Process optimization for manufacture of pearl millet-based dairy dessert by using response surface methodology (RSM)

Alok Jha · Abhishek Dutt Tripathi · Tanweer Alam ·
Rajendra Yadav

Revised: 15 March 2011 / Accepted: 17 March 2011 / Published online: 6 April 2011
© Association of Food Scientists & Technologists (India) 2011

Abstract *Kheer*, a cereal based dessert containing rice, milk and sugar as major ingredients, is very popular in India and South East Asian countries. A process for manufacturing a dairy dessert based on pearl millet and milk as main ingredients was optimized. During the investigation, the effect of different levels of dairy whitener and pearl millet, and temperature was studied by employing a 3 factor central composite rotatable design version 7.1.6. The best formulation with 18.49% dairy whitener and 6.0% pearl millet and a process temperature of 87.5 °C yielded 46.76% of the product on the basis of the dairy whitener used. This formulation was found to be most appropriate for manufacture of pearl millet-based *kheer* with predicted scores of 7.62, 7.05, 7.32, 6.97, 6.95 and 7.29 for grain to liquid ratio, consistency, sweetness, grain texture, flavour and overall acceptability respectively.

Keywords Pearl millet · Response surface methodology · Dairy dessert

Introduction

Kheer is a heat-desiccated cereal-based sweetened, condensed and nutritious Indian dairy dessert. It is preferably made from buffalo milk. In addition to milk, *kheer* contains

substantial amounts of non-dairy ingredients such as rice/wheat/*makhana*, sugar, raisins, coconut powder, flavoring agents like saffron, cardamom and dry fruits such as almonds, pistachio. Pearl millet (*Pennisetum typhoides*; Hindi Synonym: *bajra*) is the sixth most important cereal in the world which is widely cultivated in Asia, Africa and the USA. In India, pearl millet is cultivated in 13.64 million ha and the production is more than 7 million tonnes. It is one of the important coarse cereals and is a source of staple food for rural population. Commonly, it is consumed in traditional forms like *chapatti*, rolls. It is also used as feed for animals. It is a rich source of proteins, minerals and fibers (Singh and Shurpalekar 1989; Narwade et al. 2003). Pearl millet contains up to 8% fat, which is more than that in wheat, rice, barley, sorghum and maize (Rooney 1978; Lai and Varriano-Marston 1980). It contains 11.6% protein, which is higher than that in rice (7.2%) barley (11.5%), maize (11.1%) and sorghum (10.4%). It also has more minerals (2.3%) than rice, barley, maize and sorghum. It has less fibre content (1.2%) than wheat, barley, sorghum and maize (Desikachar 1975). Its protein efficiency ratio is higher than that reported for wheat and sorghum (Pushpamma et al. 1972). There is a need to develop more value added products and processes to enable optimal utilization of pearl millet as a source of nutrients and as a replacement of rice and wheat (Mani et al. 1955). In this regard, conversion of pearl millet into convenience food products in combination with milk could add value to dairy desserts and help product diversification for both agricultural and dairy foods. In view of the growing importance of utilization of coarse cereals in our day to day foods, present research was undertaken to optimize production of pearl millet-based Indian dairy dessert (*kheer*) using a statistical software tool namely response surface methodology (RSM). Validation of predicted and actual value was done in order to get the best

A. Jha (✉) · T. Alam · R. Yadav
Department of A. H. & Dairying, Banaras Hindu University,
Varanasi 221 005, India
e-mail: alok_ndri@rediffmail.com

A. D. Tripathi
Centre of Food Science and Technology,
Banaras Hindu University,
Varanasi 221 005, India

quality of pearl millet-based *kheer* in terms of sensory perceptions. RSM was used earlier to optimize the various parameters in the production of food products with desired quality (Henika 1972; Henselman et al. 1974; Castro et al. 2000; Kurien and Mishra 2008).

Materials and methods

Pearl millet (PM) var; Kalyanpur was procured from local market. Reconstituted milk was standardized to 3.5% fat and 9% SNF by using dairy whitener (DW), a commercial milk powder (Amulya brand), containing partly skim milk powder (SMP) and sugar. Three levels of dairy whitener (5–18%), different levels of pearl millet (5–7%) and three different temperatures (85° to 95 °C) were used in the investigation. Central composite rotatable design (CCRD) provided 20 trials, which were conducted to obtain a combination of selected parameters for production of the best quality pearl millet-based *kheer*.

