Optimization of ingredients for preparation of low calorie fiber enriched *chhana* balls-Sandesh like product

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Abstract The present study aimed to optimize the relative proportion of roasted flax seed flour as dietary fiber ingredient (DFI) and *jaggery*:stevia percent in preparation of *chhana* balls. Response surface methodology (RSM) was used to determine the optimum DFI proportion and *jaggery*:stevia percent. Thirteen experimental runs were conducted with varying levels of independent variables viz. dietary fiber ingredient (4.0–8.0%) and *jaggery*:stevia :: 1:1 (22.5–27.5%), as generated by central composite design. The responses investigated were pH, cooking yield, water activity (a_w), Hue angle, Chroma value and sensory attributes of *chhana* balls. The RSM results showed that the experimental data could be adequately fitted to a second-order polynomial model with a satisfactory Coefficient of determination ($R^2 > 50\%$). The study revealed that the effect of all the factors were significant on the studied responses. The optimum formulation obtained using desirability function was 5.92 and 26.42% for DFI proportion and *jaggery*:stevia respectively. The values of responses at optimum formulation were 6.36 pH, 91.80 cooking yield (%), 0.9481 water activity (a_w), – 22.62 Hue angle, 8.71 Chroma value, 6.89 sweetness and 7.10 overall acceptability. These predicted values were validated with

experimental values and found be not significantly different.

Keywords *Chhana* balls · Stevia · *Jaggery* · Dietary fiber · Central composite design · Response surface methodology

Introduction

The demand for healthy foods has been rising due to increasing incidence of lifestyle related disease and awareness among consumers about the choice of the foods and its consequences on health. It leads to a new concept of dietetic, designer and functional foods designed to fulfill the specific requirement of the people. Consumption of energy dense foods having high sugar and fat along with sedentary lifestyle, have paved way for non-communicable diseases like obesity, diabetes and cardiovascular diseases (Tanaka and Nakanishi 1996). In India, 62.4 million people lives with diabetes (Shetty 2012) and about 13% females and 9% male are overweight (IIPS 2007). Dietary guidelines recommended that 30% reduction of the energy intake from dietary fat helps to reduce the prevalence of obesity, ischemic heart disease and certain cancers.

Milk and milk products are always being the integral part of Indian heritage because of health promoting ability and organoleptic characteristics. In India 50% of total milk produced is converted into traditional milk products (Bandyopadhyay and Khamrui 2007). These products have been the most popular delivery vehicles for a number of functional ingredients like fortification of vitamins, minerals and incorporation of bio-active compounds etc. However, relatively high fat and sugar content in the milk-based sweets hinders the diabetic and health conscious people from consuming them. Further, Milk and most of

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the milk products are devoid of dietary fiber. Fortification of milk products with dietary fiber could increase its nutritional importance. The demand of value added dietary fiber fortified dairy products is growing in the market (Arora and Patel 2015, 2017; Kendall et al. 2010; Theuvsissen and Mensink 2008) and there is great scope of fortifying milk products with dietary fiber such as *dahi*, *yoghurt*, *lassi*, *kheer*, *paneer* (Kantha and Kanawjia 2007). Flax seed is a minor oilseed and a rich source of both soluble and insoluble dietary fiber. (Goyal et al. 2014) that helps in lowering blood sugar and cholesterol, and aids in digestion (Moraes et al. 2010).

Food and milk products replacing sugar with low calorie sweeteners are in great demand. Sugar substitute like *stevioside* is a high intensity non-nutritive and zero calorie sweetener used in preparing various food and milk products. *Jaggery* (also known as *gur*) is a natural, traditional sweetener made by the concentration of sugar-cane juice and is mostly used in Asia, Africa, Latin America and the Caribbean region (Unde et al. 2010). It is more complex than sugar and made up of long chains of sucrose. It contains 50% sucrose and 20% invert sugars along with other insoluble matter such as proteins, ash and bagasse fibers (Unde et al. 2010). *Jaggery* is digested slowly than sucrose with sustained release of energy and can be replaced with sugar in a variety of sweetmeats (Nath et al. 2015).

