like hardness, resilience, cohesiveness, etc could be accurately predicted by four ingredient factors viz., whey protein concentrate, maltodextrin, sucralose, and sorbitol. Nalwade et al. (2014) used RSM to study the effect of ingredients on colour profile of dietetic *sandesh*. Similar work of using RSM as an

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optimization tool was carried out for functional *chhana-murki* (Gurditta et al. 2014) and for *cham-cham* (Puri et al. 2015).

Scanning electron microscopy (SEM) is a well established technique for the study of surface topology and to develop correlations between the structure and the physical appearance of various food materials. Microstructure studies have been carried out using SEM for many Indian indigenous dairy products. Kalab et al. (1988), while studying the microstructure of *paneer*, found a uniform, dense protein matrix resembling a cottage cheese structure. Researchers utilized this advanced instrument to study the surface topology of Indian milk product, such as cow and buffalo milk *rasogolla* (Adhikari et al. 1992), *khoa* (Patil et al. 1992) and *Cham – cham* (Puri et al. 2016) ----- etc. Adhikari et al. (1993) while studying the microstructure of *Gulab Jamun* observed that frying of *khoa* in clarified butterfat resulted in the enlargement of the voids, producing a loose matrix having starch particles interlinked loosely with the agglomerated protein bodies and the clumped fat globules cemented in it (i.e., *gulabjamun*). Scanning electron microscopy (SEM) has been a useful tool for investigating the microstructures of cereal grains, wheat flours and derived products (Fannon et al. 1993; Gallant et al. 1997).

The present work deals with optimization of various process parameters of *pinni* viz., amount of wheat flour, ghee, sugar and roasting time. Also to study the effect of these parameters on sensorial attributes, instrumental color values, hardness and fracurability of *pinni* using RSM and to understand the microstructure developments using scanning electron micrographs (SEM) at high magnification in *pinni* at various stages of its production i.e., after addition of *khoa*, sugar as well as in the final product.

Materials and Methods

Materials

Fresh pooled buffalo milk (7.5% fat and 9.0% SNF) obtained from Institutes' cattle yard was received in clean, sanitized and dry aluminium can.

Preparation of *khoa*

Buffalo milk was standardized to 6.5% fat and 8.5% SNF (w/w) using buffalo cream (70% fat). *Khoa* samples used for the preparation of *pinni* were prepared using the method of De (2004). *Khoa* had moisture, protein, fat, lactose and ash content of 32.2%, 19.2%, 24.3%, 20%, and 3%, respectively.

Preparation of *pinni*

Batch approximately 2 kg of *pinni* was prepared in triplicate for each experiment. Ghee was taken in a heavy bottom pan heated up to 90°C wheat flour was added. Roasting of wheat flour was done at 90°C till typical roasted flavour and slight brown color

was developed. The *khoa* was added accompanied by continuous stirring to break the large lumps into small granules. Roasting was continued and sugar was added and stirred to properly mix the ingredients. After this stage heating was discontinued and the mixture was allowed to cool to room temperature (30°C) and then manually moulded into shape of ball approximately 25 g each. The wheat flour, ghee, powdered sugar, and roasting time were varied according to RSM runs being conducted (Table. 2 a, b). While the part of *khoa* kept constant of 20 % of total weight of product.

Sensory Evaluation

During response surface methodology (RSM) sensory evaluation of *pinni* was carried out in terms of flavor, body & texture and colour & appearance using a 9-point Hedonic scale. Seven member of trained sensory evaluation panelist constituted from the faculty of Dairy Technology Division, National Dairy Research Institute, Karnal performed the sensory evaluation. Sensory evaluation was carried out in individual booths where an intact piece of *pinni* (tempered to 30°C) was presented in random three-digit codes in closed glass containers. Samples were served monadically with deionised water. Each panelist offered independent observation on randomized samples of *pinni*.

Colour measurement

Colour measurements were conducted using Color Flex (Hunter Associates Laboratory, Inc., Reston VA, USA) colour measurement system equipped with dual beam xenon flash lamp and universal software. The results were represented by the L*, a*, b* notation. It is a 3D colour presentation method in which L* is the lightness index of colour and equals 0 for black and 100 for white, a* value is redness and greenness index (0 to 60), while b* value is the yellowness (0 to 60) or blueness (0 to - 60) index.

