Optimization of the formulation and technology of pearl millet based ‘ready-to-reconstitute’ *kheer* mix powder

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Abstract The objective of this study was to optimize the process of manufacturing instant *kheer* mix based on pearl millet instead of rice. Dairy whitener, pearl millet and powdered sugar were the responses studied by employing the 3-factor Central Composite Rotatable Design. The formulation with 15 g sugar, 30 g dairy whitener and 20 g pearl millet was found suitable for obtaining dry *kheer* mix. The analyses were based on scores of consistency, cohesiveness, viscosity and overall acceptability. The reconstituted product from the formulated *kheer* mix had an overall acceptability score of 7.66 and desirability index of 0.7663. The moisture, fat, protein, carbohydrate and ash contents of the dry mix product were 2.8, 4.38, 5.84, 85.88 and 1.1 %, respectively.

Keywords Pearl millet · *Kheer* · Optimization · Consistency · Cohesiveness · Viscosity index

Introduction

An estimated 50 to 55 % of milk produced in India is converted into a variety of traditional milk products including numerous dairy desserts. A variety of sweet desserts to suit different festive occasions are manufactured, mainly in unorganized sector across the country. One of the most common traditional dairy desserts is *kheer*. It is one such product which is offered on religious occasions, social functions and festivals. *Kheer* has evolved itself to suit regional and personal preferences (Kadam et al. 2011). It

is a semi solid cereal-based dairy dessert made by cooking rice with sugar or jaggery in milk till the point when rice starch gets gelatinized. The major ingredients of *kheer* are milk, sugar, rice, dry fruits and flavorings (Jha et al. 2011). The essential ingredients are milk and sugar, but recipe of *kheer* can be varied by replacing rice with vermicelli, semolina, and even carrot. Whole grain cereals or even beaten cereal products are used for *kheer* making. Consistency of *kheer* like desserts may vary from almost liquid to viscous semi-solid type products. Rice (Jha et al. 2002), *makhana* (Jha and Verma 2000) and cracked wheat i.e. *dalia* (Shalini et al. 2006) have been commonly used to make *kheer* but coarse cereals like pearl millet has rarely been used for developing such value added products. Usually, coarse cereals like pearl millet have been traditionally consumed in the forms like chapatti/rolls.

Pearl millet (*Pennisetum typhoideum* L.; Hindi Synonym: *Bajra*) is the sixth most important cereal crop valued for its food, feed and fodder uses in various parts of the world and it is widely cultivated in Asia, Africa and the USA (Abdelrahman and Hoseney 1984). India has the largest pearl millet growing area (9.8 million ha) in the world (Rai et al. 2008). In India and Africa, pearl millet grains are mostly used for food purposes. It is one of the important nutriceals and is a source of staple food for rural population. Pearl millet is a rich source of proteins, minerals and fibers (Singh and Shurpalekar 1989; Narwade et al. 2003). It contains 11.6 % protein, which is higher than that of rice (7.2 %), maize (11.1 %) and sorghum (10.4 %). It is richer in minerals (2.3 %) than that of rice (0.9 %), barley (1.2 %), maize (1.3 %) and sorghum (1.9 %). It has less fibre content (1.2 %) as compared to wheat (1.9 %), barley (3.9 %), sorghum (1.6 %) and maize (2.7 %) (Desikachar 1975; Maney and Shadaksharaswamy 2008). The amino acid profile of pearl millet is better than that of sorghum and maize

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and is comparable to that of wheat, barley, and rice (Ejeta et al. 1987; Hadimani et al. 1995; Abdalla et al. 1998; Malleshi and Klopfenstein 1998).