Among the several milk products, *chhana* balls (*Sandesh* like product) is very promising heat desiccated product of coagulated milk protein called *chhana* (analogous to soft cottage cheese) with sugar. *Chhana* is used as a base material for a variety of sweets and *chhana* based sweets (*Sandesh*, *chhana podo*, *chumchum*, *chhana murki*) are popular in all over country (esp in West Bengal) due to its better palatability and flavor attributes (Aneja et al. 2002). The quality of *chhana* based sweets (*chhana* balls) will be affected by various processing parameters like kneading time and temperature, cooking time and temperature and cooling rate. But now a days due to changing health scenario and increasing awareness, the acceptance of high fat and sugar rich product is declining. Therefore, reducing fat and replacing sugar with alternative ingredients like addition of dietary fiber and sugar substitutes may help in improving their intake by the consumers. Keeping all these factors into consideration, the present study was aimed to formulate the low-calorie fiber enriched *chhana* balls from roasted flax seed flour as dietary fiber ingredient (DFI) and sugar substitute (*jaggery*:*stevia* :: 1:1).

Materials and methods

Milk for the present study was obtained from Dairy Technology Section of Indian Veterinary Research Institute, Izatnagar, Bareilly (UP). Cream from milk was separated by a hand driven centrifugal cream separator (Lakshmi cream separator RS-7, 60 l/h) and the fat content in milk was standardized to 1.5%. *Jaggery*, cardamom, roasted flax seed (dietary fiber ingredient) and *Stevia* (So Sweet[®], an Indian brand) used in the study were procured from the local market.

Experimental design for optimization of product

Selection of fat content and sugar substitute for the preparation of chhana balls

A series of preliminary trials were conducted to standardize the basic formulation for the preparation of *chhana* balls. *Chaana* was prepared from milk containing different fat level as per the method described by Bhattacharya et al. (1971). The product prepared with standardized milk (4.5% fat) *chhana*, sugar and cardamom powder was most liked by the panelist and called as basic formulation that contained *chhana*-75 g, sugar-25 g and cardamom powder-0.1 g. This formulation was used for the preparation of low fat *chhana* balls using different fat levels viz., 3%, 1.5% and skim milk. *Chaana* balls prepared from skim milk *chhana* was not showing the required binding thereby affecting the processing feasibility, however, the *chhana* prepared from 3 and 1.5% fat milk had showed the better binding and textural characteristics. Hence, milk with fat 1.5% was selected for the preparation of low fat *chhana* balls.

Stevia as a sugar replacer was used in the preliminary trials and it was observed that 100 mg of *stevia* can be satisfactorily replaced with 12.5 g of sugar without affecting sweetness of the product and alternatively combination of *jaggery* and *stevia* can be used as a replacement for sugar. Therefore low fat *chhana* balls were prepared and a particular range that showed best sensorial results was used further in RSM studies.

Product optimization by RSM

Preliminary trials were conducted to select the levels of independent variables viz. sugar substitute (%) and DFI level (%) for preparing *chhana* balls. Central composite design (CCD) of RSM was adopted for the optimization of processing variables, to determine the regression model

Table 1 Experimental data for the two factors three levels response surface analysis for *chhana* balls-Sandesh like product

Runs	DFI level (X_1) %		Sugar substitute level (X_2) %		Physico-chemical properties			Colour profile		Sensory attributes					
	Coded	Un-coded	Coded	Un-coded	pH	CY (%)	a_w	Hue angle	Chroma value	CA	Flv	Tx	Jc	Sw	OA
1	0	6	0	25	6.34	91.38	0.9587	89.29	7.27	6.68	6.7	6.8	6.72	6.85	6.98
2	0	6	0	25	6.33	92.19	0.9488	89.25	7.67	6.92	6.87	6.71	6.93	6.84	6.85
3	1	8	1	27.5	6.41	92.54	0.9569	– 87.42	9.57	6.75	6.77	6.9	6.86	6.93	6.93
4	– 1	4	1	27.5	6.37	85.54	0.9539	– 85.78	10.32	7.11	6.78	6.93	6.69	6.7	6.94
5	– α	3.17	0	25	6.33	86.86	0.9629	– 88.79	8.52	6.94	7.03	6.7	6.9	6.9	7.08
6	α	8.83	0	25	6.39	92	0.9604	86.79	6.79	6.38	6.5	6.52	6.29	6.69	6.64
7	0	6	– α	21.46	6.31	91.93	0.9688	86.57	5.68	6.96	6.64	6.98	6.7	6.57	6.93
8	0	6	α	28.54	6.41	93.28	0.9524	– 86.22	10.15	6.93	7	7	7.14	7.11	7
9	0	6	0	25	6.35	92.02	0.9537	89.32	7.54	6.77	6.7	6.75	6.88	6.96	6.77
10	0	6	0	25	6.32	91.76	0.9444	89.59	7.03	6.6	6.75	6.84	6.94	6.72	6.89
11	1	8	– 1	22.5	6.35	87.72	0.9648	84.32	4.34	6.73	6.56	6.89	6.43	6.29	6.45
12	– 1	4	– 1	22.5	6.32	88.28	0.9731	87.15	6.24	6.96	6.84	6.95	6.88	6.93	6.85
13	0	6	0	25	6.34	91.09	0.9435	– 89.92	7.36	6.7	6.52	6.86	6.98	6.98	7.11