Hardness and Fracturability

Stable Micro System Texture Analyser, Model No:- TAXT2i; as described in Khamrui and Solanki (2010) Fitted with a 25 kg load cell was used to measure hardness and fracturability of cylindrical samples of *pinni* measuring 15mm height and 20mm diameter. Samples tempered to 25°C were compressed to 70% of its initial height using a aluminium make 75mm diameter compression plate (P-75), maximum force exerted by the sample, i.e., the peak of the force-time curve was measured as hardness (N) and fracturability is a force at the first significant break at the TPA curve. The texture analyzer settings that were employed to determine the textural attributes were; program: return to start, load cell: 25 kg, probe type: P-75 compression plate; pre-test, test, and post-test speed: 2 mm/s trigger type: auto, trigger force: 5 g, threshold: 50 g, time: 2 S data acquisition rate: 250 pps. This measurement was performed in triplicate on the three random samples of a batch.

Scanning Electron Microscopy

Specord-200 spectrophotometer (Thermospectronics Inc., Rochester, USA) with wavelength range of 190-1100 nm was used for measuring absorbance during chemical analysis, when needed. The *pinni* samples were cut into 2 X 2 X 2 mm³ pieces and promptly washed 3-4 times in distilled water (37-40°C). Fixation was carried out according to the method of Kalab et al. (1988).

Experimental design and statistical analysis

A four factor five level Central Composite Rotatable Design (CCRD) was selected to optimize the process using quadratic model. The four independent variables coded as X_1 , X_2 , X_3 , and X_4 were, wheat flour: 40-45, ghee: 32-38, sugar: 20-25 parts, and roasting time: 8-14 min respectively. The levels of independent variables were decided on the basis of preliminary trails. Table 1 represents coded and actual levels of the four design factors. A total of 30 experiments

Table 1 Coded and actual levels of wheat flour (gm), ghee (gm), sugar (gm) and cooking time (min)

Factor	Level				
	Axial Point	Factorial point	Centre point	Factorial point	Axial point
Coded levels	-2	-1	0	+1	+2
Wheat Flour	37.5	40	42.5	45	47.5
Ghee	29	32	35	38	41
Sugar	17.5	20	22.5	25	27.5
Time	5	8	11	14	17

Table 2 (a) Sensory scores of *pinni* prepared with different combination of processing variables

Std run	Flavour (Mean±SD)	Body and Texture (Mean±SD)	Colour and Appearance (Mean±SD)	Sweetness (Mean±SD)	Overall Acceptability (Mean±SD)
1	8.45±0.71	5.8±0.45	6.7±0.50	8.35±0.56	8.25±0.55
2	6.59±0.22	7.45±0.61	7.6±0.84	7.59±0.56	7.5±0.57
3	7.96±0.35	7.5±0.45	7.5±0.67	8.40±0.51	8.4±0.27
4	5.99±0.42	7.9±0.55	7.5±0.35	6.99±0.74	6.7±0.50
5	6.78±0.57	7.35±0.57	7.35±0.65	7.78±0.42	7.25±0.49
6	6.18±0.45	7.1±0.37	7±0.34	7.18±0.50	7.34±0.27
7	6.49±0.35	7.5±0.56	7.7±0.60	7.49±0.57	7.65±0.22
8	5.25±0.57	6.95±0.84	6.4±0.97	6.25±0.84	6.35±0.45
9	7.47±0.42	7.3±0.74	7±0.67	8.45±0.45	8.20±0.65
10	5.07±0.34	6.85±0.42	6.95±0.61	6.07±0.45	6.9±0.21
11	5.03±0.42	7.15±0.65	7±0.76	6.03±0.27	6.95±0.49
12	2.6±0.71	7.2±0.55	6.8±0.45	3±0.67	3±0.35
13	8.01±0.74	7.2±0.51	6.7±0.74	8.1±0.75	8.35±0.66
14	7.27±0.45	7.05±0.50	7.85±0.27	8.3±0.22	7.8±0.42
15	4.88±0.49	6.95±0.27	6.65±0.42	5.8±0.35	5.45±0.00
16	5.15±0.45	7.1±0.22	6.9±0.76	6.15±0.42	6.85±0.42
17	7.34±0.3	7.4±0.37	7.5±0.54	8.34±0.66	7.45±0.18
18	5.34±0.49	7.5±0.49	7.2±0.27	6.34±0.57	6.34±0.34
19	8.13±0.35	7.3±0.74	6.9±0.50	8.3±0.57	8.3±0.60
20	8.42±0.55	7.4±0.57	7.3±0.89	8.25±0.45	6.95±0.60
21	5.21±0.22	6.9±0.42	7.2±0.57	6.21±0.82	7.15±0.42
22	5.86±0.65	7.4±0.54	6.9±0.70	6.9±0.57	6.85±0.57
23	6.83±0.34	7.35±0.72	7.4±0.72	7.83±0.37	7.35±0.61
24	5.02±0.69	7±0.50	7.4±0.79	6.02±0.34	6.45±0.45
25	6.92±0.37	7±0.60	7±0.60	7.9±0.27	7.15±0.40
26	6.03±0.55	6.75±0.84	7.5±0.84	7.03±0.27	7.45±0.42
27	7.2±0.50	7.4±0.82	7.2±0.82	8.2±0.76	8.14±0.76
28	5.92±0.42	6.95±0.51	6.9±0.42	6.92±0.45	6.85±0.42
29	6.93±0.42	7±0.42	7.4±0.61	7.93±0.45	7.35±0.37
30	4.67±0.57	6.4±0.35	6.7±0.87	5.8±0.35	5.6±0.27