The most common traditional and health foods made from pearl millet are thin porridge (gruel); thick porridge (fermented and unfermented); flat, unleavened fermented bread such as *kisra*, *injera* and *dosa*; and unfermented bread viz., *chapati*. Singh and Sehgal (2008) developed a *ladoo* using popped pearl millet, dehulled chickpea and groundnut. Singh et al. (2000) developed a biscuit from blanched and malted pearl millet flour in combination with soybean flour in equal proportions, milk powder, fat, sugar and other minor additives. The product had higher mineral (calcium, iron, manganese and phosphorus) contents and improved in-vitro digestibility. Pearl millet grits and flour can be used to prepare ready-to-eat (RTE) products. Pearl millet blended with soya or protein rich ingredients such as legumes or groundnut cakes upon extrusion give nutritionally balanced supplementary foods (Malleshi et al. 1996). Sumathi et al. (2007) showed that extruded pearl millet products prepared from a blend of 30 % grain legume flour or 15 % defatted soybean had 14.7 and 16.0 % protein and 2 and 2.1 protein efficiency ratio respectively. Noodles, macroni and pasta like extruded products have been prepared from millet flour (Desikachar 1975).

Popped pearl millet is a good source of fiber, carbohydrates and energy. The popped millet is utilized mainly in developing formulations for food supplements or weaning foods (Bhaskaran et al. 1999). Fiber-regulated millet flakes could be an ideal snack for the obese and for calorie-conscious people (Hadimani and Malleshi 1993). These snack products are highly acceptable and having long shelf life. Cookies made from pearl millet flour do not spread during baking, had poor top grain character and were dense and compact (Badi et al. 1976). A *rabadi*-like fermented beverage using pearl millet with a shelf life of 7 days has also been developed (Modha and Pal 2011).

Several dry mixes based on rice, wheat, oat-based products etc., have been used in ready-to-reconstitute forms, with enhanced shelf life (Jha et al. 2002; Pelembe et al. 2002; Sadana and Chabra 2004; Mridula et al. 2008; Jha et al. 2011; Kadam et al. 2011). Pearl millet based *kheer* as ready-to-eat dessert has been prepared and reported to be liked by consumers (Jha et al. 2011). Many of these products have become popular due to ease of consumption, enhanced shelf life and close resemblance to the traditionally consumed dessert prepared at domestic level.

Response surface methodology (RSM) has been used to develop and optimize the processing parameters of several ready-to-eat and ready-to-reconstitute products. Attempts have been made earlier in applying RSM for optimizing the ready-to-eat pearl millet *kheer* dessert for obtaining a product with acceptable quality (Jha et al. 2011). Henselman

et al. (1974) used the RSM for high protein bread with acceptable quality. Wadikar et al. (2010) developed the ginger based ready-to-eat appetizers using RSM. Chakraborty et al. (2011) optimized the parameters on textural and overall acceptability of millet enriched biscuits using RSM.

The previously made pearl millet *kheer* was a ready-to-eat product which had limited shelf life (Jha et al. 2011). Therefore, it was decided to develop a pearl millet *kheer* dry mix, which had longer shelf life at ambient temperature and with improved reconstitution properties. It could be a new value added convenience product for dairy and food industry and offer value to the misquoted ‘poor man’s crop’ leading to product diversification too. It could prove to be a nutritionally superior and convenient health food for the consumers.

Materials and methods

Raw materials Pearl millet grains (*Pennisetum typhoides*) were obtained from Indian Agricultural Research Institute, New Delhi, India. Powdered sugar and dairy whitener (Everyday brand, Nestle India Pvt. Ltd., Moga; protein = 17.6 g/100 g, total carbohydrate = 50.9 g/100 g, sugar = 23 g/100 g and fat = 18.1 g/100 g) was used in the formulation of dry *kheer* mix. Dairy whitener has a insolubility index of 3 mL. Cardamom (*elaichi*) powder as a flavoring agent was procured from the local market of Varanasi, India.

