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Impact of isomalt-sucralose and FOS-sucralose concentrations on the sensory and rheological attributes of reduced-sugar sorghum-enriched chhana cakes

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Abstract

The objective of the present investigation was to develop a technology for manufacture of a reduced sugar *chhana* cake incorporating sorghum (RSCC). Sorghum incorporated chhana cake (SCC) was prepared using sorghum flour added @ 25.31% (w/w of *chhana*) in place of wheat flour. Sugar was added @ 40% w/w of chhana. Selection of most suitable pre-treatment for sorghum was carried out amongst four different pre-treatments viz. untreated sorghum flour, malted sorghum flour, roasted sorghum flour and malted-roasted sorghum flour. Untreated sorghum flour was most suitable for sorghum incorporated *chhana* cake production. In preparing RSCC without affecting the acceptability of the cake, the optimum level of replacement of sugar with sugar replacers viz. FOS-sucralose and Isomalt-sucralose was assessed employing Response Surface Method. The suggested solution was 26.990% replacement of sugar with FOS-sucralose and 30.118% replacement of sugar with Isomalt-sucralose and the desirability of the model were found to be 0.907. The proximate composition of the chhana cake prepared from optimised formulation was moisture 26.3%, protein 14.5%, fat 18.90%, total carbohydrate 39.30% and ash 1.85%. The protein content of RSCC was 2.9 times higher than commercial available cakes and it had 57.1% lower added sugar content compared to product formulation without sugar replacer.

Keywords: Reduced sugar, chhana cake, sorghum, WPC-80, gluten-free, bakery product, FOS, isomalt, sucralose

Introduction

Chhana based cake also referred to as “*Chhana podo*” is a baked product originating from the state of Orissa. It has a moderately spongy cake-like texture and soft body. The ingredients used for its manufacture are *chhana*, wheat and wheat products as binders and sugar. It contains around 15.0 to 16.0% protein making it is a rich source of milk proteins compared to around 5.0% protein in commercially available plain cakes.

Sorghum (*Sorghum bicolor* L. Moench) or “Jowar” cereal is an important coarse-grained food crop. The proximate composition of sorghum is moisture (g) 09.01±0.77; Protein (g) 09.97±0.43; Ash (g) 1.39±0.34; Total fat (g) 1.73±0.31; Fiber (g) 10.22±0.49; Carbohydrates (g) 67.68±1.03; Energy (kJ) 1398±13. It is an excellent source of polyphenols, flavonoids and condensed tannins which are antioxidant potent in nature (McDonough *et al.*, 1986) [13]. Sorghum also contains good amount of dietary fiber that is 9.7-14.3 g/100 g (Rao, 2003) [14], which has a significant positive effect on preventing and managing the diseases like constipation, irritable bowel syndrome and obesity. Sorghum is considered as a gluten free grain for development of novel baked goods (Adiamo *et al.*, 2018; Curti *et al.*, 2022; Jambukiya *et al.*, 2022; Cairns *et al.*, 2023) [1, 6, 8, 5].

Fructooligosaccharides (FOS) are non-digestible carbohydrates classified as key bifidogenic oligosaccharides. Commonly referred to as oligofructose, oligo fructan, fructose oligomers, fructans, or glucofructans, these oligosaccharides consist of fructose chains linked by β (2→1) glycosidic bonds. FOS exhibits a standard pH range of 4.0–7.0, ensuring high food stability.

They possess greater thermal stability than sucrose and remain stable at refrigerated temperatures for up to one year. Additionally, FOS is highly hygroscopic, aiding in moisture retention and controlling microbial contamination. Their low sweetness intensity (0.3-0.6 times sweeter than sucrose) and low caloric content (1.5 kcal/g) make them suitable for low-sugar formulations in various food products, such as ice creams, milk desserts, yogurts, and bakery items. FOS is non-carcinogenic, as they are not metabolized by oral bacteria to produce acids that lead to tooth decay (Kherade *et al.*, 2021) [9].

Isomalt (Iso) is an equimolar mixture of two disaccharide alcohols: alpha-D-glucopyranosyl-alpha-(1-6)-sorbitol and alpha-D-glucopyranosyl-alpha-(1-6)-mannitol. It is produced industrially through the catalytic hydrogenation of isomaltulose (Bornet, 1994) [4] and provides about 50% of the sweetness of sucrose (Zumbe *et al.*, 2001) [17]. As a sugar replacer, isomalt is derived from sugar and can be used similarly, substituting sugar cup for cup. It retains many of the functional properties of sugar, facilitating the development of high-quality confectionery products with specific nutritional and functional characteristics, such as sugar-free, low glycaemic, low insulinaemic, reduced-calorie products that do not promote tooth decay (Sentko and Willibald-Ettle, 2012) [16].