were carried out in randomized order. It was assumed that the response (Y) i.e., the dependent variables is a function of the experimental factors, (independent variables) i.e. $Y = f(X_1, X_2, X_3, X_4)$. Second order polynomial models were developed by multiple regression technique for each of the response:

$$Y = \hat{a}_0 + \hat{a}_1 X_1 + \hat{a}_2 X_2 + \hat{a}_3 X_3 + \hat{a}_4 X_4 + \hat{a}_{12} X_1 X_2 + \hat{a}_{13} X_1 X_3 + \hat{a}_{14} X_1 X_4 + \hat{a}_{23} X_2 X_3 + \hat{a}_{24} X_2 X_4 + \hat{a}_{34} X_3 X_4 + \hat{a}_{11} X_1^2 + \hat{a}_{22} X_2^2 + \hat{a}_{33} X_3^2 + \hat{a}_{44} X_4^2 + \hat{a}$$

Where, $\hat{a}_0$ is the intercept, $\hat{a}_1, \hat{a}_2, \hat{a}_3$ and $\hat{a}_4$ are first order coefficients; $\hat{a}_{12}, \hat{a}_{13}, \hat{a}_{14}, \hat{a}_{23}, \hat{a}_{24}$ and $\hat{a}_{34}$ are the interaction (cross point) coefficients; $\hat{a}_{11}, \hat{a}_{22}, \hat{a}_{33}$ and $\hat{a}_{44}$ are second order coefficients and $\hat{a}$ is random error. The partial regression coefficients of parameters taken into consideration are represented in Table. 3 and are described using significance at 1 and 5% levels of confidence.

The optimization of variable levels was achieved by desirable maximization of the necessary responses such as colour and appearance, flavour, sweetness, body and texture, overall acceptability and whiteness index (L^* value) along the fitted quadratic models by numerical optimization procedure of Design Expert VR 8.0 software. The effect of change in the processing variables on the response parameters i.e., flavour, body and texture, color and appearance, sweetness, overall acceptability, L^* value, a^* value, b^* value, hardness and fracturability are represented in response plots in Fig. 1 and 2.

Results and Discussion

Effects of factors on sensory attributes

Successive regression analyses were conducted to obtain quadratic models for various sensory responses of *pinni* viz., flavour, body and texture, colour and appearance and overall acceptability score. The effects of different factors on sensory attributes of *pinni* were assessed by the regression coefficients of the second order polynomial equations (Table. 3).