Preparation of pearl millet-based *kheer*

After milling and dehulling, pearl millet was ground in a hammer mill. Husk was separated by winnowing and the millet washed thrice with water. The millet was presoaked in water in the ratio of 1 : 6 for 6 h followed by precooking (93 °C for 45 min) in a vessel. The reconstituted milk (DW: water, 1:4) was heated gently to boiling. The precooked pearl millet and sugar were then added and the slurry was cooked (90±5 °C for 30±5 min) while stirring continuously until desired consistency was obtained. After that, it was unloaded from the vessel and allowed to cool at 10 °C. Detailed procedure of manufacture of pearl millet-based *kheer* along with mass balance is given in Fig. 1.

The yield of pearl millet based *kheer* was estimated by using the following formula.

$$\text{Yield Per cent} = \frac{\text{Weight of } kheer}{\text{Weight of reconstituted milk}} \times 100$$

Chemical characteristics of pearl millet-based *kheer*

All chemical analyses were carried out in triplicate. Moisture, total solids, fat, sugar, lactose and ash contents of the product were analysed by the method given in AOAC (1990). Protein content of the sample was determined by Kjeldahl method (IDF 2001).

Sensory characteristics of pearl millet-based *kheer*

Sensory quality of pearl millet-based *kheer* samples was judged by a panel of 8 judges. The *kheer* samples of each

trial were evaluated for sensory attributes viz., appearance, grain-to-liquid ratio (GLR), consistency, grain texture, sweetness, flavour and overall acceptability based on 9-point hedonic scale (Amerine et al. 1965) with slight modifications.

Statistical analysis

Analysis of data generated during the present investigation was carried out using RSM by employing central composite rotatable design. The experimental data obtained from the design were analyzed by the response surface regression procedure using the second-order polynomial equation.

$$Y_i = \beta_0 + \sum \beta_{iix} + \sum \beta_{iix21} + \sum \beta_{iixji}$$

Regression analysis for different models indicated that the fitted quadratic models accounted for more than 80% of the variations in the experimental data, which were significant.

Results and discussion

Optimization of parameters

All main effects, linear, quadratic and interaction effects were calculated for each model. Fig. 2 shows the response surface plot for various sensory parameters. The sensory scores were influenced by different levels of dairy whitener and pearl millet (Table 1). With increasing level of dairy whitener, the sensory score of GLR in the pearl millet *kheer* increased upto 15%, beyond which, the score tended to decline due to the presence of excess grains (Fig. 2a). From the response surface plot (Fig. 2a) for GLR, it was observed that GLR score is influenced by pearl millet levels. It can also be seen that with increasing levels of dairy whitener, the sensory score of GLR is also increased in the pearl millet *kheer* upto 12.5% of dairy whitener.

Proximate composition of pearl millet-based *kheer*

The chemical composition of pearl millet-based *kheer* prepared by using 18.49% of dairy whitener and 6.0% of pearl millet was determined and the results are presented in Table 2. The total solids content of pearl millet *kheer* was 38.23±0.98%. Slightly lower total solids contents (32.26±0.23%) were earlier reported for *kheer* prepared from safflower and buffalo milk (Narwade et al. 2003). The fat, protein, carbohydrate and ash contents of the product were 6.38±0.23, 5.44±0.22, 14.69±0.68 and 1.23±0.15%, respectively. Total sugar content increased with increase in the content of DW, which contains sugar in significant amount.

Fig. 1 Flow chart for manufacturing pearl millet-based dairy dessert

Consistency

The consistency score was significantly affected by the increase in amount of DW (linear and quadratic terms) and pearl millet (linear term). The level of DW and PM was 10.51 and 6.0%, respectively and temperature was 87.5 °C, in experiment No.17, which scored minimum scores for sensory parameters while the experiment No. 8 having scored maximum points, had the corresponding levels of 18.49 and 6.0% and the temperature remained the same (Table 1). The coefficient estimates of consistency model (Table 3) showed that the DW, PM and temperature had a positive effect on consistency ($P < 0.01$). The interactive effects of the factors were non-significant ($P > 0.05$). It can be seen from Fig. 2b that by increasing the level of dairy whitener, the consistency score in pearl millet-based *kheer* has increased rapidly up to 6% of pearl millet at all temperatures but the maximum increment was found at 87.5 °C with increasing levels of DW up to 18.49%. This could be attributed to the increase in amount of DW as a source of total solids. In a similar study, Jha et al. (2002), reported an increase in consistency scores of rice-based *kheer* mix, as a result of increase in the amount of rice grains in the formulation.