DFI dietary fiber ingredient, CY cooking yield (%), a_w water activity, CA colour and appearance, Flv flavour, Tx body and texture, Jc juiciness, Sw sweetness, OA overall acceptability

equations and in studying the interactions of various parameters affecting the process (Chattoraj et al. 2013). In the present study, a two factor, three independent level central composite design (CCD) with five replicates at centre point was used and total thirteen combinations [ranges of sugar substitutes (*jaggery:stevia* :: 1:1) viz., 22.5–27.5% w/w and DFI level 4.0–8.0% w/w] were performed to develop predictive models for response parameters.

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

The following second order polynomial equation of function X_i was fitted for each factor assessed:

From the equation presented, where Y is the response variable; β_0 is the constant term; β_i , β_{ij} and β_{ii} are coefficients of the linear effect, double interactions; x_i , x_j are the independent variables or factors and ε is error. i and j are

the levels of the factors with k being the number of factors assessed.

The significant terms in the model (Eq. 1) were found by analysis of variance (ANOVA) for each response and the significance was judged by calculating the model F value at the probability level of $< 5\%$. The optimal values of the process conditions were obtained by the desirability function, a multi-response analysis, proposed by Derringer and Suich (1980). Experimental results of the two factors, three independent levels CCD are shown in Table 1. The statistical software package (Design-Expert 10.0.6 Trial version, 2017) was used to conduct the regression analysis of experimental data and to plot the response surface.

Preparation of *chhana* balls

The method of preparation of *chhana* balls is given below:

Flow diagram for the preparation of chhana balls

The product obtained were evaluated for physico-chemical properties [pH, water activity (a_w) cooking yield], Hue angle and Chroma value and sensory attributes (colour/appearance, flavour, body/texture, juiciness, sweetness, and overall acceptability) on 8 point Hedonic scale to determine the optimum DFI (%) and sugar substitute level (%).

Physico-chemical analysis

pH

pH of samples were determined as per the procedure of Trout et al. 1992.

Yield (in %)

Cooking yield were calculated according to the following equation:

$$\text{Percent(\%)cooking yield} = \frac{\text{Cooked product weight}}{\text{Raw product weight}} \times 100 \quad (2)$$

Water activity

Water activity of the samples was measured using water activity meter (aqua lab dew point water activity meter 4TE, USA). The grounded sample was placed in the

sample container up to 1/2 to 3/4th level and kept inside the sample holder and reading was recorded. The average of three readings was taken as water activity.

Colour profile analysis

The colour of product was measured using a Lovibond Tintometer (Model F, Greenwich, UK). The sample colour was matched by adjusting the red (a^*) and yellow (b^*) units, keeping the blue unit fixed at 3. The corresponding colour values displayed on the instrument were noted. The Hue (relative position of colour between redness and yellowness) and Chroma (Intensity, brightness or vividness of colour) was determined by using the following formula (Riquelme et al. 2016).

$$\text{Hue angle} = (\tan^{-1})b/a \quad (3)$$

$$\text{Chroma value} = [a^2 + b^2]^{0.5} \quad (4)$$

where a = red unit, b = yellow unit.