Flavour is an important criterion for deciding the quality of any food product, which in turn determines its consumer acceptability. The sensory scores for the flavour of *pinni* ranged between 2.6 – 8.45 (Table 2, a). Wheat flour, ghee and sugar had significant ($p < 0.05$) positive influence on the score revealing that increasing of wheat flour in ghee resulted in higher flavour scores of product. Linear positive significant ($p < 0.05$) effect of wheat flour and ghee on flavour scores of *pinni* is shown in Fig 1. Milk fat has been known to provide rich and mellow flavour to the dairy products. Similar observations was reported by Reddy (1992), and found increase in flavour score of plain *peda* and brown *peda*, respectively; with an increase fat content.

Particularly for heat desiccated solid products like *peda*, *burfi*, *pinni* etc body and texture is one of the most important

characteristics that determine the overall acceptability. *Pinni* should have moderately hard body and granular texture. The body and texture score of the experimental samples varied from 5.8 to 7.9. The partial coefficients of regression model revealed that the linear ($p < 0.01$) and quadratic terms ($p < 0.05$) of ghee was negatively significant, which means with increasing ghee, body and texture score of *pinni* decreased. Decrease in ghee content helped to retain compact body and firmer texture of the product and higher levels rendered the product greasy and softer. Fig 1 depicts the quadratic effect of ghee on body and texture score the surface plot being upwardly concave.

Colour and appearance scores of *pinni* ranged from 6.4 to 7.85 (Table 2, a). Wheat flour had positive effect on ($p < 0.01$) effect on colour and appearance score of *pinni*. The response surface plot (Fig 1) of colour and appearance score as function of wheat flour levels indicated that the same increased throughout the entire range of wheat flour levels. Pagote and Rao (2012) reported light brown to dark brown in *khoa jalebi*, a fried product made from heat desiccated milk product *khoa* and soaked in sugar syrup after deep fat frying.

It could be seen from the Table 2 (a) that a wide variation in sweetness score of *pinni* was observed and it ranged from 3.0 to 8.45. Table 3 reveal that linear effect of wheat flour, ghee and sugar had significant ($p < 0.05$) positive effect on sweetness of *pinni*. It means increase in sugar and wheat flour content also increase the sweetness score of *pinni* as shown in Figure 1.

Overall acceptability is the most important and deciding parameter of sensory quality of any product in totality and measures overall effect colour and appearance, flavour, body and texture on sensory acceptance. Overall acceptability is an important criterion for deciding the final acceptability by the consumer. The overall acceptability score of *pinni* ranged from 3.0-8.40. (Table 2, a). Wheat flour, ghee, sugar and roasting time had significant ($p < 0.01$) positive effect on overall acceptability score of *pinni*. Thus with increasing level of these variables overall acceptability of *pinni* increased (Fig. 1). While on other hand negative significant ($p < 0.05$) coefficient of interaction between time and flour as well as ghee suggested that overall acceptability of *pinni* increased with increasing flour and ghee percentage at lower level of roasting time, but at higher levels of roasting time opposite trend was observed. Each independent variables studied i.e, fat, sugar and germinated wheat flour showed a significant positive effect on overall acceptability attribute of *doda burfi*.

Effect of factors on colour value of *pinni*

L^* value indicates the lightness index of the product representing the surface characteristics and it depends on whether the surface reflects or absorbs light. L^* value of *pinni* varied from 45.10 to 58.14. Partial coefficients of regression model presented in Table 3 indicated that only flour level had significant ($p < 0.01$) linear

Fig.1 Response surface plots depicting effect of (a) Wheat flour and ghee on flavour score; (b) Ghee on body and texture score; (c) Ghee and flour on color and appearance score; (d) Sugar on sweetness score and (e) Ghee and flour on overall acceptability score of *pinni*

(a)

(b)

(c)

(d)

Fig. 2 Response surface plots depicting effect of (a) Wheat flour and sugar on L^* value; (b) flour on a^* value; (c) Ghee on b^* value; (d) Flour and ghee on hardness value and (e) Ghee and flour on fracturability value of *pinni*

