Optimization and Shelf-Life Evaluation of Pearl Millet Based Halwa Dry Mix

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Optimization and Shelf-Life Evaluation of Pearl Millet Based *Halwa* Dry Mix

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Abstract: Indian traditional sweet dish i.e. *halwa* was developed from pearl millet grains. Pearl millet grains (*Pennisetum typhoides* var. *PHB-2168*) were steamed for 20 min at 1.05 kg cm^{-2} in order to minimize lipase activity, total phenols, phytic acid and tannins content. Steamed grains were dried (12 ± 0.5% moisture content), pearled, milled, sieved through sieve opening size of 0.234 mm and were used for study. Central composite rotatable design (CCRD) with three independent variables i.e. *vanaspati*, sugar and water for rehydration were used to design the experiments. Sensory responses and rehydration ratio were used to study the individual and interactive effects of variables. Sensory score for colour varied from taste 6.3-7.9, mouth feel 6.4-7.8, overall acceptability (OAA) 6.5-7.9 and rehydration ratio (RR) from 1.4 to 2.3. All the responses fitted into quadratic equation with $R^2 > 0.80$. *Halwa* dry mix was also evaluated for stability in polyethylene pouches at ambient conditions and the peroxide and free fatty acids value were 21.35 $meqO_2$ kg^{-1} fat, 0.55% (oleic acid), respectively after 6 months of storage. Based on compromise optimization, optimum levels of the ingredients recommended with 86.4% desirability were: *vanaspati* 38.6 g 100 g^{-1} pearl millet semolina (PMS), sugar 88.7 g 100 g^{-1} PMS and water for rehydration 151 mL 100 g^{-1} dry mix.

Key words: Pearl millet, hydrothermal treatment, anti-nutritional factor, *halwa*, rehydration ratio.

1. Introduction

Several technologies have been developed to standardize and commercialize ready-to-eat (RTE) or easy-to-reconstitute (ETR) mixes of traditional or popular Indian foods. These products have been found microbiologically safe and organoleptically acceptable for periods ranging from 3 months to 1 year [1]. Dry mixes of several traditional Indian foods have gained worldwide popularity. These include instant *kadhi* mix [2], instant *khichadi* mix [3], instant *rava idli* mix [4], instant vegetable *pulav* mix [5] and instant *sooji upma* mix [6]. Some major factors for their popularity include rapid urbanization, industrialization and consequent changes in eating habits of people.

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Halwa, a delicious sweet preparation of north India, is rich in nutrients, especially fat and carbohydrates. Although it may be flour-based or nut-based, the most common forms of *halwa* are made from wheat flour semolina and known as wheat *sooji* (semolina) *halwa*. Instant *sooji halwa* mix [7] having shelf life of one year became very popular among the civilians and armed forces. Several unconventional ingredients such as soybean have been used for preparation of *halwa*. Yadav et al. [8] optimized soy-fortified instant *halwa* mix that had three times higher protein content than wheat *sooji halwa* and shelf life of more than six months at ambient conditions.

Response surface methodology (RSM) helps to optimize the levels of independent variables for desired product based on statistical and mathematical techniques. The RSM technique gives the effect of individual parameter as well as their interactive effect. Some products optimized using response surface methodology include sweet potato based pasta [9], *halwa* dry mix [8], baking parameters of *chapatti* [10], peanut curd [11] and *rabadi*-like fermented milk beverage using pearl millet [12].

Pearl millet (*Pennisetum typhoides)*, cultivated mostly in semi-arid parts of Africa and Asia, is major source of energy and proteins. India has pearl millet production of 8.59 MT [13] which is the highest in the world. The nutritive content of pearl millet is equivalent or even superior to those of other cereals [14]. Pearl millet has high amount of balanced protein and lipids as well as calcium, iron and zinc [15]. Being gluten free, pearl millet products can be conveniently used by celiac or people suffering from gluten intolerance. Despite the numerous potential benefits, this crop has limited commercial demand, especially in the urban areas. Consumer preference for pearl millet has fallen due to irregular supplies, rising incomes and rapid urbanization, and at present food habits of pearl millet eating people are changing towards rice and wheat products (milled rice, wheat flour etc.). In spite of high nutritional quality, it holds a secondary place in actual dietary system due to bitter taste, grittiness or difficulty to cook, shorter shelf-life of flour and presence of many anti-nutritional factors as well as lack of processing technologies. In order to realize the full potential of pearl millet as a food crop, there are possibilities for alternative uses of pearl millet in the preparation of convenience mixes.