Sensory evaluation

Trained panel members (n = 7) from department of Live-stock Products Technology division were selected for sensory evaluation of the prepared *chhana balls*. The panelists were detailed about the product characteristics and sensory Performa. The test samples were presented to the panelists for sensorial evaluation. Plain water was

Table 2 ANOVA of response surface model for physico-chemical characteristics and colour profile of *chhana* balls-Sandesh like product

Source	pH			CY (%)			a_w			Hue angle			Chroma value		
	F value	p value	R ²	F value	P value	R ²	F value	p value	R ²	F value	p value	R ²	F value	p value	R ²
Model	26.39*	0.0002	0.9496	6.40*	0.0152	0.8205	6.55*	0.0143	0.8239	5.78*	0.0214	0.5364	78.58*	< 0.0001	0.9282
X ₁	30.70*	0.0009		12.29*	0.0099		0.40	0.5449		1.69	0.2224		15.10*	0.0030	
X ₂	80.92*	<0.0001		1.04	0.3417		13.11*	0.0085		9.88*	0.0105		142.07*	< 0.0001	
X ₁₂	0.26	0.6284		7.47*	0.0292		1.32	0.2877		–	–		–	–	
X ₁₁	11.36*	0.0119		11.19*	0.0123		11.01*	0.0128		–	–		–	–	
X ₂₂	11.36*	0.0119		0.10	0.7609		9.22*	0.0189		–	–		–	–	
Lack of fit	0.42	0.7495		20.43*	0.0069		0.04	0.9893		0.47	0.8038		5.19	0.0663	
CV %	–	0.16		–	1.53		–	0.51		–	326.11		–	6.12	
Coded equation	$6.34 + 0.02X_1 - 0.03X_2 + 2.50 \times 10^{-3}X_1X_2 + 0.01X_1^2 + 0.01X_2^2$														
Actual equation	$6.59 - 0.03X_1 - 0.04X_2 + 5.00 \times 10^{-4}X_1^2 + 3.16 \times 10^{-3}X_1^2 + 2.02 \times 10^{-3}X_2^2$														

*Significant ($P < 0.05$), X_1 dietary fiber ingredient (DFI) level (%), X_2 sugar substitute level (%), R^2 coefficient of determination, CV coefficient of variation, CY cooking yield (%), a_w water activity

Table 3 ANOVA of response surface model for sensory attributes of *chhana* balls-Sandesh like product

Source	CA			Flv			Tx			Jc			Sw			OA		
	F value	p value	R ²	F value	p value	R ²	F value	p value	R ²	F value	p value	R ²	F value	p value	R ²	F value	p value	R ²
Model	6.13*	0.0170	0.8142	6.61*	0.0148	0.5693	5.20*	0.0261	0.7878	7.04*	0.0117	0.8341	10.67*	0.0025	0.7805	4.89*	0.0330	0.4946
X ₁	20.11*	0.0029		9.43*	0.0118		2.23	0.1793		10.83*	0.0133		4.72	0.0580		6.89*	0.0254	
X ₂	0.17	0.6913		3.79	0.0802		6.27 × 10 ⁻³	0.9391		6.17*	0.0420		13.00*	0.0057		2.90	0.1197	
X ₁₂	0.36	0.5696		-	-		0.034	0.8594		6.38*	0.0395		14.28*	0.0044		-	-	
X ₁₁	0.15	0.7143		-	-		3.96	0.0868		11.54*	0.0115		-	-		-	-	
X ₂₂	9.41*	0.0181		-	-		17.20*	0.0043		8.83x10 ⁻³	0.9278		-	-		-	-	
Lack of fit	0.58	0.6587		0.84	0.5975		2.69	0.1819		2.08	0.2454		1.37	0.3920		1.23	0.4404	
CV %	-	1.60		-	1.78		-	1.19		-	1.81		-	1.69		-	2.02	
Coded equation	6.73 - 0.17X ₁ + 0.02X ₂ - 0.03X ₁ X ₂ - 0.02X ₁ ² + 0.13X ₂ ²			6.74 - 0.13X ₁ + 0.08X ₂			6.79 - 0.04X ₁ + 2.29 × 10 ⁻³ X ₂ + 7.50 × 10 ⁻³ X ₂ ²			6.89 - 0.14X ₁ + 0.11X ₂ + 0.16X ₁ X ₂ - 0.16X ₁ ² + 4.38 × 10 ⁻³ X ₂ ²			6.81 - 0.09X ₁ + 0.15X ₂ + 0.22X ₁ X ₂			6.79 - 0.04X ₁ + 2.29 × 10 ⁻³ X ₂ + 7.50 × 10 ⁻³ X ₁ X ₂ - 0.06X ₁ ² + 0.13X ₂ ²		
Actual equation	9.71 + 0.04X ₁ - 0.46X ₂ - 6.50 × 10 ⁻³ X ₁ X ₂ - 3.94 × 10 ⁻³ X ₁ ² + 0.20X ₂ ²			6.72 - 0.06X ₁ + 0.03X ₂			9.68 + 0.14X ₁ - 0.52X ₂ + 1.50 × 10 ⁻³ X ₁ X ₂ - 0.02X ₁ ² + 0.02X ₂ ²			7.79 + 0.02X ₁ - 0.16X ₂ + 0.03X ₁ X ₂ - 0.03X ₁ ² + 7.00 × 10 ⁻⁴ X ₂ ²			9.60 - 0.59X ₁ - 20X ₂ + 0.04X ₁ X ₂			9.68 + 0.14X ₁ - 0.52X ₂ + 1.50 × 10 ⁻³ X ₁ X ₂ - 0.02X ₁ ² + 0.02X ₂ ²		