(e)

effect on L* value (Fig 2). Thus, with the increasing level of flour, whiteness index of the product increased. Indrasinh et al. (2014) carried out Hunter colour lab analysis of dietetic *peda* samples. The L* value of the dietetic *peda* samples varied from 74.69 to 80.26. a* value of the *pinni* varied from 4.6 to 11.25. Flour, ghee and sugar had positive ($p<0.05$) effect on a* value of *pinni* at the linear level, revealing that the increasing level of flour, ghee and sugar a* value increased (Fig 2). The enhancement of a* value might be due to increase in extent of caramelization and Maillard browning reaction during roasting of the ingredients in ghee while preparation. Indrasinh et al. (2014) reported a* values of dietetic *peda* ranging from -5.00 to -3.07. Chawla et al (2010) reported a* values of *doda burfi* samples from 9.23 to 15.42. The b* value of the *pinni* varied from 23.22 to 29.04 (Table 2, b), indicating it was slightly yellowish tinge. Indrasinh et al. (2014) reported b* value of the dietetic *peda* varied from 18.53 to 23.73. The significant ($p<0.01$) positive effect of *ghee* on b* value of *pinni* at the linear level revealed that increasing the level of ghee

b* value increased (Fig 2) and negative effect of sugar on b* value revealed that increasing the level of sugar, b* value decreased.

Effect of processing parameters on instrumental Texture Profile Analysis (TPA) of *pinni*

Hardness of *pinni* varied from 9.25 N to 32.54 N (Table 2, b). Flour ($p<0.01$) and roasting time ($p<0.05$) had significant positive effect on hardness of *pinni* revealing that with increased levels of wheat flour and cooking time, hardness of *pinni* increased. *Ghee* has significant ($p<0.01$) negative linear effect on hardness (Fig 2). Also the negative significant ($p<0.05$) coefficient of interaction between ghee and sugar suggested that hardness of *pinni* increased with increasing ghee percentage at lower level of sugar, but at higher levels of sugar opposite trend was observed. Greater retention of moisture at lower sugar level might which led to decrease in the hardness of *pinni* because the hardness of any

Table 2 (b) Instrumental colour values, hardness and fracturability value of *pinni* prepared with different combination of processing variables