Therefore, the present study was aimed to develop instant pearl millet *halwa* mix with an acceptable flavour in order to utilize the nutritive richness of pearl millet.

2. Materials and Methods

2.1 Raw Material

Pearl millet grains (var. *PHB-2168*), grown in the year 2010 were obtained from Punjab Agricultural University, Ludhiana, India. The grains were cleaned using Destoner (Model 6276, Indosaw, Ambala, India). The cleaned grains were stored in gunny bags at 10 ± 2 °C till further use. The other ingredients i.e. sugar, cardamom and cashew nuts were procured from the local market, cleaned and used. All reagents used for chemical analysis were of analytical grade and procured from Central Drug House, New Delhi, India.

2.2 Preparation of Pearl Millet Semolina (PMS)

Soaked pearl millet grains (10-12 h, moisture 30 ± 2%) were steamed for 20 min at 1.05 kg cm^{-2} in order to inactivate lipase activity and anti-nutritional factors [16]. Steamed grains were dried to 12 ± 0.5% moisture content and pearled in millet pearler (Mathesis Engineers, Hyderabad, India) upto 80% pearling efficiency. The pearled grains were passed through a pulverizer (Lakshmi Industries, Ludhiana) and sieved in a sieve shaker (Model 7290; Indosaw, Ambala, India) to obtain different sized particles. Based on pre-trials, the 0.234 mm sized particles were chosen for *halwa* preparation and mentioned as pearl millet semolina (PMS) throughout the manuscript.

2.3 Experimental Design

Response surface methodology was used to optimize the levels of *vanaspati* (vegetable fat), sugar and water for rehydration of PMS based *halwa* mix. After preliminary tests, upper and lower levels for these variables were established. A central composite rotatable design (CCRD) was prepared to select variables level i.e. *vanaspati* 35-45 g 100 g^{-1} PMS, sugar 85-95 g 100 g^{-1} PMS and water for rehydration 120-160 mL 100 g^{-1} dry mix in each experiment. The levels of these variables along with the experimental plan have been given in Table 1. For the analysis of experimental design by the response surface, it was assumed that n-mathematical functions, f_k (k=1, 2….. n), Y_k in terms of m independent processing factors X_i (i=1,2, …., m) existed for each response variable.

$$Y_k = f_k(X_1, X_2, ..., X_m) \quad (1)$$

In this case, n = 4, m = 3

Table 1 Central composite design arrangement and response values.

Exp. No.	*Vanaspati* (g 100 g^{-1} PMS)	Sugar (g 100 g^{-1} PMS)	Water (mL 100 g^{-1} dry mix)	Taste	Mouth feel	OAA	RR
1	35	85	120	6.8	7	7.2	1.7
2	45	85	120	7	7.2	7.4	1.5
3	35	95	120	6.6	6.8	7	1.8
4	45	95	120	6.3[a]	6.5	6.7	1.6
5	35	85	160	7.3	7.5	7.7	2
6	45	85	160	7.5	7.7	7.9	1.8
7	35	95	160	7	7.2	7.4	2.1
8	45	95	160	7.2	7.4	7.6	1.7
9	31.6	90	140	7.4	7.3	7.4	2.2
10	48.4	90	140	7.3	7.2	6.8	1.4[a]
11	40	81.6	140	7.4	7.3	7.6	1.7
12	40	98.4	140	7.6	6.4[a]	7	1.9
13	40	90	106.4	6.7	7	6.5[a]	1.5
14	40	90	173.6	7.3	6.7	7.1	2.3[b]
15	40	90	140	7.9[b]	7.7	7.8	1.8
16	40	90	140	7.8	7.6	7.8	1.8
17	40	90	140	7.9	7.8[b]	7.7	1.9
18	40	90	140	7.8	7.8	7.9[b]	1.8
19	40	90	140	7.7	7.7	7.8	1.9
20	40	90	140	7.9	7.8	7.7	1.8

PMS, pearl millet semolina; DM, dry mix; OAA, overall acceptability; RR, rehydration ratio; [a] minimum; [b] maximum.

Full second-order equation was fitted in each response to describe it mathematically and to study the effect of variables. The equation was as Eq. (2):

$$Y_K = \beta_0 + \sum_{i=1}^{m} \beta_i X_i + \sum_{i=1}^{m-1} \sum_{j=i+1}^{m} \beta_{ij} X_I X_j + \sum_{i=1}^{m} \beta_{ii} X^2{}_i \quad (2)$$

where, Y_k = response variable, β_0 is the value of the fitted response at the centre point of the design i.e. (0,0) and β_i, β_{ij}, β_{ii} are the linear, quadratic and interactive regression coefficients, respectively. X_i and X_j are the coded independent variable.