Sucralose (1, 6-dichloro-, 1, 6-dideoxy-β-D-dructofuranosyl-4-chloro-deoxy-α-D-galacto-pyranoside) is synthesized from sucrose by selectively replacing 3 hydroxyl groups with chlorine atoms (Kroger *et al.*, 2006). It is a zero-calorie sweetener that is 600 times sweeter than sucrose. Sucralose tastes like sugar, has no unpleasant or bitter aftertaste (Giese, 1993) [7], and is non-caloric, non-carcinogenic, and proven safe for human consumption. Sucralose is highly soluble in water and alcohol, chemically compatible with all common food ingredients, and stable in a wide range of pH levels and thermal processes. Thus, it could be a suitable sweetener for bakery products (Barndt and Jackson, 1990) [2]. Although sucralose provides the sweetness and crystallization properties of sucrose, it cannot mimic the structural contribution of sucrose to baked products (Martinez-Cervera *et al.*, 2012) [12]. It cannot create bulk properties in the cake batter as sucrose does. As a result, sucralose must be combined with other substances to match sucrose's bulking properties viz. FOS and isomalt.

Scanty information is available in literature on use of sucralose in combination with isomalt and FOS in chhana cakes. In one study, dietetic chhana podo was prepared using sucralose and maltodextrin. The product was prepared with low fat milk i.e. 2% fat milk and maltodextrin was used as bulking agent. But only 50% replacement of sugar was possible. By these treatments, the calorie content was reduced by 25%. The dietetic chhana podo was slightly softer than the control product. Hardness was observed to be lower than control (Kumar, 2008) [11].

Reduced sugar products are designed so as to meet the dietary requirements of obese, persons at risk of CVDs, diabetics and persons on weight management diets (Sahay and Sahay, 2002) [15]. Therefore, the present project was contemplated to evaluate the effect of replacing sugar with FOS-sucralose and isomalt-sucralose on the acceptability of sorghum incorporated chhana based cake and to develop a reduced sugar chhana based cake with sorghum.

Materials and Methods

Whole milk, pasteurised (~6.0% milk fat) was procured from Vidya Dairy, Anand was used for manufacturing chhana. Sorghum flour was collected from Me to millet store of Anand city. Skim milk powder of "Sagar" brand, marketed by Gujarat Cooperative Milk Marketing Federation, Anand was used in preparation of chhana based cake. High quality, packed WPC-80 was procured from Arla foods to manufacture chhana based cake as per standardized procedure. Sugar used in this study was of Madhur Sugars and Chemicals Pvt. Ltd., Maharashtra collected from local market of Anand. FOS-sucralose and Isomalt-sucralose considered as low calorie sweetener used in this study was of Diet sweet, Kapse Patil Krushi Producer Co. Ltd., Maharashtra procured. This combination of intense sweetener i.e. sucralose and bulking ingredient i.e. fructooligosaccharide and isomalt has been declared to be equivalent sweetness to that of sucrose by Diet sweet company. It can be used in equivalent quantity as to replace quantity of sugar. Baking powder and baking soda of Blue bird brand, Mumbai was used in this study.

Method of manufacture of chhana

Fresh, Pasteurized whole milk (6.0% Fat and 9.0% MSNF) was filtered, heated to 90 °C for 5 min and cooled to 70 °C. Citric acid solution (1.0%) was heated to 70 °C and gradually added to the milk, stirring gently with a ladle until the milk coagulated. Milk coagulum was hold with the whey for 5 minutes. Then, the whey was strained through muslin cloth, and the coagulated mass was hung for complete whey drainage to obtain chhana.

Method for manufacture of chhana cake

The chhana prepared as outlined above served as the base for manufacture of sorghum incorporated chhana cake. Chhana cake was prepared according to the method standardized by Barot (2024) [3]. Sucrose was added @ 40% w/w of chhana for SCC. RSCC were prepared by replacing sucrose with FOS-sucralose (20-25% replacement) and Isomalt-sucralose (20-25% replacement). First, the white butter @ 15.31%, cottonseed oil @ 10.21%, calculated amount of FOS-sucralose, Isomalt-sucralose and sucrose was kneaded in the Hobart mixture for about 1.5 to 2.0 min and creamy whipped texture was achieved. Then chhana was added to the Hobart mixture and kneaded for about 1 min. Then all the dry ingredients viz. sorghum flour @ 25.21%, skimmed milk powder @ 15%, WPC-80 @ 9.78%, baking powder @ 2.0% and baking soda @ 1.0% (all w/w of chhana) were dry blended together sieved and added to the Hobart mixture and it was again kneaded thoroughly for 1.5 to 2.0 min. and smooth dough was obtained. The dough was then transferred into aluminium moulds (~400 g capacity) and baked at 130 °C for 80 min. Thereafter it was cooled to room temperature packed in LDPE pouches and stored at 7 ± 1 °C till; it was subjected to sensory evaluation and other parameters evaluation.