Std run	L* Value (Mean±SD)	a* Value (Mean±SD)	b* Value (Mean±SD)	Hardness in N (Mean±SD)	Fracturability in N (Mean±SD)
1	51.7 ± 0.14	11.25 ± 0.04	27.93 ± 1.02	12.73 ± 1.77	7.34 ± 1.71
2	54.66 ± 0.05	8.59 ± 0.08	25.01 ± 0.17	27.57 ± 1.78	16.74 ± 1.12
3	57.92 ± 0.05	9.96 ± 0.15	26.52 ± 0.23	29.7 ± 0.58	17.21 ± 1.55
4	55.27 ± 0.07	7.99 ± 0.35	24.57 ± 0.50	18.47 ± 2.99	15.9 ± 1.07
5	54.34 ± 0.10	8.78 ± 0.33	24.73 ± 0.67	25.4 ± 1.36	17.21 ± 1.29
6	53.99 ± 0.38	8.18 ± 0.06	25.51 ± 0.14	23.24 ± 1.97	19.57 ± 1.00
7	56.28 ± 0.05	8.49 ± 0.05	26.23 ± 0.33	29.72 ± 2.66	17.89 ± 0.62
8	45.31 ± 0.20	7.25 ± 0.16	26.77 ± 1.02	11.65 ± 1.12	6.1 ± 1.43
9	56.94 ± 0.12	9.47 ± 0.06	24.74 ± 0.10	18.29 ± 1.28	10.9 ± 1.43
10	51.37 ± 0.25	7.07 ± 0.11	24.74 ± 0.18	12.57 ± 3.04	7.85 ± 1.63
11	50.77 ± 0.10	10.42 ± 0.10	25.17 ± 0.10	18.72 ± 1.51	10.73 ± 1.81
12	45.47 ± 0.05	4.6 ± 0.06	23.22 ± 0.07	19.71 ± 1.11	13.88 ± 1.67
13	48.7 ± 0.12	10.01 ± 0.11	26.58 ± 0.28	10.95 ± 1.33	6.49 ± 2.35
14	54.56 ± 0.11	9.27 ± 0.06	29.04 ± 0.27	20.23 ± 1.01	9.38 ± 1.85
15	48.52 ± 0.19	6.88 ± 0.09	25.45 ± 0.19	28.35 ± 1.32	16.21 ± 1.80
16	47.31 ± 0.14	7.15 ± 0.04	26.68 ± 0.07	9.25 ± 1.83	6.19 ± 1.60
17	51.3 ± 0.11	9.34 ± 0.14	26.67 ± 0.10	17.09 ± 3.90	8.58 ± 3.49
18	52.09 ± 0.39	7.34 ± 0.54	24.96 ± 0.50	32.54 ± 1.03	22.88 ± 3.16
19	48.17 ± 0.06	10.13 ± 0.05	24.13 ± 0.43	25.7 ± 1.69	18.21 ± 1.36
20	53.98 ± 0.06	9.2 ± 0.12	24.36 ± 0.20	20.07 ± 0.82	15.68 ± 0.27
21	58.14 ± 0.11	7.21 ± 0.24	26.16 ± 0.26	32.06 ± 0.70	18.58 ± 1.59
22	45.10 ± 0.02	7.86 ± 0.09	26.6 ± 0.15	15.22 ± 1.78	10.06 ± 0.46
23	52.82 ± 0.42	8.83 ± 0.09	26.39 ± 0.10	16.31 ± 1.82	7.49 ± 0.00
24	54.23 ± 0.10	7.02 ± 0.55	28.03 ± 0.22	20 ± 1.73	13.48 ± 1.88
25	53.78 ± 0.08	7.03 ± 0.16	24.91 ± 0.27	21.13 ± 1.40	15.21 ± 1.61
26	55.14 ± 0.05	8.03 ± 0.03	26.46 ± 0.07	19.55 ± 1.14	11.08 ± 1.93
27	51.9 ± 0.30	8.92 ± 0.10	26.76 ± 0.02	21.28 ± 0.28	17.46 ± 0.69
28	49.4 ± 0.05	7.92 ± 0.20	26.28 ± 0.62	16.93 ± 1.59	6.35 ± 1.57
29	55.27 ± 0.32	8.93 ± 0.09	27.17 ± 0.14	19.7 ± 1.94	11.15 ± 1.16
30	46.32 ± 0.44	6.67 ± 0.85	27.53 ± 0.41	10.53 ± 0.58	10.51 ± 1.55

Fig. 3 Scanning Electron Micrographs of processing changes in *pinni* after (a,b) addition of *khoa*, (c, d) addition of sugar, and (e, f) final stage Respectively

Table 3 Regression coefficients and ANOVA of the model for sensory, colour responses, hardness and fracturability of *pinni*