2.4 Preparation of Halwa Mix

The PMS samples (1 kg) were roasted in stainless steel vessel on flame with constant stirring till (20-25 min) the roast attained 150 ± 3 °C and started to give characteristics aroma and colour of a cooked product. *Vanaspati* (Table 1) was heated (180 ± 5 °C) in a pan and roasted PMS was added and mixed. Sugar (Table 1) was added and mixed with the contents of the pan. Ground cardamom and shallow fried cashew nuts were also added to enhance the flavour of the mix. The samples were cooled and packed in polyethylene pouches (75 μ) and stored at ambient condition (20-35 °C).

2.5 Reconstitution of Halwa Dry Mix

Dry mix of PMS based *halwa* was reconstituted with measured amount of water (Table 1) and stirred on low flame until the desired consistency was attained (started to leave the pan).

2.6 Sensory Analysis

The re-constituted samples were served in numbered plates to a semi-trained panel of judges (ten) selected from the Institute staff. Four samples were presented at a time to the judges in plates containing approximately 100 g sample at separate booth and asked to rate the samples in terms of taste, mouth feel and overall acceptability (OAA) using nine point hedonic scale [17] from liked extremely (9) to disliked extremely (1).

2.7 Rehydration Ratio

Rehydration ratio (RR), a measure of water absorption by the dehydrated product, was calculated using following equation [18].

$$RR = \frac{W_r}{W_d} \quad (3)$$

where: W_r (g) = weight of the rehydrated *halwa* mix;

W_d (g) = weight of the dry *halwa* mix used for rehydration.

2.8 Chemical Analysis

Pearl millet (whole, steamed and pearled), PMS and *halwa* mix samples were analyzed for moisture (method 44-19), protein (method 46-12), fat (method 30-25) and ash (method 8-01) using AACC [19] methods. Minerals were determined using atomic absorption spectrophotometer (EC Ltd. Model Nr AAS 4141) following the digestion of samples in tertiary acid mixture (HNO_3: H_2SO_4: HCl; 10:1:4 v/v) [20].

Carbohydrate was calculated by subtracting the sum of moisture, protein, fat and ash from 100 [21]. The changes in chemical parameters in the form of peroxide value and free fatty acids were monitored by AOCS [22] methods. Thiobarbituric acid value was estimated by the distillation method [23]. Phytic acid, tannins, total phenols and lipase activity was analyzed as method described by Sadasivam [24].

2.9 Statistical Analysis

Response surface methodology (RSM) was adopted in experimental design and analysis [25]. Multiple regression analysis was used to fit the model, represented by an equation, to the experimental data. Maximization and minimization of the polynomials thus fitted was done by numeric techniques, using the numerical optimization technique given in the software package [Design expert(r) software version 8.0.4.1, 2010; Minneapolis, MN, USA]. The response surfaces for the models were plotted as a function of the two variables while keeping the other one at optimum level. The storage data were analyzed using the analysis of variance (ANOVA) [26] technique.

3. Results and Discussion

3.1 Effect of Processing Operations on Anti-nutritional Factors

The various processing operations such as soaking, steaming, pearling and size reduction resulted reduction in anti-nutritional factors (Table 2). Whole pearl millet contained 975 ± 8 mg 100 g^{-1} phytic acid, which was reduced to 436 ± 6 mg following all these operations. About 55.28% reduction was observed, while maximum (50.76%) reduction was observed during pearling operation. This indicated that maximum of phytic acid was concentrated in outer layer of the grain. However, soaking and steaming also significantly ($P \leq 0.05$) reduced the phytic acid, which may be associated due to heat induced degradation of phytic acid. Shobhana [16] reported reduced phytate and polyphenol contents due to hydrothermal treatment and decortication of finger millet. Tannins and total phenol contents also reduced significantly ($P \leq 0.05$) during these processing operations. It was interesting to note that during soaking, higher amount (12.5%) of total phenols was reduced than tannins (7.9%). However, pearling reduced 29.92% tannins and 21.63% of total phenols, which showed that tannins were more concentrated in outer layer among total phenolic compounds. Higher tannins content in outer layer might result in bitterness of whole pearl millet flour. Reduction in polyphenols and tannins due to soaking, sprouting and roasting has been reported [27-29] in pearl millet. Heat induced degradation of tannins and polyphenols is also reported by Shinde [30]. Though there was reduction in each of the anti-nutritional factors after size reduction but it was not significant. Overall, there were 55.28, 39.47 and 41.25% decrease in phytic acid, tannins and total phenols, respectively due to the various operations performed on whole grains to obtain semolina.