Selection of pretreatments for sorghum

In order to select the most suitable pretreatment to be given to sorghum grain which is intended to be used as a binder for chhana cakes, experimental samples of SCC were prepared using untreated sorghum flour and two treatments viz. malting and roasting of sorghum grains. Samples were coded as follows: untreated sorghum flour (T₁), malted

sorghum flour (T_2), roasted sorghum flour (T_3), malted and roasted sorghum flour (T_4). Each treatment was replicated 4 times. In all 16 batches of *chhana* cakes were prepared.

Sensory evaluation

Samples were withdrawn from the refrigerator at 7 ± 1 °C and microwaved at 2450 MHz frequency for 12 s before subjecting it for sensory evaluation. Sensory analysis was done after 24 h of manufacturing of *chhana* cake at a temperature of 23 ± 1 °C. The sensory panellist ($n = 10$) includes staff members and post-graduate students working in the institution. The 9-point hedonic scale was used for this purpose. The sensory parameters were colour and appearance, volume, body and texture, flavour, crumb colour, crust colour and overall acceptability.

Texture profile analysis of *chhana* based cake

Four samples of each experimental *Chhana* based cake are subjected to uniaxial compression to 50% of the initial sample height, using a Food Texture Analyzer of Lloyd Instruments LRX Plus material testing machine, England; fitted with 0-500 kg load cell. The force-distance curve was obtained for a two-bite deformation cycle employing a Cross Head speed of 20 mm/min, Trigger 10 gf and 60% Compression of the samples to determine various textural attributes of *Chhana* based cake held for 1 h at 25 ± 1 °C and 55% RH. The complete work of calculations of area under the force-distance curve, statistical analysis of data generated and their conversion into various textural attributes were carried out by direct transfer of the data to Lloyd Instruments NEXYGEN data analysis and applications software. The rheological parameters evaluated were hardness, cohesiveness, springiness, gumminess and chewiness.

Statistical analysis

The mean values generated from the analysis of duplicate samples of *chhana* cakes obtained in three replications, were subjected to statistical analysis using completely randomized design (CRD) using the OPSTAT software. To carry out their optimization of selected parameters, an advanced statistical software program named Design Expert (Version 13.0.5.0.) was employed.

Results and Discussion

Effect of selected pretreatments for sorghum grains on sensory attributes of SCC

The influence of varied treatment given to sorghum on acceptability of SCC is presented in Table 1. It can be seen from Table 1 that the flavour score of T_1 was significantly ($p < 0.05$) higher compared to all the other samples. Flavour scores of T_2 and T_3 were at par ($p > 0.05$) with each other. Malting and roasting reduced flavor acceptability of samples which could be attributed to treatment-induced undesirable flavor development, affecting final product palatability. The body and texture score of T_1 was higher than all the other samples. However, it was at par ($p > 0.05$) with sample T_3 . Malting and roasting treatment adversely affected the body and texture of the samples. These samples were generally criticized for their dense and heavy body and brittle texture. The samples lacked desired soft and tender crumb structure. The colour and appearance scores of T_1 was significantly ($p < 0.05$) higher compared to all the other samples. Regarding colour and appearance, samples made with

treated sorghum flours scored lower than untreated flour. This was because they lacked appealing appearance and sometimes had a non-uniform colour development, ranging from light to dark brownish tinges with visible patches of white. This uneven colouration adversely affected the appearance of products containing treated sorghum flours.

The overall acceptability score of T_1 was significantly ($p < 0.05$) higher compared to all the other samples. And the overall acceptability score of T_4 was significantly ($p < 0.05$) lower compared to all the other samples. Treated samples were criticized for lacking the desired moistness and crumbs structure. They lacked the desired mouthfeel and were criticised for grittiness. They had a typical undesirable aftertaste. Compared to other experimental samples T_1 had a moister body and the interior of the cake was softer and it had good crumb structure. It was relatively lighter and had a spongy texture with good internal structure. The outer crust of the cake was slightly moist and golden brown in colour. It was concluded that untreated sorghum flour (T_1) was most suitable for RSCC. Hence, it was selected and was used in subsequent study study phases.