Partial coefficient	Flavour	Body & Texture	Colour & Appearance	Sweetness	Overall acceptability	L*	a*	b*	Hardness (N)	Fracturability in N
Intercept	6.96	7.28	7.23	7.54	7.33	52.43	8.96	25.71	19.10	12.53
A – Flour	0.52*	0.098 ^{NS}	0.30*	0.53*	0.48**	3.84**	0.52*	0.089 ^{NS}	3.45**	1.94**
B – Ghee	0.56*	-0.26**	-0.04 ^{NS}	0.53*	0.48**	0.065 ^{NS}	0.56*	0.81**	-4.53**	-3.62**
C – Sugar	0.48*	0.065 ^{NS}	-6.250E-003 ^{NS}	0.50*	0.50**	0.28 ^{NS}	0.48*	-0.48*	1.23 ^{NS}	0.62 ^{NS}
D – Time	0.21 ^{NS}	6.250E-003 ^{NS}	0.077 ^{NS}	0.23 ^{NS}	0.34*	0.35 ^{NS}	0.21 ^{NS}	0.38 ^{NS}	1.61*	0.79 ^{NS}
AB	0.059 ^{NS}	-0.022 ^{NS}	3.125E-003 ^{NS}	7.500E-003 ^{NS}	-0.053	-0.41 ^{NS}	0.059 ^{NS}	-0.12 ^{NS}	0.84 ^{NS}	0.10 ^{NS}
AC	-0.36 ^{NS}	-0.034 ^{NS}	-0.016 ^{NS}	-0.39 ^{NS}	-0.37	-0.43 ^{NS}	-0.36 ^{NS}	-0.25 ^{NS}	-0.59 ^{NS}	-0.26 ^{NS}
AD	-0.44 ^{NS}	-0.15 ^{NS}	0.016 ^{NS}	-0.47 ^{NS}	-0.44*	0.083 ^{NS}	-0.44 ^{NS}	0.36 ^{NS}	1.38 ^{NS}	0.50 ^{NS}
BC	-0.30 ^{NS}	0.078 ^{NS}	-0.059 ^{NS}	-0.33 ^{NS}	-0.12	-0.049 ^{NS}	-0.30 ^{NS}	-0.35 ^{NS}	-2.07*	-0.86 ^{NS}
BD	-0.51 ^{NS}	0.016 ^{NS}	0.059 ^{NS}	-0.57*	-0.62**	-0.31 ^{NS}	-0.51 ^{NS}	-0.17 ^{NS}	-0.27 ^{NS}	-0.48 ^{NS}
CD	-0.34 ^{NS}	3.125E-003 ^{NS}	0.053 ^{NS}	-0.37 ^{NS}	-0.30 ^{NS}	-0.40 ^{NS}	-0.34 ^{NS}	-0.22 ^{NS}	-0.93 ^{NS}	0.61 ^{NS}
A ²	-0.13 ^{NS}	5.729E-003 ^{NS}	-0.066 ^{NS}	-0.014 ^{NS}	-0.033 ^{NS}	-0.39 ^{NS}	-0.13 ^{NS}	0.20 ^{NS}	0.19 ^{NS}	-0.45 ^{NS}
B ²	0.044 ^{NS}	-0.14*	-0.066 ^{NS}	0.065 ^{NS}	0.054 ^{NS}	-0.32 ^{NS}	0.044 ^{NS}	0.15 ^{NS}	0.68 ^{NS}	0.41 ^{NS}
C ²	-0.33 ^{NS}	5.729E-003 ^{NS}	0.071 ^{NS}	-0.21 ^{NS}	-0.13 ^{NS}	0.32 ^{NS}	-0.33 ^{NS}	0.17 ^{NS}	0.96 ^{NS}	0.41 ^{NS}
D ²	-0.37 ^{NS}	-0.057 ^{NS}	-0.060	-0.26 ^{NS}	-0.096 ^{NS}	-0.12 ^{NS}	-0.37 ^{NS}	-0.18 ^{NS}	-0.51 ^{NS}	0.063 ^{NS}
R ²	0.7	0.6957	0.8352	0.74	0.81	0.9074	0.7073	0.7042	0.8666	0.7192
Adj. Pre.	7.74	7.017	8.566	8.929	11.04	13.511	7.740	6.390	9.551	6.260
PRESS	68.15	6.91	2.55	59.86	40.71	185.85	68.15	61.83	842.83	692.04
Model F- Value	2.59	2.45	5.43	3.15	4.63	10.50	2.59	2.55	6.96	2.74
lack of fit	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

food product is inversely related to its moisture content (Khamrui and Solanki, 2010). A softening effect of wheat flour as a result of the increased moisture content of *khoa*, used for making *pinni*, has also been reported by earlier workers for *peda* (Patel et al. 1990).

Fracturability is the force with which the sample crumbles cracks or shatters (Bourne, 2002). Fracturability of *pinni* varied from 6.1 to 22.88 N. Wheat flour ($p < 0.01$) had significant positive effect on fracturability of *pinni* revealing that with increased levels of wheat flour fracturability of *pinni* increased (Fig 2). Ghee has significant ($p < 0.01$) negative linear effect on fracturability i.e., increase ghee level in *pinni* preparation resulted in decrease in fracturability.