*Significant ($P < 0.05$), X_1 dietary fiber ingredient (DFT) level (%), X_2 sugar substitute level (%), R^2 coefficient of determination, CV coefficient of variation, CA colour and appearance, f_{lv} flavour, T_x body and texture, J_c juiciness, S_w sweetness, O_A overall acceptability

Fig. 1 Surface plot (3-D) for physico-chemical characteristics of *chhana* balls-Sandesh like product

served to rinse the mouth in between the samples. The sensory attribute evaluated were colour and appearance, flavour, body and texture, juiciness, sweetness and overall acceptability using 8 point hedonic scale (Keeton 1983), where 8 is excellent and 1 is extremely poor.

Proximate composition

The moisture, protein, fat and ash content of sample were determined by standard methods using hot air oven, kjeldahl assembly, soxhlet extraction apparatus and muffle furnace respectively as per AOAC (1995). Total dietary fiber (TDF), soluble dietary fiber (SDF) and insoluble dietary fiber (IDF) were determined by slight modification of an enzymatic method given by Furda (1981).

Results and discussion

The results of analysis of variance (ANOVA), R^2 and coefficient of variation values are shown in Tables 2 and 3. The linear, quadratic and 2FI regression models were significant for the response variables with a satisfactory coefficient of determination ($R^2 > 50\%$). Further, 3-D surface plots, showed the interaction among independent variables in relation to the observed responses.

Diagnostic checking of fitted model for physico-chemical properties

pH

The second order polynomial equation generated relating pH and two independent variables (DFI and sugar substitute level) in terms of actual and coded factors is given in Table 2. A response surface quadratic model for pH was generated using two independent variables. In the present study, variation in DFI and sugar substitute level were found to have significant linear and quadratic effect

($P < 0.05$) on the pH. The analysis of variance showed that the model F value (26.39) was significant ($P < 0.05$), while the lack of fit F value of 0.42 implied that it was not significant ($P > 0.05$) relative to the pure error (Table 2). The R^2 value (0.9496) indicated that 94.96% of the total variation was explained by the model. With continuous increase in DFI and sugar substitute level, pH was first decreased and then increased due to interaction of DFI and sugar substitute level (Fig. 1). It might be due to the moderate alkaline effect of used fiber and sugar substitute.

Cooking yield (CY)

The second order polynomial equation generated for cooking yield (CY) and two independent variables (DFI and sugar substitute level) in terms of actual and coded factors is given in Table 2. A response surface quadratic model for CY (%) had shown that the DFI level was found to have significant ($P < 0.05$) linear and quadratic, while DFI*sugar substitute level interaction effect on CY. The analysis of variance showed that the model F value of 6.40 and lack of fit F value of 20.43 was significant ($P < 0.05$) (Table 2). The R^2 value (0.8205) indicated that 17.95% of the total variation was not explained by the model. With increase in sugar substitute level in product, there was a progressive decrease in cooking yield and the maximum value for cooking yield were found to be (94%) and it was observed at minimum sugar substitute level i.e. 10% (Fig. 1). With continuous increase in DFI level, cooking yield was first increased and then decreased due to the interaction of DFI and sugar substitute level (Fig. 1). Presence of high amount of insoluble dietary fiber in flax seed contributes significantly in improving cooking yield by holding more water during the heat treatment and in the final product. Further with reduction of particle size of fiber there is an increase in water holding capacity by increasing the surface area (Kurek and wyrwiz. 2015).