Optimization of *chhana* cake formulation for replacing sucrose With Isomalt-Sucralose and FOS-Sucralose

In order to replace both these sugar replacers partly i.e. at levels 20 to 40% levels each. These levels were selected based on preliminary trials. Two factor Response Surface Methodology (RSM) was used to optimize levels of Isomalt-Sucralose (A) and FOS-Sucralose (B) as part replacement of sugar. The design matrix with the experimental data on sensory attributes of *chhana* cake for response analysis is presented in Table 2 and the regression analysis of the data is presented in Table 3.

Influence of varying the level of Isomalt-Sucralose and FOS-Sucralose on the sensory properties

Colour & appearance score

From Table 3, FOS-Sucralose ($p < 0.05$) showed significant while Isomalt-Sucralose ($p \geq 0.1$) didn't show any significant changes on colour and appearance score at linear terms. A non-significant positive interactive effect on colour and appearance score was observed with interactive effect $A \times B$ ($p \geq 0.1$). FOS-Sucralose and Isomalt-Sucralose both had significant changes at quadratic terms ($p < 0.05$) (Table 3). No references are available in literature on the influence of varying levels of sugar replacement employed utilizing FOS-sucralose and Isomalt-sucralose on the colour and appearance scores of *chhana* cakes.

Volume score

FOS-Sucralose ($p < 0.1$) showed significant while Isomalt-Sucralose ($p \geq 0.1$) didn't show any significant changes on volume score at linear terms (Table 3). A non-significant ($p \geq 0.1$) negative interactive effect on volume score was observed with interactive effect ($A \times B$) of varying FOS-Sucralose and Isomalt-Sucralose in *chhana* based cake. FOS-Sucralose and Isomalt-Sucralose both had significant changes at quadratic terms ($p < 0.05$) (Table 3). Influence of level of FOS-Sucralose and Isomalt-Sucralose on the volume score of *chhana* based cake is illustrated in figure 3.

Crust colour score

The crust colour score of *chhana* based cake was observed in the range from 6.90 to 7.93 as per Table 2. FOS-Sucralose ($p < 0.1$) showed significant while Isomalt-

Sucralose ($p \geq 0.1$) didn't show any significant changes on crust colour score at linear terms (Table 3). A non-significant ($p \geq 0.1$) negative interactive effect on crust colour score was observed with interactive effect (A×B) of varying FOS-Sucralose and Isomalt-Sucralose in *chhana* based cake. FOS-Sucralose and Isomalt-Sucralose both had significant changes at quadratic terms ($p < 0.05$) (Table 3).

Crumb colour score

It can be seen from table that the crumb colour score of *chhana* cake was observed in the range of 7.00 to 8.00. FOS-Sucralose ($p < 0.05$) showed significant while Isomalt-Sucralose ($p \geq 0.1$) didn't show any significant changes on crumb colour score at linear terms (Table 3). A non-significant positive interactive effect on crumb colour score was observed with interactive effect (A×B) of varying FOS-Sucralose and Isomalt-Sucralose in *chhana* based cake manufacturing ($p \geq 0.1$). FOS-Sucralose had significant changes at quadratic terms ($p < 0.05$) while Isomalt-Sucralose had non-significant changes at quadratic terms ($p \geq 0.1$) (Table 3).

Body and texture score

FOS-Sucralose ($p < 0.05$) and Isomalt-Sucralose ($p < 0.1$) both showed significant changes on body and texture score at linear terms (Table 3). A significant ($p < 0.05$) positive interactive effect on body and texture score was observed with interactive effect (A×B) of varying FOS-Sucralose and Isomalt-Sucralose in *chhana* based cake. FOS-Sucralose and Isomalt-Sucralose both had significant changes at quadratic terms ($p < 0.05$) (Table 3).

Flavour score

The regression analysis of the data is presented in Table 3. FOS-Sucralose and Isomalt-Sucralose both showed significant ($p < 0.05$) changes on flavour score at linear terms. A significant ($p < 0.05$) positive interactive effect on flavour score was observed with interactive effect (A×B) of varying FOS-Sucralose and Isomalt-Sucralose in *chhana* based cake. FOS-Sucralose and Isomalt-Sucralose both had significant changes at quadratic terms ($p < 0.05$) (Table 3). Influence of level of FOS-Sucralose and Isomalt-Sucralose on the flavour score of *chhana* based cake is illustrated in figure 1.