3.2 Effect of Processing Operations on Lipase Activity

Lipase activity increased significantly ($P \leq 0.05$) from 137.5 ± 5 to 157.42 ± 7 μmol FFA h^{-1} g^{-1} in whole grains during soaking (Table 2). Nithya [28] also observed increase in activity of several enzymes due to soaking treatment. This may have resulted from induction of enzyme activity due to initiation of seed germination during soaking [31]. Further, enzyme activity was not detected after steaming as steam at high pressure (1.05 kg cm^{-2}) may have inactivated lipase enzyme. Bookwalter [32] also reported inactivation of lipase and extended storage after hydrothermal treatment of pearl millet.

3.3 Effect of Processing Operations on Minerals

All the above processing operations caused reduction in minerals content (Table 2). Similar trend in mineral contents due to several processing treatments has been reported [28, 29]. Soaking caused significant ($P \leq 0.05$) reduction in Ca, P, Fe, Cu

Table 2 Effect of soaking and steaming on anti-nutritional factors, lipase activity and mineral content of pearl millet.

Chemical parameters	Whole pearl millet grains	Soaked	Steamed	Pearled	Pearl millet semolina	CD ($P \leq 0.05$)
Phytic acid (mg 100 g^{-1})	975±8[a]	932±12[b]	910±7[c]	448±5[d]	436±6[d]	14.51
Tannins (mg 100 g^{-1})	152±4[a]	140±4[b]	130±5[c]	95±3[d]	92±4[d]	7.37
Total phenols (mg 100 g^{-1})	320±8[a]	280±5[b]	245±7[c]	192±6[d]	188±4[d]	12.16
Lipase activity (μmol FFA h^{-1} g^{-1})	137.5±5[a]	157.42±7[b]	ND	ND	ND	13.79
Minerals (mg 100 g^{-1})						
Ca	38±4[a]	32±3[b]	30±3[b]	25.7±2[c]	25.5±2[c]	5.27
P	292±8[a]	276±4[b]	271±6[b]	204.5±5[c]	202.6±4[c]	9.98
Fe	8.2±0.2[a]	7.6±0.3[b]	7.4±0.2[b]	6.76±0.25[c]	6.65±0.24[c]	0.44
Cu	1.07±0.03[a]	1.01±0.02[b]	0.98±0.02[b]	0.85±0.03[c]	0.82±0.02[c]	0.04
Zn	3.12±0.02[a]	2.85±0.03[b]	2.80±0.02[c]	2.12±0.03[d]	2.08±0.02[d]	0.04
Mn	1.12±0.03[a]	1.10±0.03[a]	1.07±0.04[ab]	1.02±0.03[b]	1.02±0.02[b]	0.06

Values with different letters in the same column vary significantly ($P \leq 0.05$); ND, not detected.

and Zn contents, while Mn was not affected significantly ($P \leq 0.05$). This may indicate that Mn may be much more distributed in endosperm than outer layer. Maximum loss of Ca (15.78%) and Zn (8.65%) followed by Fe (7.32%), Cu (5.6%) and P (5.47%) was observed during soaking. The reduction of minerals may be attributed to loss of nutrients due to leaching during soaking [33]. Steaming caused slight reduction in minerals but it was non-significant ($P \leq 0.05$). Pearling of pearl millet caused maximum reduction in all the minerals except manganese. Thus, it was re-confirmed that manganese is concentrated in endosperm rather than outer layer. Similar results were also observed by Shobhana [16]. Maximum reduction in P (24.7%) and Zn (24.3%) was observed followed by Ca (14.3%), Cu (13.3%) and Fe (18.6%) during pearling. Size reduction of pearled grains caused insignificant reduction in minerals content.

3.4 Diagnostic Checking of the Fitted Models

All main, linear, quadratic and interactive effects were calculated for each model. The models were considered adequate when the calculated *F*-ratio was more than the table *F*-value (3.02), R^2 value was more than 80%, and LOF was insignificant [34]. The regression coefficient, multiple correlation coefficients (R^2) and *F*-value are given in Tables 3 and 4. The correlation coefficients for the responses, i.e. taste,

Table 3 Estimated coefficients of the fitted quadratic equation for different responses.