Fig. 2 Surface plot (3-D) for Hue angle and Chroma value of *chhana* balls-Sandesh like product

Water activity (a_w)

The second order polynomial equation generated related to water activity (a_w) and two independent variables (DFI and sugar substitute level) in terms of actual and coded factors is given in Table 2. A response surface quadratic model for water activity (a_w) was generated with the two variables. In this study, DFI level was found to have significant ($P < 0.05$) quadratic effect, while sugar substitute level had linear and quadratic effect on water activity (a_w). The analysis of variance showed that the model F value of 6.55 was significant ($P < 0.05$), while the lack of fit F value of 0.04 implied that it was non-significant ($P > 0.05$) relative to the pure error (Table 2). The R^2 value of 0.8239 indicated that 17.61% of the total variation was not explained by the model. A low value of the coefficient of variation (0.51%) indicated the higher precision and reliability of the model. With continuous increase in DFI and sugar substitute level, water activity (a_w) was first decreased and then increased due to the interaction of DFI and sugar substitute level (Fig. 1). Khouryieh and Aramouni (2012) also reported that, as the level of flaxseed flour was increased in cookies, the corresponding water activity decreased.

Diagnostic checking of fitted model for colour profile

Hue angle

Hue is defined as the degree to which a stimulus can be described as similar or different from stimuli that are described as red, green, blue, and yellow (Singh et al. 2018; Sharma and Singh. 2016). The second order polynomial equation generated relating Hue angle and two independent variables (DFI and sugar substitute level) in terms of actual and coded factors is given in Table 2. A response surface linear model for Hue angle was generated with the two variables. In this case, sugar substitute level was found to have significant ($P < 0.05$) linear effect, while the effect was non-significant for DFI level. The analysis of variance showed that the model F value of 5.78 was significant

($P < 0.05$), while the lack of fit F value of 0.47 implied that it was non-significant ($P > 0.05$) relative to the pure error (Table 2). The R^2 value of 0.53 indicated that 53.64% of the total variation was explained by the model. A high value of coefficient of variation (326.11%) indicated the lower precision and unreliability of the model. As per model, there was linear increase in Hue angle with decrease in sugar substitute level while it increased with increase in DFI level (Fig. 2). Chetana and Sunkireddy (2011) concluded that the addition of 20% flaxseeds had significant effect on the colour profile viz., a^* and b^* values compared to *Chikki* prepared without addition of flaxseed.

Chroma value

It may be defined as the strength or dominance of the hue. The second order polynomial equation generated relating Chroma value and two independent variables (DFI and sugar substitute level) in terms of actual and coded factors is given in Table 2. A response surface linear model for Chroma value was generated with the two variables. DFI and sugar substitute level were found to have significant ($P < 0.05$) linear effect on Chroma value. The analysis of variance showed that the model F value of 78.58 was significant ($P < 0.05$), while the lack of fit F value of 5.19 implied that it was non-significant ($P > 0.05$) relative to the pure error (Table 2). The R^2 value of 0.94 indicated that 5.98% of the total variation was not explained by the model. As per model, there was linear increase in Chroma value with increase in sugar substitute level while it declined with increase in DFI level (Fig. 2). Negative relationship with DFI might be attributed to the increased reddish brown and positive relationship with sugar substitute might be due to the yellow colour contributed by sugar substitute to the prepared product.

Fig. 3 Surface plot (3-D) for sensory attributes of *chhana* balls-Sandesh like product

Diagnostic checking of fitted model for sensory attributes

Colour and appearance (CA)

Colour and appearance is one of the most appealing attributes of any food product before its intake, hence influences the consumer acceptability (Nalwade et al. 2014). The second order polynomial equation generated related to colour and appearance (CA) and two independent variables (DFI and sugar substitute level) in terms of actual and coded factors is given in Table 3. A response surface quadratic model for CA was generated with the two variables. In the study, DFI and sugar substitute level were found to have significant ($P < 0.05$) linear and quadratic effect on CA score respectively. The analysis of variance showed that the model F value (6.13) was significant ($P < 0.05$), while the lack of fit F value (0.58) was non-significant ($P > 0.05$) relative to the pure error (Table 3). The R^2 value (0.8142) indicated that 81.42% of the total variation was explained by the model. With increase in DFI level in the product, there was a continuous decrease in CA score and maximum score of 6.60 was observed when 4% DFI was incorporated in the product (Fig. 3). The decrease in CA score can be directly correlated with the instrumental color measurements. Flaxseed incorporated at higher

concentration led to darkening of the product and brownish appearance probably due to the phenolic compounds present in flaxseeds and maillard reactions between flaxseed protein and sugar (Khouriye and Aramouni 2012). With increase in sugar substitute level, CA score was first decreased and then increased due to the interaction of fiber and sugar substitute level (Fig. 3). Moreover, the yellowish white appearance of the product might have positive influence on the sensory acceptance.