Overall acceptability score

The Overall acceptability score of *chhana* cake was observed in the range from 7.10 to 8.07. FOS-Sucralose ($p < 0.05$) and Isomalt-Sucralose ($p < 0.10$) both showed significant changes on overall acceptability score at linear terms (Table 3). A significant ($p < 0.1$) positive interactive effect on overall acceptability score was observed with interactive effect (A×B) of varying FOS-Sucralose and Isomalt-Sucralose in *chhana* based cake. FOS-Sucralose and Isomalt-Sucralose both had significant changes at quadratic terms ($p < 0.05$) (Table 3). Influence of level of FOS-Sucralose and Isomalt-Sucralose on the overall acceptability score of *chhana* based cake is presented in figure 2.

No references are available in literature on the influence of varying different levels of two sugar replacer i.e. FOS-sucralose and Isomalt-sucralose on the overall acceptability scores of *chhana* cakes. Kumar (2008) [11] reported that sucralose was found to be the best sugar replacement, with 50% replacement producing a product i.e. dietetic pod

having very similar to the control in terms of sensory attributes.

Influence of varying the level of FOS-Sucralose and Isomalt-Sucralose on rheological properties

Hardness

Table 4 illustrate the impact of sugar replacement level of two different replacers on the hardness of *chhana* cake. The Hardness of *chhana* cake was observed in the range from 13.13 to 35.09 (N). The regression analysis of the data is presented in Table 5. FOS-Sucralose and Isomalt-Sucralose both showed significant changes ($p < 0.05$) on Hardness at linear terms in negative and positive manner respectively indicating negative and positive linear effect of both FOS-Sucralose and Isomalt-Sucralose on Hardness. A non-significant negative interactive effect on Hardness was observed with interactive effect (A×B) with varying levels of FOS-Sucralose and Isomalt-Sucralose on *chhana* based cake ($p \geq 0.1$). Both the factors, Isomalt-Sucralose ($p < 0.05$) and FOS-Sucralose ($p \geq 0.05$) had significant positive changes at quadratic terms (Table 5). Influence of level of FOS-Sucralose and Isomalt-Sucralose on the Hardness of *chhana* based cake is illustrated in figure 4.

No references are available in literature on the influence of varying different levels of two sugar replacer i.e. FOS-sucralose and Isomalt-sucralose on the Hardness of *chhana* cakes.

Cohesiveness

FOS-Sucralose and Isomalt-Sucralose both showed significant changes ($p < 0.05$) on Cohesiveness at linear terms in positive manner indicating positive linear effect of both FOS-Sucralose and Isomalt-Sucralose on Cohesiveness. A non-significant negative interactive effect on cohesiveness was observed with interactive effect (A×B) with varying levels of FOS-Sucralose and Isomalt-Sucralose on *chhana* based cake ($p \geq 0.1$). The factors, FOS-Sucralose ($p \geq 0.1$) being non-significant negative and Isomalt-Sucralose ($p \geq 0.05$) had significant negative changes at quadratic terms (Table 5).

Springiness

FOS-Sucralose and Isomalt-Sucralose both showed significant changes ($p < 0.05$) on springiness at linear terms in positive manner indicating positive linear effect of both FOS-Sucralose and Isomalt-Sucralose on springiness. A non-significant negative interactive effect on springiness was observed with interactive effect (A×B) with varying levels of FOS-Sucralose and Isomalt-Sucralose on *chhana* based cake ($p \geq 0.1$). Both the factors, FOS-Sucralose ($p \geq 0.1$) and Isomalt-Sucralose ($p \geq 0.1$) had non-significant positive and negative changes respectively at quadratic terms (Table 5).

Gumminess

FOS-Sucralose and Isomalt-Sucralose both showed significant changes ($p < 0.05$) on gumminess at linear terms in positive and negative manner respectively indicating the positive and negative linear effect of FOS-Sucralose and Isomalt-Sucralose on gumminess respectively. A significant ($p < 0.05$) negative interactive effect on gumminess was observed with interactive effect (A×B) with varying levels of FOS-Sucralose and Isomalt-Sucralose on *chhana* based cake. The factors, FOS-Sucralose and Isomalt-Sucralose had

($p < 0.05$) significant positive and significant negative changes respectively at quadratic terms (Table 5).

Chewiness

FOS-Sucralose and Isomalt-Sucralose both showed significant changes ($p < 0.05$) on chewiness at linear terms in negative and positive manner respectively indicating negative and positive linear effect of FOS-Sucralose and Isomalt-Sucralose on Chewiness respectively. A significant positive interactive effect on Chewiness was observed with interactive effect (A×B) with varying levels of FOS-Sucralose and Isomalt-Sucralose on *chhana* based cake ($p < 0.1$). Isomalt-Sucralose ($p \geq 0.1$) had non-significant negative while FOS-Sucralose ($p < 0.05$) had significant positive changes on Chewiness at quadratic terms respectively (Table 5).