Factors	Estimated coefficients			
	Taste	Mouth feel	OAA	RR
β_0	-83.24	-96.78	-47.55	-15.65
β_1	0.88	0.53	0.67	-0.17*
β_2	1.316	1.91*	0.73*	0.26
β_3	0.20*	0.13	0.15*	0.03*
$\beta_1\beta_2$	-0.003	-0.003	-0.0025	-0.001
$\beta_1\beta_3$	0.00063	0.00063	0.00063	-0.0003
$\beta_2\beta_3$	0.00038	0.00037	0.00038	-0.0003
β_1^2	-0.0093*	-0.0049	-0.0068*	-0.00096
β_2^2	-0.0071*	-0.012*	-0.004	-0.00096
β_3^2	-0.00088*	-0.00066*	-0.0007*	0.00003
R^2	0.86	0.80	0.82	0.88

*Significant at $P \leq 0.05$; OAA = overall acceptability; RR = rehydration ratio.

Table 4 Analysis of variance of different models.

Response	Sources of variance	Sum of squares	d.f.	Mean square	*F*-value
Taste	Model	3.59	9	0.40	6.81*
	Residual	0.59	10	0.059	
	Cor.Total	4.17	19		
Mouth feel	Model	2.90	9	0.32	4.40*
	Residual	0.73	10	0.073	
	Cor.Total	3.63	19		
OAA	Model	2.82	9	0.31	5.04*
	Residual	0.62	10	0.062	
	Cor.Total	3.44	19		
RR	Model	0.86	9	0.096	8.14*
	Residual	0.12	10	0.012	
	Cor.Total	0.98	19		

* Significant at $P \leq 0.05$; OAA, overall acceptability; RR, rehydration ratio.

mouth feel, OAA and RR were 0.86, 0.80, 0.82 and 0.88, respectively, indicating that all the values were equal to or more than 80%. The calculated *F*-values (Table 4) were more than the table value (3.02) indicating the adequacy of the models. All four responses were considered adequate to describe the effect of variables on the quality of PMS based *halwa* samples.

3.5 Effect of Variables on Sensory Quality

The actual values for the test variables and the experimental results for taste, mouth feel and OAA ranged between 6.3-7.9, 6.4-7.8 and 6.5-7.9 respectively (Table 1). Water for rehydration had significant ($P \leq 0.05$) effect on taste of *halwa* at linear level, whereas at the quadratic level all variables affected taste significantly ($P \leq 0.05$). Sugar had significant ($P \leq 0.05$) positive effect on the mouth feel at linear level. Both sugar and water for rehydration had significant ($P \leq 0.05$) negative effect on mouth feel at quadratic level. Sugar and water had significant ($P \leq 0.05$) positive effect on OAA at linear level (Fig. 1).

3.6 Effect of Variables on Rehydration Ratio

The observed rehydration ratio with different combinations of the ingredients (Table 1) varied from 1.4-2.3. Table 3 reveals that RR decreased with increase in level of *vanaspati*. This might be attributed to the fact that it makes fat layer surrounding the PMS and thus prevents the water absorption. Patki [3] observed that incorporation of *vanaspati* and spices in pre-cooked dried *kabuli channa* increased the re-constitution time due to formation of hydrophobic coating of oil, which decreased the water penetration in the grain. Water had positive linear effect ($P \leq 0.05$) on rehydration ratio. The increase in RR with increase in amount of water might be due to availability of more water as well as time for reconstitution to get desired consistency. The effect of amount of water and *vanaspati* level on RR was presented in Fig. 2. This is in agreement with the findings of Yadav and Sharma [35] as for soy fortified *upma*.