Optimization of ingredient and processing parameter for *pinni*

The RSM data were used to work out optimized solution primarily based on sensory rating. The optimization command of the Design Expert 8.07.1 software was used in order to achieve the best combination of the processing variables. Sensorial attributes viz., colour and appearance, flavour, sweetness, body and texture, overall acceptability and whiteness index (L^* value) was taken as the criteria for optimization and were maximized keeping a^* value, b^* value, hardness and fracturability of *pinni* in range. The combination having 44.99 part wheat flour, 35.62 ghee, 24.99 part sugar and 9.06 min roasting time yielded highest desirability of 0.773 hence was selected as the optimised solution for preparation of *pinni*. The final recipe of *pinni* was 35.50% wheat flour, 28.11% ghee, 19.72% sugar, 16.67% *khoa* and 9.06 min roasting time.

Microstructure of *pinni*

Microstructure developments in *pinni* at various stages of its production i.e., after addition of *khoa*, sugar as well as the final product were studied using scanning electron micrographs (SEM) at high magnification. As can be observed from Fig 3 (a,b), severe heating of *khoa* in ghee might have altered its structural make-up by shattering the interlinkages of the heat coagulated protein agglomerates, producing a weak matrix in *pinni*.

After addition of sugar change of appearance in the sense that starch granules from wheat flour are more embedded into the gluten (protein) matrix, as shown in Fig. 3 c and d, which are pictures taken after mixing of sugar. The starchy materials and the fat globules might have acted as weak plasticisers among the protein agglomerates in *pinni*. Close examination of flour particles revealed a tight, nonporous compact structure, with no air spaces. Here individual flour particles can still be recognized as broken-up endosperm tissue. Lentil shaped and round starch grains can be seen clearly. Surrounding the starch grains and distinctly different from the starch is a structural element with rough, broken and curled edges; this is the proteinaceous matrix. Observation of the SEM images showed irregularly shaped particles of different

sizes (Fig 3 e, f). Individual flour particles can be recognized as broken-up endosperm tissue in final stage of *pinni*. Lentil-shaped and circular starch granules of various sizes, protein matrix, and adhesive protein areas attached to starch granule surfaces can also be observed.

The microstructure of *pinni* as a whole was characterized with loose matrix, uneven surfaces and thick protein complexes joined together. Frying of wheat flour and *khoa* in ghee resulted in a somewhat different structural manifestation as evidenced in *pinni*. The defatted matrix of *pinni* (Fig 3 e, f) showed agglomerated proteins and starch particles adhered loosely together and the protein and starch bodies stand out as the consequence of removal of fat (evident as void spaces) from the matrix during the sample preparation for SEM. During the preparation of sample for SEM, they were chemically dehydrated by passing through a graded series of alcohol-water mixture which resulted in removal of fat. The void spaces as evident from the photographs might have developed as a result of the fat extraction during sample preparation for electron microscopy. Microstructure of *khoa* revealed an agglomerated, dense, threaded protein bodies forming a ragged surface. The gritty, loose matrix of coagulated milk protein vanished completely during patting stage. Similar studies on *gulabjamun* (a product obtained by frying *khoa*, admixed with starch, in clarified butterfat and subsequently soaked in 60 % sugar syrup) also shows frying of *khoa* in clarified butterfat resulted in the enlargement of the voids, producing a loose matrix having starch particles interlinked loosely with the agglomerated protein bodies and the clumped fat globules cemented in it (Adhikari et al. 1993). Structural features of *khoa* were studied by light microscopy and electron microscopy. Freshly prepared cooled *khoa* had a granular structure consisting of protein granules several hundred micrometers in diameter (Patil et al. 1992).

Conclusions

The effect of wheat flour, ghee, powder sugar and roasting time on sensory, colour and texture responses of *pinni* was studied and its formulation was optimised using response surface methodology. In linear terms, wheat flour significantly influenced all the responses except body and texture and yellowness and blueness colour index. On the other hand ghee in linear terms also had significant effect on all responses except colour and appearances and L^* value. Wheat flour and ghee had significant ($p < 0.05$) positive influence on the flavour as well as on overall acceptability score. While ghee had negative influence on body and texture score. Furthermore, wheat flour had significant positive effect and ghee has negative effect on hardness as well as fracturability score of *pinni*. Agglomerated proteins and starch particles adhered loosely together and the protein and oval and round shaped starch bodies stand out in microstructure of *pinni* due to breakage of endosperm tissues. Severe heating during

preparation produced a weak matrix in *pinni* by shattering the interlinkages of the protein agglomerates.

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