Optimization of product formulation for *chhana* cake (RSCC) manufacture

The goals or responses that were set for obtaining the best possible acceptability were kept maximum during optimization as these characteristics are having higher importance in the new product development in terms of sensory values. Combination is illustrated in Table 6. Considering the parameters and their limits, the RSM suggested the one most suited solution. Suggested solution from RSM analysis for *chhana* based cake is presented in Table 7. The predicted sensory scores and rheological attributes of optimized reduced sugar *chhana* based cake from RSM analysis are depicted in Table 8.

The final product was manufactured employing this suggested formulation and the actual results were obtained from the RSCC manufacture. The predicted values of the criteria/responses selected for optimization under study were compared with the actual values of the selected responses. The results obtained confirmed that the selected combination is the best one in terms of the sensory and textural responses delineated at the beginning of the study. The results are also validated statistically by 't' test. The calculated 't-value' for all the parameters are reported in Table 8. The values for 't' test being less than the table values, it is inferred that there is no significant ($p > 0.05$) difference between the predicted and actual values of responses as shown in Table 8. Based on the results obtained in Table 7, it was decided to replace sugar with 26.990% FOS-Sucralose and 30.118% Isomalt-sucralose in the formulation which was the suggested proportion from RSM for % sugar replacement and the desirability of the model was found to be 0.907.

Based on the results obtained, a formulation was standardized for manufacture RSCC. All the ingredients were added based on w/w of *chhana* i.e. sorghum flour @ 25.31%, WPC-80 @ 9.78%, skimmed milk powder @ 15%, white butter @ 15.31%, cottonseed oil 10.21% (considering ratio = 1.5:1 = butter: oil = 25.52), sugar @ 17.15%, FOS-Sucralose @ 10.80%, Isomalt-Sucralose @ 12.05%, baking soda @ 1.00% and baking powder @ 2.00%. The proximate composition of the developed product was: 26.3±2.83% moisture, 18.00±1.07% fat, 14.5±0.93% protein, 39.30±2.82% carbohydrate and 1.85±0.15% ash.

Table 1: Influence of varied treatment given to sorghum on acceptability of *chhana* cake (9-point hedonic scale)

Sample code	Flavour score	Body and texture score	Colour and appearance score	Overall acceptability score
T ₁	7.14 ^a ±0.07	6.71 ^a ±0.13	7.09 ^a ±0.22	7.15 ^a ±0.16
T ₂	6.74 ^{bc} ±0.13	6.34 ^b ±0.25	6.71 ^{bc} ±0.08	6.77 ^b ±0.13
T ₃	6.83 ^b ±0.13	6.43 ^{ab} ±0.23	6.79 ^b ±0.08	6.86 ^{ab} ±0.12
T ₄	6.56 ^c ±0.12	6.17 ^b ±0.12	6.50 ^c ±0.24	6.59 ^b ±0.42
S.Em.±	0.057	0.095	0.087	0.120
CD(0.05)	0.18	0.29	0.27	0.37
CV (%)	1.68	2.98	2.58	3.52

Figures given in table represent average of 4 replications ± SD

^{a,b,c}: Superscript letters following numbers in the same column denote significant difference ($p < 0.05$)

Table 2: Design matrix with the experimental data on sensory attributes of *chhana* cake for response analysis

Run	Variables (% sugar replacement)		Sensory attributes as response (9 point hedonic scale)						
	FOS-Sucralose (A)	Isomalt-Sucralose (B)	Colour and appearance	Volume	Crust Colour	Crumb Colour	Body and Texture	Flavour	Overall acceptability
1	30.00	44.14	7.50	7.50	7.20	7.80	7.70	7.35	7.51
2	40.00	40.00	7.35	7.40	6.90	7.50	7.70	7.40	7.38
3	30.00	30.00	7.98	8.13	7.88	7.67	7.92	8.13	7.94
4	20.00	40.00	7.55	7.80	7.50	7.80	7.70	7.30	7.60
5	30.00	30.00	8.14	8.32	7.89	7.79	8.04	8.19	8.05
6	44.14	30.00	7.25	6.90	7.50	7.00	7.00	7.20	7.10
7	40.00	20.00	7.30	7.50	7.10	7.30	7.10	7.30	7.30
8	30.00	30.00	7.99	8.27	7.66	7.68	8.00	8.20	7.96
9	30.00	30.00	8.11	8.29	7.86	7.64	7.86	8.16	8.00
10	20.00	20.00	7.61	7.36	7.46	8.00	7.84	7.74	7.65
11	30.00	15.86	7.43	7.43	7.18	7.64	7.43	7.43	7.36
12	15.86	30.00	7.93	7.36	7.46	7.93	7.64	7.57	7.59
13	30.00	30.00	8.21	8.14	7.93	7.93	8.21	8.13	8.07