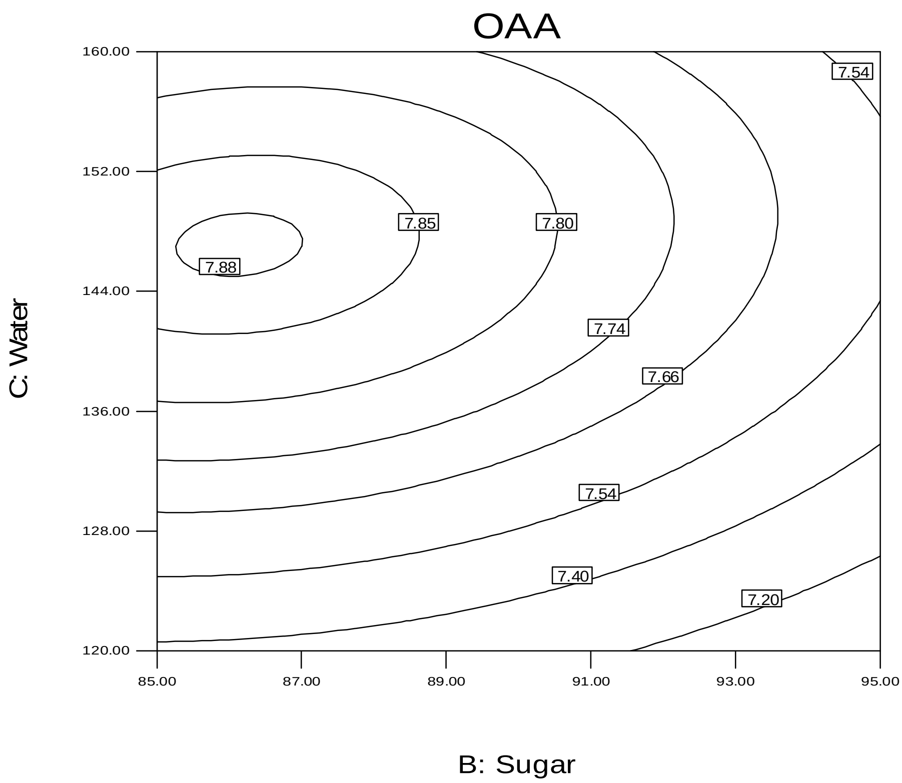

Fig. 1 Effect of sugar and water on overall aceptability (OAA).

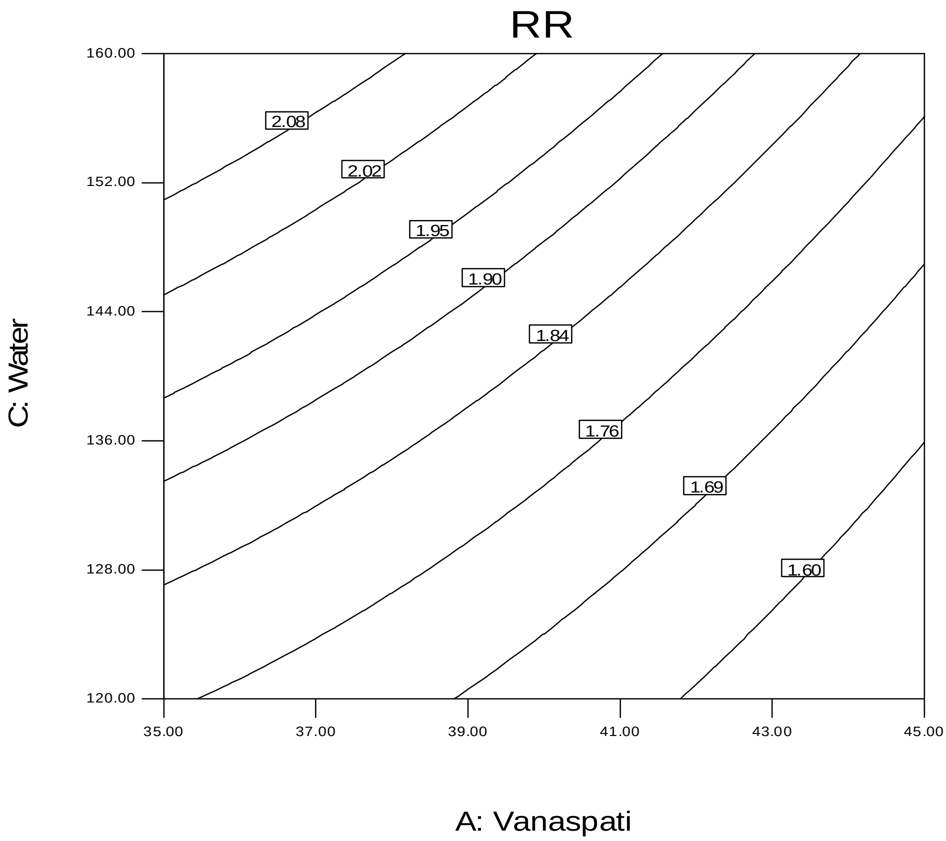

Fig. 2 Effect of *vanaspati* and water on rehydration ratio (RR).

3.7 Analysis of Variance

When a model had been selected, an analysis of variance was calculated to assess how well the model represented the data. *F*-value for all the responses indicated that all the three variables affected the responses significantly ($P \leq 0.05$) (Table 4). On this basis, it can be concluded that the selected models adequately represented the data for sensory quality and RR of *halwa* samples.