Manufacture of pearl millet kheer mix Pearl millet grains were dehulled using wooden pestle and mortar with sprinkling of water to loosen its outer coat, followed by winnowing and washing with water thrice. Thereafter, these grains were spread to form a 1 cm thick layer and allowed to sun dry for 1 h and 45 min followed by autoclaving (TOMY SX-500, Japan, High Pressure Steam Sterilization System) at 121 °C for 15 min. Sterilization was done to soften the grains as it was to be used for the preparation of a ready-to-reconstitute products. Incubation at 35 °C for 30 min was done to dry the sterilized/moist products before incorporating in the dry mix. This was followed by dry blending of powdered sugar and dairy whitener with pretreated pearl millet grains. Cardamom was added @ 0.25 % of the finished product. Dry mix was packaged in polyethylene (PE) laminates (thickness: 350 gauge; grease resistance: very good; size of the pouches: 15 × 19 cm) under modified atmospheric condition (nitrogen flushing in gas mixer Model: MAP Mix 9001 MK, Make: PBI Densensor, Ringsted, Denmark) and after vacuum, nitrogen flushing was done by VAC-STAR* S 220 MP (Sugiez, Switzerland). Packaged dry mix was stored at 10 °C.

Detailed procedure for manufacture of pearl millet *kheer* mix along with mass balance is given in Fig. 1.

Reconstitution of pearl millet *kheer* mix into *kheer* Potable water was boiled in a pan and the contents of one pouch approx. (67 g) was added to it in the ratio of 1:5 (dry mix: water). Temperature of water was maintained at 90 °C for 5 min or till desired consistency was obtained; the product was gently stirred occasionally during the cooking process. Reconstitution of pearl millet-dry mix was also attempted at 25, 50 and 75 °C and the ratio between dry mix and water was also attempted at 1:2, 1:3, 1:4 and 1:6. Reconstituted product was allowed to cool to 25 °C before it was subjected to textural studies and sensory evaluation.

Chemical analysis As pearl millet *kheer* mix was a heterogeneous product consisting of pearl millet, dairy whitener, sugar and cardamom, was first mixed and then ground in a mixer (Model: HL 1632, Philips, New Delhi, India) before it was analysed. Moisture content was determined by oven-dry method (AOAC 1990) and ash content of the pearl millet *kheer* mix was determined by the standard procedure as given in AOAC (1995). Crude protein was determined by Kjeldhal method (IDF 2001) and crude fat was estimated using the automatic SOCS PLUS (SCS 4, Pelican Equipments,

Chennai, India) by employing the standard method AOAC (2000).

Textural analysis Textural properties of reconstituted pearl millet *kheer* were analyzed in terms of consistency, cohesiveness and viscosity index using Back extrusion rig probe as suggested by Singh and Shurpalekar (1989). These properties were measured by a Texture Analyzer (TA-XT Plus, Stable Micro Systems, Surrey, UK) using the following parameters: pre-test speed = 1 mm/s, test speed=1 mm/s, post speed=10.0 mm/s, distance= 20 mm and trigger force of 5 g. Mean value was used to obtain a force-time curve (XT Exponent Lite; Stable Micro Systems, UK) calculated as texture parameters at 25 °C. Consistency means as to how a material flows under its own weight during a given time interval, which is the area within curve during extrusion thrust. Cohesiveness is a ratio having relationship with the biting characteristics, a measurement of how well the structure of a product withstands compression, which is maximum force during withdrawal of probe from sample. The strength of internal bonds makes up the body of the product. Viscosity index (VI) is an arbitrary measure for the change of viscosity with temperature, which is denoted by the area within negative region of curve probe withdrawal.

Fig. 1 Process flow chart for the manufacture of pearl millet *kheer* dry mix

Sensory evaluation Freshly reconstituted *kheer* prepared from dry pearl millet *kheer* mix was evaluated for its sensory characteristics such as colour, flavour, body and texture, sweetness, consistency and overall acceptability (OA) scores based on 9-point Hedonic scale (Amerine et al. 1965) using semi-trained sensory panel consisting of 7 judges drawn from Centre of Food Science and Technology at Banaras Hindu University, Varanasi, India. Sensory evaluation was done at room temperature (25 °C).