Grain texture

The average grain texture score varied from 3.66 to 7.00 (Table 1). The minimum and maximum score was obtained for experiment Nos. 17 and 8, respectively. In experiment No. 17, the levels of dairy whitener, pearl millet and temperatures were 10.51%, 6.0% and 87.5 °C, respectively while the experiment No. 8 had the levels of dairy whitener, pearl millet and temperature as 18.49%, 6.0% and 87.5 °C, respectively. The coefficient estimates of grain texture model (Table 3) showed that the increased level of dairy whitener and temperature had a positive effect on the grain texture but only the level of dairy whitener had a significant effect ($P < 0.01$). It can be inferred from Fig. 2c that with increasing the level of dairy whitener, the grain texture score increased linearly at all levels of pearl millet, the trend being more perceivable at lower levels of pearl millet. The grain texture score increased rapidly with increasing levels of dairy whitener up to 13.5% and 6.0% of pearl millet. There was linear increment in grain texture score with the increasing level of dairy whitener up to about 10% at all levels of pearl millet. In a similar study on rice-milk based *kheer*, an increase in grain texture score was observed due to the presence of more rice grains (Jha et al. 2002).

Fig. 2 Response surface of grain to liquid ratio as influenced by level of dairy whitener and pear millet for pearl millet based *kheer*

These results are also in agreement with the findings of Singh and Shurpalekar (1989) who reported that *kheer* texture is affected by the amount of grain particles.

Sweetness

The coefficient estimates of sweetness score (Table 3) showed that pearl millet and temperature had insignificant effect on sweetness but the quadratic interactive terms (AB and AC)

depicts that in presence of dairy whitener pearl millet and temperature showed significant effect ($P < 0.01$) on sweetness of the product. The sweetness score increased rapidly with increasing levels of dairy whitener up to 15.0% at 7.0% of pearl millet (Fig. 2d). There was linear increment in sweetness score with the increasing level of dairy whitener up to about 10.0% at all levels of pearl millet. Similarly, with increasing level of dairy whitener, the sensory score of sweetness in the pearl millet *kheer* had increased rapidly

Table 1 Experimental runs and actual values of factors used in central composite rotatable design

	Variables			Sensory attributes scored on 9-point hedonic scale						Yield (%)
	Dairy Whitener (%)	Pearl millet (%)	Temperature (°C)	Grain to liquid ratio	Consistency	Grain texture	Sweetness	Flavor	Overall rating	
1	5.00	7.00	95.00	5.16	5.33	5.00	4.66	5.00	5.00	37.10
2	10.00	6.00	100.11	6.16	6.55	6.33	6.16	6.66	6.50	46.20
3	10.00	6.00	87.50	5.50	5.83	5.83	5.83	6.00	5.50	45.00
4	15.00	7.00	80.00	7.16	6.50	6.50	7.00	6.50	6.83	61.00
5	10.00	6.00	87.50	6.83	6.50	6.83	6.50	6.83	6.66	55.30
6	5.00	5.00	95.00	6.00	5.16	5.16	4.83	4.83	5.33	33.40
7	15.00	5.00	80.00	6.66	6.50	6.83	7.00	6.83	6.83	59.40
8	18.49	6.00	87.50	7.33	7.66	7.00	7.33	7.16	7.33	66.20
9	15.00	5.00	95.00	6.66	6.33	6.50	6.50	6.83	6.83	50.40
10	10.00	6.00	87.50	6.66	7.00	6.83	6.50	6.83	6.83	55.40
11	10.00	7.68	87.50	6.50	6.83	6.66	6.83	7.00	6.83	58.60
12	15.00	7.00	95.00	6.83	6.66	6.83	6.83	7.16	6.66	60.80
13	10.00	6.00	74.89	6.33	6.50	6.66	6.00	6.33	6.50	55.00
14	5.00	7.00	80.00	4.66	4.83	4.83	4.16	4.50	4.33	38.40
15	5.00	5.00	80.00	4.66	4.83	4.50	4.16	4.50	4.33	33.60
16	10.00	6.00	87.50	6.16	6.16	6.00	5.83	5.50	5.83	55.40
17	10.51	6.00	87.50	2.00	2.83	3.66	2.33	2.16	2.83	28.80
18	10.00	4.38	87.50	5.33	5.66	5.66	6.16	5.66	5.66	42.80
19	10.00	6.00	87.50	6.00	6.16	6.16	5.83	5.50	6.16	45.20
20	10.00	6.00	87.50	6.00	6.50	5.83	6.16	5.50	6.33	44.80

upto $15 \pm 0.25\%$ of dairy whitener at all levels of temperature. As the proportion of dairy whitener increased, the sweetness level also increased significantly. Earlier work of Singh and Shurpalekar (1989) showed that the sugar content of dairy whitener significantly affects the sweetness in *kheer*.