3.8 Optimization of the Level of Independent Variables

Numerical optimization was carried out for the level of ingredients to obtain the best product. The desired goals for each factor and response were chosen and different weights were assigned to each goal to adjust the shape of its particular desirability function (Table 5). Among the solutions obtained, the solution with maximum desirability was selected as optimum ingredients composition. The observed experimental values (mean of 3 measurements) and values predicted by the equations of the model are presented in Table 5. Closeness between the experimental and predicted values of the quality parameters indicated the suitability of the corresponding models. Fig. 3 depicts overlay plot showing the optimum level of ingredients and corresponding response values as *vanaspati* 38.6 g 100 g^{-1} PMS, sugar 88.7 g 100 g^{-1} PMS and water for rehydration 151.4 mL 100 g^{-1} dry mix. Developed *halwa* dry mix had protein 4.6 g, fat 18.3 g, ash 0.65 g, carbohydrates 75.8 g, Ca 11.5 mg, P 91.2 mg, Fe 2.9 mg, Cu 0.37 mg, Zn 0.94 mg and Mn 0.46 mg 100g^{-1}, respectively.

3.9 Shelf-Life Studies on Optimized Halwa

In foods, lipid peroxidation and enzymatic hydrolysis cause shelf-life problems. The most limiting factor in determining the shelf-life of dehydrated convenience mixes is the auto-oxidation of fats and oils causing off flavours [36]. The optimized pearl millet

Table 5 Constraints, criteria for optimization, solution along with predicted and actual response values.

Constraints	Goal	Lower limit	Upper limit	Predicted values	Actual response values
Vanaspati, g 100 g^{-1}PMS	is in range	35	45	38.6	-
Sugar, g 100 g^{-1} PMS	is in range	85	95	88.7	-
Water, mL 100 g^{-1} DM	is in range	120	160	151.4	-
Taste	Maximize	6.3	7.9	7.8	7.8±0.03
Mouth feel	Maximize	6.4	6.4	7.7	7.7±0.02
OAA	Maximize	6.5	7.9	7.8	7.8±0.14
RR	Maximize	1.4	2.3	1.98	1.95±0.15

OAA, overall acceptability; RR, rehydration ratio.