Experimental plan Response surface methodology which involves design of experiments, selection of levels of variables in experimental runs, fitting mathematical models and finally selecting variables' levels by optimizing the response (Khuri and Cornell 1996) was employed in the study. A Central Composite Rotatable Design (CCRD) was used to design the experiments comprising of three independent processing parameters (Table 1). Twenty sets of experiments were performed taking into account 3 factors viz., levels of pearl millet, powdered sugar and dairy whitener (Table 2). There were 6 experiments at centre point to calculate the repeatability of the method (Ylimaki et al. 1988). A

good model must be significant and the lack-of-fit must be insignificant. Coefficient of determination (R^2) values should be close to 1. R^2 explains the percentage of the variability of the result. The predicted R^2 value should be in reasonable agreement with the adjusted R^2 . Adequate precision measures signal to noise ratio and was computed by dividing the difference between the maximum predicted response and the minimum predicted response by the average standard deviation of all predicted responses. Ratios greater than 4 are considered to be desirable, which indicated adequate signals to use this model to navigate the design space.

The present study was carried out for the optimization and the effect of these ingredients on the pearl millet *kheer* mix and also on the reconstituted *kheer*. This was based on the textural and sensory characteristics of the consistency, cohesiveness, viscosity index, body and texture, colour, flavour and mouth feel and also upon the OA score of the reconstituted *kheer* made from pearl millet dry *kheer* mix.

Data analysis The experiments were performed and responses were fitted in the design. After each individual experiment, responses were analyzed to assess the effect of independent variables on them. The first order or second order polynomial

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

Sr. no.	Variables			Responses					
	A (g)	B (g)	C (g)	Consistency (g.sec)	Cohesiveness (g)	Viscosity index (g.sec)	Colour	Flavour	OA score
1	16	31.02	22.5	2826.79	210.20	226.89	7.79	6.84	7.50
2	15	27	20	2776.35	101.28	114.81	6.43	6.73	7.50
3	17	30	25	1026.02	37.28	145.13	6.11	5.90	7.00
4	17	27	25	1058.70	62.41	108.15	5.69	5.35	7.00
5	17	27	20	1452.77	87.34	116.21	6.02	6.01	7.12
6	15	27	25	2359.18	90.08	131.77	5.89	6.08	7.25
7	16	25.98	22.5	1351.54	78.99	99.92	5.63	7.00	7.00
8	16	28.5	22.5	1416.04	48.37	132.56	6.31	6.25	7.25
9	17	30	20	1476.44	65.16	152.15	6.37	6.87	7.12
10	15	30	20	3902.01	280.20	253.14	6.49	6.78	7.75
11	16	28.5	26.70	1953.45	90.08	114.95	5.17	4.73	7.00
12	16	28.5	22.5	1733.15	56.92	131.71	6.19	6.93	7.12
13	16	28.5	18.30	1360.16	74.24	131.06	7.27	6.95	7.37
14	16	28.5	22.5	1311.39	52.06	139.99	6.21	6.99	7.12
15	15	30	25	3227.23	264.90	240.04	6.78	6.28	7.50
16	16	28.5	22.5	2155.81	114.27	134.49	6.37	6.25	7.25
17	14.31	28.5	22.5	3611.23	181.75	176.09	5.43	7.37	7.75
18	17.68	28.5	22.5	1021.20	40.55	109.99	6.69	5.87	7.00
19	16	28.5	22.5	1577.86	94.62	112.67	6.28	6.99	7.00
20	16	28.5	22.5	2324.46	130.21	140.79	6.22	6.93	7.25

A, B, C, OA = Sugar, dairy whitener, pearl millet, overall acceptability {Colour, Flavour, OA—Out of 9.0}

Table 2 Levels of responses fixed for optimization of pearl millet *kheer* mix

Constraints	Goal	Lower limit	Upper limit
A: Sugar	Minimize	15	17
B: Dairy whitener	Is in range	27	30
C: Pearl millet	Minimize	20	25
Consistency	Maximize	1021.2	3902.01
Cohesiveness	Maximize	37.28	280.2
Viscosity index	Is in range	99.92	253.14
Colour	Is in range	5.17	7.79
Flavour	Maximize	4.73	7.37
Overall acceptability	Maximize	7.00	7.75