Table 3: Coefficient of the full second order polynomial model for coded sensory responses to different levels of ingredients of *chhana* cake

Parameters		Sensory scores (9 point hedonic scale)						
		Colour and appearance	Volume	Crust colour	Crumb colour	Body and Texture	Flavour	Overall acceptability
Intercept		8.09	8.23	7.84	7.74	8.01	8.16	8.00
Linear Level	A	-0.1840 [#]	-0.1138 [*]	-0.1129 [*]	-0.2894 [#]	-0.2056 [#]	-0.1079 [#]	-0.1582 [#]
	B	0.0111 ^{ns}	0.0549 ^{ns}	-0.0165 ^{ns}	0.0283 ^{ns}	0.1052 [*]	-0.0566 [#]	0.0303 [*]
Interactive Level	A*B	0.0275 ^{ns}	-0.1350 ^{ns}	-0.0600 ^{ns}	0.1000 ^{ns}	0.1850 [#]	0.1350 [#]	0.0325 [*]
Quadratic Level	A ²	-0.2667 [#]	-0.4956 [#]	-0.2057 [#]	-0.1241 [#]	-0.3074 [#]	-0.3766 [#]	-0.3056 [#]
	B ²	-0.3292 [#]	-0.3281 [#]	-0.3507 [#]	-0.0034 ^{ns}	-0.1849 [#]	-0.3741 [#]	-0.2611 [#]
R ²		0.9469	0.9403	0.8546	0.9092	0.9217	0.9900	0.9720
Model F-value		24.97	22.06	8.23	14.02	16.48	138.82	48.61
APV		11.447	11.4967	6.5517	12.1733	11.284	26.1833	17.4347
Suggested Model		Quadratic	Quadratic	Quadratic	Quadratic	Quadratic	Quadratic	Quadratic

*: $0.05 \leq p < 0.1$; #: $p < 0.05$; ns: non-significant, $p \geq 0.1$; APV = Adequate Precision Value; A = FOS-Sucralose; B = Isomalt-Sucralose; R² = Coefficient of determination

Table 4: Design matrix with the experimental data on rheological attributes of sugar reduced *chhana* based cake for response analysis

Run	% sugar replacement		Rheological Attributes				
	FOS-Sucralose (A)	Isomalt-Sucralose (B)	Hardness (N)	Cohesiveness	Springiness (mm)	Gumminess (N)	Chewiness (Nmm)
1	30.00	44.14	29.97	0.32	10.03	3.50	35.05
2	40.00	40.00	22.62	0.35	10.30	4.46	47.31
3	30.00	30.00	21.99	0.28	9.36	6.97	64.66
4	20.00	40.00	35.09	0.31	9.24	3.77	33.92
5	30.00	30.00	20.56	0.29	9.45	6.39	58.89
6	44.14	30.00	13.13	0.33	10.03	13.86	112.21
7	40.00	20.00	16.00	0.26	9.99	14.19	158.14
8	30.00	30.00	20.19	0.29	9.74	7.21	70.90
9	30.00	30.00	18.44	0.29	9.89	7.68	70.75
10	20.00	20.00	22.45	0.18	8.79	4.88	43.41
11	30.00	15.85	14.43	0.22	9.09	5.68	52.53
12	15.85	30.00	30.73	0.24	9.18	5.29	50.15
13	30.00	30.00	18.00	0.31	9.46	5.82	59.13

Table 5: Coefficient of the full second order polynomial model for coded specific volume and rheological responses to different levels of ingredients of *chhana* cake

Rheological attributes						
		Hardness (N)	Cohesiveness	Springiness (mm)	Gumminess (N)	Chewiness (Nmm)
Intercept		19.84	0.29	9.58	6.81	0.0155
Linear Level	A	-5.4700 [#]	0.0309 [#]	0.4328 [#]	2.7600 [#]	-0.0051 [#]
	B	5.1500 [#]	0.0452 [#]	0.2612 [#]	-1.7400 [#]	0.0043 [#]
Interactive Level		A*B	-1.5100 ^{ns}	-0.0100 ^{ns}	-0.0350 ^{ns}	-2.1500 [#]
Quadratic Level	A ²	1.5400 [*]	-0.0041 ^{ns}	0.0119 ^{ns}	1.3200 [#]	-0.0003 ^{ns}
	B ²	1.6800 [#]	-0.0116 [#]	-0.0106 ^{ns}	-1.1800 [#]	0.0043 [#]
R ²		0.9540	0.9523	0.8430	0.9259	0.9474
Model F-value		29.06	27.93	7.52	17.49	25.23
APV		16.9814	16.6236	8.7469	14.0833	16.5679
Suggested Model		Quadratic	Quadratic	Quadratic	Quadratic	Quadratic