Flavour

The average flavour score varied from 2.16 to 7.16 (Table 1). The minimum score was observed for experiment No. 17, while the maximum score was observed in experiment Nos. 8 and 12. Experiment No. 12 had 15.0 and 7.0% of dairy whitener and pearl millet respectively

and temperature was 95 °C while in the experiment No. 8, the level of dairy whitener and pearl millet respectively was 15.0 and 7.0% and temperature was 87.5 °C. The regression analysis of experimental design demonstrated that the quadratic model term A^2 (Dairy whitener) was significantly negative ($P < 0.01$) while that of pearl millet and temperature were positive but non-significant, which shows that individual factors may not be influencing the sensory properties but it is the interaction between factors which affects a sensory attribute. Fig. 2e shows the response surface plot for flavour score as influenced by dairy whitener and pearl millet levels. It can be seen from Fig. 2e that with increasing level of dairy whitener, the flavour score increased linearly at all levels of pearl millet, the trend being more perceivable at lower levels of pearl millet. The maximum flavour score appeared to occur with levels of dairy whitener (15.0%) and pearl millet ($6.0 \pm 1\%$). It can be seen from Fig. 2e that with increasing level of dairy whitener, the sensory score of flavour in the pearl millet-based *kheer* increased rapidly upto 12.5% of dairy whitener at all levels of temperature. A sharp convergence of the curve near the boundary explains that addition of dairy whitener and pearl millet above certain limit would not contribute to increase in sensory attributes. Flavour scores increased by increasing level of total solids and fat

Table 2 Proximate chemical composition of pearl millet-based *kheer*

Constituents	%
Total Solids	38.23 $\pm$ 0.98
Fat	6.38 $\pm$ 0.23
Protein	5.44 $\pm$ 0.22
Sugar	9.45 $\pm$ 0.55
Lactose	5.24 $\pm$ 0.13
Ash	1.23 $\pm$ 0.15
Moisture	34.01 $\pm$ 0.11

Table 3 Coefficients of full second order polynomial model of coded factors for different levels of ingredients in pearl millet-based *kheer*

Factor	Coefficients						
	Grain to liquid ratio	Consistency	Grain texture	Sweetness	Flavor	Overall rating	Yield (%)
Intercept	6.18	6.37	6.09	6.11	6.03	6.22	50.27
A. Dairy whitener	1.16 ^b	1.02 ^b	0.94 ^b	1.31 ^b	1.24 ^b	1.15 ^b	11.13 ^b
B. Pearl millet	0.13	0.18	0.14	0.09	0.18	0.11	3.45 ^a
C. Temperature	0.09	0.06	0.02	0.05	0.15	0.11	−1.87
AB	0.19	0.02	−0.02	0.06	−0.02	0.02	0.44
AC	−0.27	−0.11	−0.10	−0.23	−0.02	−0.23	−0.96
BC	−0.15	0.06	0.02	0.02	0.10	−0.06	0.96
A ²	−0.46 ^b	−0.44 ^b	−0.31 ^b	−0.48 ^b	−0.49 ^b	−0.44 ^b	−1.54
B ²	−0.01	−0.08	−0.01	0.11	0.09	−0.02	−0.41
C ²	0.10	0.01	0.10	−0.04	0.16	0.06	−0.44

^a Significant at 5% level^b Significant at 1% level

content in dairy whitener used for *kheer* preparation. These results are in conformity with findings of earlier workers like Jha et al. (2002) and Narwade et al. (2003).

Overall acceptability

The average overall rating score varied from 2.83 to 7.33 (Table 1). The minimum score was obtained for experiment No. 17, while the maximum score was obtained in the experiment No. 8. In experiment No. 17, the level of dairy whitener and pearl millet was 10.51 and 6.0% respectively and temperature was 87.5 °C. The experiment No. 8 had 18.49 and 6.0% of dairy whitener and pearl millet, respectively and temperature was 87.5 °C. The coefficient estimates of overall score (Table 3) showed that quadratic model terms (A² and B²) were significant (P<0.01). However, the interactive effects of AB and AC were non-significant. Temperature showed positive effect, but was non-significant (P<0.01). With increment in level of dairy whitener, the sensory score for overall rating increased linearly at all levels of pearl millet, the trend being more

perceivable at lower levels of pearl millet (Fig. 2f). The significant increase in the score of overall rating appeared to occur with increase in all levels of dairy whitener (12.5%) and pearl millet (6%). It may be due to increase in total solids content in dairy whitener which positively affect on all sensory attributes of pearl millet-based *kheer* and a decline in overall acceptability score with increasing proportion of rice and decreasing milk solids in *kheer* was due to the decline in other sensory attributes. The findings of Singh and Shurpalekar (1989), Jha et al. (2002) and Narwade et al. (2003) also showed that the grain particle, milk solids and sugar content affects the overall acceptability of *kheer* and *kheer* like dairy desserts.