Lower weight = 1, Upper weight = 1, Importance = 3

equation (Eq. 1) examines the statistical significance of the model and the following form was fitted to the responses:

$$Y = \beta_0 + \sum_{i=1}^4 \beta_i X_i + \sum_{i=1}^4 \beta_{ii} X_i^2 + \sum_{i=1}^3 \sum_{j=i}^4 \beta_{ij} X_i X_j \quad (1)$$

Where,

Y response variable
 $\beta_0, \beta_i, \beta_{ii}$ & β_{ij} regression coefficient
 X_i, X_j & X_{ij} coded independent variables

Numerical optimization technique of the Design-Expert software (8.0.5) was used for simultaneous optimization of the multiple responses. The desired goals for each factor and responses were chosen (Table 2). Responses obtained after each trials were analyzed to visualize the interactive effect of various parameters on sensory attributes and textural properties of reconstituted pearl millet *kheer*.

Results and discussion

Proximate composition and reconstitutability of the mix Pearl millet dry *kheer* mix could be reconstituted into *kheer* in just 5 min as compared to 40–45 min for making conventional rice-based *kheer* (Jha et al. 2002). However, reconstituted product did not dissolve well at 25, 50 and 75 °C and powder lumps were floating on the surface. Reconstitution in the ratio of 1:2, 1:3 and 1:4 yielded a product with unsatisfactory consistency. Product with 1:6 ratio of reconstitution was very thick and viscous. The average moisture, fat, protein, carbohydrate and ash contents of the pearl millet *kheer* mix were 2.80, 4.38, 5.84, 5.88 and 1.10 %, respectively. In another study Jha et al. (2011) reported a composition of 6.38 % fat, 5.44 % protein, 34.01 % moisture, 38.23 % total solids and 1.23 % ash for ready-to-eat pearl millet based dairy dessert.

Effect of process variables on textural properties of reconstituted *kheer*

Consistency Consistency represents flow of material under its own weight. It is also influenced by the variation in level of soluble solids. The linear equation obtained by the response surface analysis (RSA) of the data showing the effect of dairy whitener (D), powdered sugar (S) and pearl millet (P) is as follows:

$$\text{Consistency} = 9999.84348 - 849.88380 * S + 217.99884 * D - 27.49246 * P \quad (2)$$

The coefficient of determination (R^2) was 0.7840. The “Pred R-Squared” of 0.6613 was in reasonable agreement with the “Adj R-Squared” of 0.7435. “Adeq Precision” was 14.433 and greater than 4, which is the desirable value indicating an adequate signal. The consistency of the reconstituted *kheer* was found to be in the range of 1021.4–3902.01 g.sec (Table 1). The linear model for consistency was found to be significant ($P < 0.0001$).

It could be seen from Fig. 2a that consistency was mainly affected by the level of dairy whitener and sugar. The consistency of the product increased with the increase in the level of dairy whitener (30 g) and also with an increase in the level of powdered sugar (17 g), reconstitution temperature being 90 °C. Results were on expected lines as increase in solids level would normally lead to increase in consistency of reconstituted product. It could be due to the fact that increased level of sugar hampers the gelatinization of grains and starch does not get solubilized properly (Spices and Hoskeney 1982). In a similar study, Jha et al. (2011) too reported an increase in the consistency of pearl millet based *kheer* with increasing levels of dairy whitener. Pearl millet grain levels have been reported to have a significant effect on the consistency of *kheer*. In a similar study on rice-based *kheer*, it was shown that rice grains had a significant effect on the consistency scores of *kheer* (Jha et al. 2002).