Flavour (Flv)

The second order polynomial equation generated related to flavour and two independent variables (DFI and sugar substitute level) in terms of actual and coded factors is given in Table 3. A response surface linear model for flavour was generated with the two variables. In the study, DFI level was found to have significant ($P < 0.05$) linear effect, however, the effect was non-significant for varying sugar substitute level. The analysis of variance showed that the model F value of 6.61 was significant ($P < 0.05$), while the lack of fit F value of 0.84 implied that it was non-significant ($P > 0.05$) relative to the pure error (Table 3). The R^2 value (0.5693) indicated that 43.07% of the total variation was not explained by the model. As per model, there was a trend of linear increase in flavour score with

increased in sugar substitute level, while the score declined with increase in DFI level (Fig. 3). The characteristic flavour of DFI might had a negative effect on the flavour however; the sugar substitute has contributed pleasant flavour to the product. Sawant et al. (2010) also reported that as the level of sugar increased there was increase in the flavour scores of the *chhana podo*.

Body and texture (Tx)

The second order polynomial equation generated related to body and texture and two independent variables (DFI and sugar substitute level) in terms of actual and coded factors is given in Table 3. A response surface quadratic model for body and texture score was generated with the two variables. In this case, sugar substitute level was found to had significant ($P < 0.05$) quadratic effect on body and texture. The analysis of variance showed that the model F value of 5.20 was significant ($P < 0.05$), while the lack of fit F value of 2.69 implied that it was non-significant ($P > 0.05$) relative to the pure error (Table 3). The R^2 value (0.7878), being a measured as of the goodness of fit of the model, indicated that 78.78% of the total variation was explained by the model. A low value of the coefficient of variation (1.19%) indicated higher precision and reliability of the model. With increase in DFI incorporation level, the score for body and texture first increased and then decreased due to interaction of DFI and sugar substitute level (Fig. 3). In consonance with the present study, Khouryieh and Aramouni (2012) stated that the texture score decreased with increased level of flaxseed flour incorporated in the product. The reduced body and texture scores could be attributed to the interactions of the fiber with the milk solids (Raju and Pal 2014). With the increased sugar substitute level, texture score was first decreased and then increased due to interaction of DFI and sugar substitute level (Fig. 3).

Juiciness (Jc)

The second order polynomial equation generated related to juiciness (Jc) and two independent variables (DFI and sugar substitute level) in terms of actual and coded factors is given in Table 3. A response surface quadratic model for juiciness score was generated with the two variables. In this case, DFI level (linear and quadratic effect), DFI level*sugar substitute interaction and sugar substitute level (linear effect) were found to have significant ($P < 0.05$) effect on juiciness score. The analysis of variance showed that the model F value of 7.04 was significant ($P < 0.05$), while the lack of fit F value of 2.08 implied that it was non-significant ($P > 0.05$) relative to the pure error (Table 3). The R^2 value of 0.8341 indicated that 16.59% of the total variation was not explained by the model. With continuous increase

in DFI level, juiciness was first increased and then again decreased due to interaction of DFI and sugar substitute level (Fig. 3). The mucilaginous property of DFI might contributed to the juiciness of the product and binding of the ingredient and thereby have a negative effect on moisture loss from product. With increased sugar substitute level in the product, there was a profound increase in juiciness score of the developed product (Fig. 3).

Sweetness (Sw)

The second order polynomial equation generated related to sweetness and two independent variables (DFI and sugar substitute level) in terms of actual and coded factors is given in Table 3. A response surface 2FI model for Sweetness was generated with the two variables. In this case, sugar substitute level was found to have significant linear ($P < 0.05$) and fiber level*sugar substitute interaction effect on Sw. The analysis of variance showed that the model F value of 10.67 was significant ($P < 0.05$), while the lack of fit F value of 1.37 implied that it was non-significant ($P > 0.05$) relative to the pure error (Table 3). The R^2 value (0.7805) indicated that 78.05% of the total variation was explained by the model. A low value of the coefficient of variation (1.69%) indicated higher precision and reliability of the model. With linear increase in DFI level, sweetness decreased linearly due to interaction of DFI and sugar substitute level (Fig. 3). With linear increase in sugar substitute level, sweetness increased in linear manner.