Conclusions

Optimization of levels of dairy whitener and pearl millet and temperature for manufacture of pearl millet-based *kheer* is predicted based on score of sensory quality using RSM package. Out of 8 suggested formulations, the formulation No.

Table 4 Predicted score of the suggested formulation of pearl millet-based *kheer* by Design Expert 7.1.6

No.	DW%	PM%	Temp °C	GLR	Consistency	Sweetness	Grain texture	Flavour	Overall rating	Yield%	Desirability
1	15.00	7.00	80.00	7.62	7.05	7.32	6.97	6.95	7.29	64.76	0.740
2	15.00	7.00	80.23	7.60	7.05	7.32	6.96	6.95	7.28	64.73	0.739
3	15.00	6.95	80.00	7.60	7.05	7.30	6.97	6.94	7.28	64.66	0.739
4	15.00	6.86	80.00	7.56	7.06	7.28	6.97	6.92	7.27	64.50	0.738
5	15.00	7.00	80.81	7.56	7.05	7.31	6.95	6.94	7.26	64.65	0.738
6	15.00	6.64	80.00	7.44	7.05	7.20	6.98	6.87	7.23	63.87	0.735
7	15.00	6.49	80.00	7.36	7.04	7.16	6.97	6.84	7.20	63.43	0.734
8	15.00	6.13	80.00	7.25	7.02	7.11	6.96	6.81	7.16	62.80	0.732

1 had better overall rating of 7.29 than all other formulations and also the desirability was 0.74, highest amongst all other formulations (Table 4). Hence, the formulation with 18.49% dairy whitener, 6.0% pearl millet and cooking temperature of 87.5 °C was considered to be the most appropriate for manufacturing pearl millet-based dairy dessert with the predicted scores of 7.62 for grain to liquid ratio, 7.05 for consistency, 7.32 for sweetness, 6.97 for grain texture, 6.95 for flavour, 7.29 for overall rating and 64.76% for yield. From these results, it could be concluded that pearl millet-based *kheer* can be manufactured by the dairy industry to promote value addition, export promotion and product diversification.

References

- AOAC (1990) Official methods of analysis, 15th edn. Association of official Analytical Chemists, Arlington
- Amerine MA, Pongborn RH, Roesler EB (1965) Principles of sensory evaluation of food. Academic, New York, pp 338–339
- Castro IA, Tirapegui J, Silva RSSF (2000) Protein mixtures and their nutritional properties optimized by response surface methodology. *Nutrition Res* 20:1341–1353
- Desikachar HSR (1975) Processing of maize, sorghum and millets for food uses. *J Sci Ind Res* 34:231–237
- Henika RG (1972) Simple and effective system for use with response surface methodology. *Cereal Sci* 39:943–946
- Henselman MR, Donatoni SM, Henika RG (1974) Use of response surface methodology in the development of acceptable high protein bread. *J Food Sci* 39:943–946
- IDF (2001) Determination of total nitrogen content—part 1: Kjeldahl method. IDF standard 20–1, Brussels, Belgium
- Jha A, Patel AA, Singh RRB (2002) Physico-chemical properties of instant *kheer* mix. *Lait* 82:501–513
- Kurien V, Mishra HN (2008) Modeling of acidification kinetics and textural properties in *dahi* (Indian yogurt) made from buffalo milk using response surface methodology. *Int J Dairy Technol* 61:284–289
- Lai CC, Varriano-Marston E (1980) Lipid content and fatty acid composition of free and bound lipids in pearl-millet. *Cereal Chem* 57:271–274
- Mani GS, Lilly G, Balasubramaniam SC, Basu KP (1955) Composition and nutritional value of some indigenous dairy products. *Ind J Medi Res* 43:237–242
- Narwade SG, Patil GR, Sontakke AT, Patil RA (2003) Preparation of *kheer* from safflower milk blended with buffalo milk. *Ind J Dairy Sci* 56:197–202
- Pushpamma S, Parrish DB, Deyoe CW (1972) Improving protein quality of millet, sorghum and maize diets by supplementation. *Nutr Rep Int* 5:93–100
- Rooney LW (1978) Sorghum and pearl millet lipids. *Cereal Chem* 55:584–590
- Singh B, Shurpalekar SR (1989) Studies on ready-mixed for *kheer*. *J Food Sci Tech* 26:12–17