Cohesiveness Cohesiveness is related with biting characteristics and strength of internal bonds which influences the body of the *kheer*. The quadratic equation obtained by the RSA of the data showing the effect of D, S and P could be presented as follows:

$$\begin{aligned} \text{Cohesiveness} = & -3841.03204 + 546.19085 * S \\ & - 37.05625 * D + 13.82023 * P \\ & - 33.42108 * S * D - 1.31545 * S * P \\ & - 0.23543 * D * P + 11.97063 * S^2 \\ & + 10.57581 * D^2 + 0.27543 * P^2 \end{aligned} \quad (3)$$

The coefficient of determination (R^2) was 0.9142. The “Pred R-Squared” of 0.7419 was in reasonable agreement with the “Adj R-Squared” of 0.8370. “Adeq Precision” was

Fig. 2 Effect of process variables on textural properties of pearl millet *kheer* mix; **a** Dairy whitener and sugar powder Vs consistency, **b** Dairy whitener and sugar powder Vs cohesiveness, **c** Pearl millet and sugar powder Vs cohesiveness, **d** Pearl millet and dairy whitener Vs cohesiveness, **e** Dairy whitener and sugar powder Vs viscosity index, **f** Pearl millet and sugar powder Vs viscosity index, **g** Pearl millet and dairy whitener Vs viscosity index

11.565 which was greater than 4, indicating an adequate signal. Hence, the model could be used to navigate the design space. The coefficient of estimation is presented in Table 3. Cohesiveness of reconstituted *kheer* ranged from 37.28 to 280.20 g for the 20 trials conducted as shown in Table 1.

The response surface plot as shown in Fig. 2b showed that with increasing level of dairy whitener (30 g), a significant increase in the cohesiveness of product was found. Increase in the level of powdered sugar (17 g) had a reverse effect on cohesiveness. As is evident from Fig. 2c, increased levels of sugar exerted greater negative effect on cohesiveness as compared to the effect exerted by pearl millet levels. Figure 2d showed that with an increase in the level of dairy whitener, the cohesiveness of product tended to increase.

Viscosity index Viscosity index is a measure of the change of viscosity with temperature. The quadratic equation obtained by the RSA of the data showing the effect of D, S and P is as follows:

$$\begin{aligned} \text{Viscosity index} = & -978.58992 + 191.62829 * S - 75.68634 * D \\ & + 43.59250 * P - 14.47292 * S * D \\ & - 0.94735 * S * P - 0.96743 * D * P \\ & + 6.81417 * S^2 + 6.22881 * D^2 - 0.044158 * P^2 \end{aligned} \quad (4)$$

The coefficient of determination (R^2) was 0.9601. The “Pred R-Squared” of 0.7777 was in reasonable agreement with the “Adj R-Squared” of 0.9241. “Adeq Precision” was 15.634 which is higher than 4, indicating an adequate signal.

Hence, this model could be used to navigate the design space. The coefficient of estimation is presented in Table 3. The viscosity index ranges from 99.92 to 253.14 g.sec (Table 1).

The response surface plot shown as Fig. 2e shows that with the increase in the level of dairy whitener, there was a considerable increase in the viscosity index. However, the viscosity index tended to decrease with increasing levels of sugar in the formulation. Higher levels of sugar exerted more negative influence on the viscosity index than the levels of pearl millet (Fig. 2f). A significant increase in viscosity index was observed with an increase in the levels of dairy whitener in the formulation (Fig. 2g). There was a slight increase in the viscosity index with increasing levels of pearl millet. Similar findings showing influence of dairy whitener and sugar on the texture of *kheer* has been reported by Jha et al. (2011).

Effect of process variables on sensory properties of reconstituted pearl millet based *kheer*

Colour The linear equation obtained by the Response surface analysis (RSA) of the data showing the effect of D, S and P is as follows:

$$\text{Colour} = 0.85874 + 0.052652 * S + 0.26129 * D - 0.1280 * P \quad (5)$$

The coefficient of determination (R^2) was 0.5238. The “Pred R-Squared” of 0.1281 is in reasonable agreement with the “Adj R-Squared” of 0.4345. “Adeq Precision” was 7.631 which is higher than 4, indicating an adequate signal. Hence, the model could be used to navigate the design space. The coefficient of estimation is presented in Table 3. The minimum and maximum colour score varied

Table 3 Coefficient of estimates of coded factors for different levels of ingredients in pearl millet *kheer* mix