Overall acceptability (OA)

The second order polynomial equation generated related to overall acceptability (OA) and two independent variables (DFI and sugar substitute level) in terms of actual and coded factors is given in Table 3. A response surface linear model for OA was generated with the two variables. In this case, DFI level was found to have significant linear effect ($P < 0.05$), while the effect was non-significant for sugar substitute level. The analysis of variance showed that the model F value of 4.89 was significant ($P < 0.05$), while the lack of fit F value of 1.23 implied that it was non-significant ($P > 0.05$) relative to the pure error (Table 3). The R^2 value (0.4946) indicated that 50.44% of the total variation was not explained by the model. A low value of the coefficient of variation (2.02%) indicated higher precision and reliability of the model. As per model, there was linear increase in overall acceptability with increased in sugar substitute level, while OA of the product declined with increased DFI incorporation level (Fig. 3). Gartaula and Bhattarai (2014) prepared *bomboyson* incorporated with sugar and *jaggery*, but the addition of *jaggery* had not altered the overall acceptability characteristics of the

product. Further, a bagel-type product incorporated with 5% flaxseed flour in the formulation showed no significant difference in the flavor or overall acceptability scores compared to the control wheat flour (Alpaslan and Hayta 2006).

Optimization and model validation

The independent variables were optimized numerically using statistical software Design Expert, Trial version-10.0.6 2017 (Stat-Ease Inc.). The variables were kept in range during optimization. The goals were assigned to each response parameters. The pH, cooking yield, Hue angle, Chroma value were in range; overall acceptability was at maximum and water activity was kept at minimum. From the numerical analysis, it was observed that 5.92% of DFI and 26.42% of *jaggery:stevia* (1:1) gave an optimized product of desirability 0.85. The values of responses at optimum formulation were 6.36 pH, 91.80 cooking yield (%), 0.9481 water activity (a_w), – 22.62 Hue angle, 8.71 Chroma value, 6.89 sweetness and 7.10 overall acceptability. These predicted values were validated with experimental values and found be not significantly different. Validation of optimized *chhana* balls formulation was done by preparing the product in triplicate and comparing the observed result with the optimum predicted data using two-tailed, one sample *t* test. No significant difference was observed between the values of experimental responses and the predicted responses. Thus, suitability of the models to predict various responses was ascertained.

Proximate composition of optimized *chhana* balls

The moisture, protein, fat and ash content in the developed functional *chhana*-balls was 48.19 ± 0.51 , 20.68 ± 0.36 , 9.03 ± 0.31 and $3.94 \pm 0.09\%$ respectively. The carbohydrate content computed by difference was $18.16 \pm 0.54\%$ and the mean calorie value calculated on the basis of fat, protein and carbohydrate content was 236.63 ± 4.23 kcal/100 g. Further, the moisture protein ratio was computed to be 2.33 ± 0.07 and the dietary fiber, insoluble dietary fiber and soluble dietary fiber content was recorded as 3.34 ± 0.12 , 2.19 ± 0.15 and $1.15 \pm 0.08\%$ respectively. The total dietary fiber content of flaxseed was 30.8–37.3%.

Conclusion

Designed experiments using CCD successfully exhibited the effect of independent variables (DFI and *jaggery:stevia*) on the response variables (pH, cooking yield, a_w , Hue angle, Chroma value, colour and appearance,

flavour, body and texture, juiciness, sweetness and overall acceptability) of *chhana* balls. The developed models found to be statistically valid and demonstrated adequate information regarding the behavior of *chhana* balls characteristics upon variation of process variables. Addition of roasted flaxseed increases the cooking yield and decreased the water activity. The preferred *chhana* balls was obtained by adding roasted flax seed and *jaggery:stevia* in an optimized way keeping in view on the overall acceptability and a_w . The optimized combinations of independent variables found were 5.92% of DFI and 26.42% of *jaggery:stevia* (1:1). It is concluded that roasted flax seed flour (DFI) and *jaggery:stevia* can be used for the preparation of low calorie, fiber rich *chhana* balls with acceptable sensory attributes and physico-chemical characteristics.

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