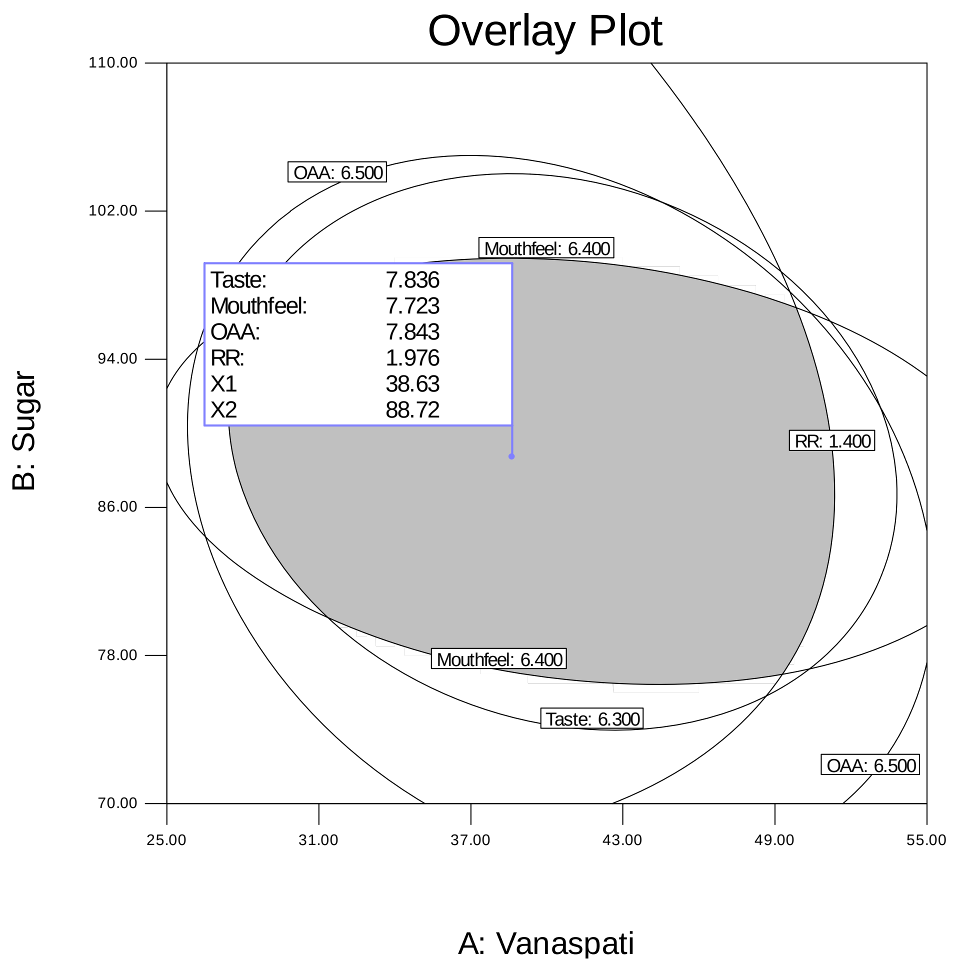

Fig. 3 Overlay plot showing the optimum level of ingredients and corresponding response values.

halwa samples were stored in polyethylene pouches at ambient conditions (20-35 °C) and continuously monitored for peroxide value (PV, meqO_2 kg^{-1} fat), free fatty acids (FFA, % oleic acid), thiobarbituric acid (TBA, mg melonaldehyde kg^{-1} sample) and sensory quality in terms of OAA during storage (Table 6). The PV values did not show any significant ($P \leq 0.05$) increase during the first two months and increased slightly, thereafter. After 6 months storage, PV increased from 6.64 to 21.35 meqO_2 kg^{-1} fat and FFA from 0.39% to 0.55% as oleic acid. The increase was due to breakage of long chain fatty acids in to individual moieties. The overall increase in PV and FFA was lower than the earlier reported [36] during

Table 6 Changes in chemical and sensory properties of *halwa* dry mix during storage at ambient conditions.

Storage period, months	PV (meqO_2 kg^{-1} fat)	FFA (% oleic acid)	TBA (mg melonaldehyde kg^{-1} sample)	OAA
0	6.64 ± 0.52^{a}	0.39 ± 0.05^{a}	0.039 ± 0.003^{a}	7.8 ± 0.2^{a}
1	6.80 ± 0.50^{a}	0.39 ± 0.02^{a}	0.044 ± 0.002^{b}	7.8 ± 0.5^{a}
2	7.62 ± 0.58^{a}	0.41 ± 0.06^{ab}	0.059 ± 0.003^{c}	7.7 ± 0.4^{a}
3	10.42 ± 0.72^{b}	0.44 ± 0.02^{ab}	0.071 ± 0.002^{d}	7.7 ± 0.4^{a}
4	13.39 ± 0.62^{c}	0.47 ± 0.03^{bc}	0.091 ± 0.004^{e}	7.5 ± 0.5^{a}
5	17.27 ± 1.52^{d}	0.52 ± 0.06^{cd}	0.113 ± 0.003^{f}	7.5 ± 0.4^{a}
6	21.35 ± 1.10^{e}	0.55 ± 0.03^{d}	0.132 ± 0.002^{g}	7.4 ± 0.4^{a}
CD ($P \leq 0.05$)	1.52	0.07	0.05	0.73

Values with different letters in the same column vary significantly ($P \leq 0.05$); PV, peroxide value; FFA, free fatty acids; TBA, thiobarbituric acid; OAA, overall acceptability.

storage of wheat semolina based *halwa*. This might be due to PMS contained good amount of polyphenolic compounds as compared to wheat semolina and that might had worked as antioxidants. Phytochemicals, which possess more than one hydroxyl group in phenolic structure, can donate hydrogen atom from hydroxyl groups to lipids free radicals such as peroxyl radicals ($ROO^{\cdot}$) efficiently and retard the rate of formation of new lipid radicals [37]. The TBA value which is an index of secondary lipid oxidation also followed similar pattern and ranged from 0.039 to 0.132 mg melonaldehyde kg^{-1} sample throughout the storage. The *halwa* samples were acceptable up to 6 months of storage as indicated by OAA score (Table 6).

4. Conclusion

The ingredients level for pearl millet *halwa* was successfully optimized using response surface methodology and shelf-life studies of optimized sample revealed that the *halwa* was acceptable up to 6 months at ambient conditions. Pearl millet *halwa* mix, being gluten free, can be given to patients suffering from gluten intolerance. Since it had good amount of protein (4.6 g/100 g) and minerals, hence could be utilized as mid day meal in different feeding programme to overcome malnutrition in developing countries.

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