Factor	Coefficient estimates					
	Consistency(g.sec)	Cohesiveness(g)	Viscosity index (g.sec)	Colour	Flavour	OA
Intercept	1996.09	82.45	131.59	6.27	6.73	7.17
A	-849.88	-52.85	-24.11	0.053	-0.36	-0.22
B	327.00	38.60	39.03	0.39	0.051	0.098
C	-68.73	-3.86	-2.81	-0.32	-0.43	-0.10
AB	—	-50.13	-21.71	—	0.23	-0.062
AC	—	-3.29	-2.37	—	-0.15	0.031
BC	—	-0.88	-3.63	—	-0.11	0.000
A ²	—	11.97	6.81	—	-0.059	0.075
B ²	—	23.80	14.01	—	0.047	0.031
C ²	—	1.72	-0.28	—	-0.33	7.533E-003

A, B, C, OA = Sugar, dairy whitener, pearl millet, overall acceptability

a)

b)

c)

e)

d)

f)

g)

Fig. 3 Effect of process variables on sensory properties of pearl millet *kheer* mix; **a** Dairy whitener and sugar powder Vs colour score, **b** Dairy whitener and sugar powder Vs flavour score, **c** Pearl millet and sugar powder Vs flavour score, **d** Pearl millet and dairy whitener Vs flavour score, **e** Pearl millet and sugar powder Vs overall acceptability score, **f** Pearl millet and dairy whitener Vs overall acceptability score, **g** Dairy whitener and sugar powder Vs overall acceptability score

from 5.17 to 7.79 on a 9-point hedonic scale (Table 1). The linear model for colour was found to be significant ($P < 0.0001$).

The response surface plot presented as Fig. 3a shows the effect of the levels of dairy whitener and sugar on the colour score of reconstituted *kheer*. It can be seen that increasing the levels of dairy whitener had a positive effect on colour scores. Sugar had the same effect as exerted by dairy whitener till being added in the range of 15 to 17 g.

Flavour The quadratic equation obtained by the RSA of the data showing the effect of D, S and P is as follows:

$$\begin{aligned} \text{Flavour} = & 21.22936 - 1.56495 * S - 2.99327 * D \\ & + 4.00118 * P + 0.15500 * S * D - 0.059000 * S * P \\ & - 0.028667 * D * P - 0.059013 * S^2 \\ & + 0.020912 * D^2 - 0.053566 * P^2 \end{aligned} \quad (6)$$

The coefficient of determination (R^2) was 0.8271. The “Pred R-Squared” of 0.1963 is in reasonable agreement with the “Adj R-Squared” of 0.6715. “Adeq Precision” was 7.940 which is greater than 4, indicating an adequate signal. “Adeq Precision” measures the signal to noise ratio. A ratio of 7.940 indicates an adequate signal and therefore this model could be used to navigate the design space. The coefficient of estimate presented in Table 3 showed that the quadratic model was significant ($P > 0.05$). Hedonic flavour score ranged from 4.73 to 7.37 (Table 1).

The response surface plot presented as Fig. 3b shows the effect of levels of dairy whitener and sugar powder on flavour score of reconstituted pearl millet *kheer*. It can be seen that increasing levels of dairy whitener (27 to 30 g) led

to increased flavor score. Response surface plot (Fig. 3c) shows the increasing level of sugar also led to increased flavour score of *kheer*. Figure 3d shows the effect of levels of pearl millet and dairy whitener on flavour score. It seems, SNF and fat content of dairy whitener had a major effect on sensory flavour scores. Flavour scores of reconstituted *kheer* increased slightly with increasing levels of pearl millet (20 to 25 g). Similar findings were earlier reported by Jha et al. (2002); Narwade et al. (2003) and Jha et al. (2011).

Overall acceptability The quadratic equation obtained by the RSA of the data showing the effect of D, S and P on overall acceptability score is shown below:

$$\begin{aligned} \text{Overall acceptability} = & 25.98440 - 1.70491 * S - 0.040900 * D \\ & - 0.29443 * P - 0.041667 * S * D \\ & + 0.012500 * S * P - 1.06832E \\ & - 015 * D * P + 0.074708 * S^2 \\ & + 0.013562 * D^2 + 1.20529E - 003 * P^2 \end{aligned} \quad (7)$$

The coefficient of determination (R^2) was 0.9318. The “Pred R-Squared” of 0.7633 is in reasonable agreement with the “Adj R-Squared” of 0.8704. “Adeq Precision” was 13.45 which is higher than 4, indicating an adequate signal. Hence, the model can be used to navigate the design space. The coefficient of estimation is presented in Table 3. The overall acceptability score ranged from 7.0 to 7.75 (Table 1). The coefficient estimates of overall acceptability score shown in Table 3 showed that quadratic model terms (A, B, C and A^2) were significant ($P < 0.05$).

The response surface plot presented as Fig. 3e shows the effect of levels of dairy whitener and sugar powder on overall acceptability (OA) score of *kheer*. Increasing the levels of dairy whitener had a positive effect on OA score. Similar effects were observed in response plot presented as Fig. 3f. There was a significant decrease in the OA score of

Table 4 Optimized solutions of pearl millet *kheer* mix with desirability by Design Expert 8.0.5

Sugar powder (g)	Dairy whitener (g)	Pearl millet (g)	Consistency (g.sec)	Cohesiveness (g)	Viscosity index (g.sec)	Colour	Flavour	OA score	Desirability
15.00	30.00	22.26	3179.59	259.94	237.66	6.64	6.22	7.66	0.7663
15.00	30.00	22.20	3181.27	259.99	237.76	6.64	6.21	7.67	0.7663
15.00	30.00	22.14	3182.84	260.03	237.85	6.65	6.21	7.67	0.7662
15.00	30.00	22.41	3175.43	259.84	237.42	6.62	6.24	7.66	0.7662
15.00	30.00	22.52	3172.29	259.77	237.23	6.60	6.26	7.65	0.7658
15.00	30.00	22.01	3186.34	260.13	238.05	6.67	6.18	7.68	0.7658
15.00	30.00	22.70	3167.39	259.68	236.94	6.58	6.28	7.64	0.7648
15.00	29.97	22.50	3166.33	257.07	235.50	6.60	6.27	7.65	0.7633

OA Overall acceptability

reconstituted *kheer* till the addition of 16 g of dairy whitener, beyond which the score remained almost constant with the further increase in the levels of dairy whitener. Likewise, there was a decline in OA score of *kheer* with increasing levels of addition of pearl millet up to 16 g, beyond which the scores remained unaffected (Fig. 3g). Out of 23 suggested formulations, formulation no. 1 had superior OA rating (i. e. 7.66) and highest desirability index (0.7663) compared to all other formulations (Table 4). Previous studies on pearl millet ready-to-eat *kheer* showed that OA score was largely dependent on level of pearl millet grain and level of dairy whitener (Jha et al. 2011). Singh and Shurpalekar (1989), Jha et al. (2002) and Narwade et al. (2003) also demonstrated that the rice grain particle, milk solids and sugar content affected the OA score of *kheer* and *kheer* like dairy desserts.

Conclusion

The optimized levels of powdered sugar, dairy whitener and pearl millet for the manufacture of the pearl millet based *kheer* mix were predicted based on consistency, cohesiveness, viscosity index and overall acceptability (OA) score using RSM. Out of 23 suggested formulations, formulation no. 1 had superior OA rating (i.e. 7.66) and highest desirability index (0.7663) compared to all other formulations. Hence, the formulation with powdered sugar (15 g), dairy whitener (30 g) and pearl millet (20 g) was considered most suitable for manufacturing pearl millet-based *kheer* dry mix, which could be then reconstituted into *kheer*. The predicted scores of 3241.7 g.sec for consistency, 262.96 g for cohesiveness, 241.07 g.sec for viscosity index and 7.66 for OA score were obtained. Developing such value-added products from coarse cereals often dubbed as ‘poor man’s crops’ could bring them to the regular dietary regime of consumers offering them nutritional benefits. This could also lead to product development leading to diverse uses of millet.

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