*: $0.05 \leq p < 0.1$; #: $p < 0.05$; ns: non-significant, $p \geq 0.1$; APV = Adequate Precision Value; A = Sorghum flour; B = Butter + oil; C = WPC-80; R² = Coefficient of determination

Table 6: Criteria/responses chosen for process optimization of *chhana* cake manufacture

Sr. No	Parameter	Units	Goal	Lower Limit	Upper Limit	Level of Importance
1	A: FOS-Sucralose	%	In range	20.00	40.00	3
2	B: Isomalt-Sucralose	%	In range	20.00	40.00	3
3	Colour and appearance	1-9	Maximize	7.25	8.21	5
4	Volume	1-9	Maximize	6.90	8.32	5
5	Crust colour	1-9	Maximize	6.90	7.93	5
6	Crumb colour	1-9	Maximize	7.00	8.00	5
7	Body and Texture	1-9	Maximize	7.00	8.21	5
8	Flavour	1-9	Maximize	7.20	8.20	5
9	Overall acceptability	1-9	Maximize	7.10	8.07	5
10	Hardness	N	In range	13.13	35.09	3
11	Cohesiveness	-	In range	0.18	0.35	3
12	Springiness	mm	In range	8.79	10.30	3
13	Gumminess	N	In range	3.50	14.19	3
14	Chewiness	Nmm	In range	33.92	158.14	3

Table 7: Suggested solution from RSM analysis for *chhana* cake

Solution No.	Solutions		Desirability
	A: FOS-Sucralose (% replacement)	B: Isomalt-Sucralose (% replacement)	
1	26.990	30.118	0.907

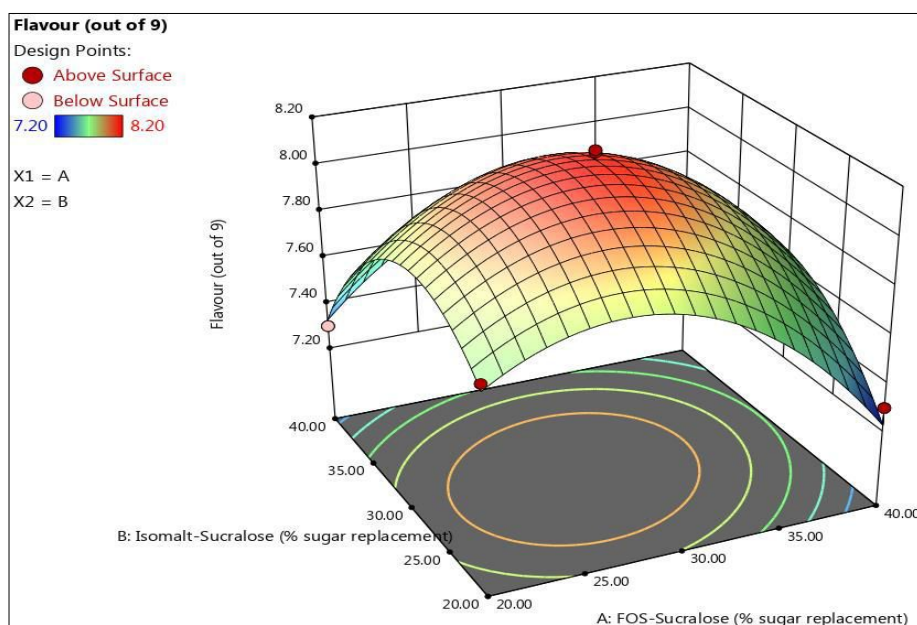
Table 8: Comparison of predicted v/s actual values of responses used for process optimization of *chhana* cake manufacture

Response	P Value	Predicted Value *	Actual Value @	Cal. t-Value #	Level of Significance
Colour and appearance (1-9)	0.9623	8.117	8.121	0.049	NS
Volume (1-9)	0.4564	8.220	8.129	0.796	NS
Crust colour (1-9)	0.5326	7.859	7.907	0.662	NS
Crumb colour (1-9)	0.3108	7.818	7.729	1.107	NS
Body and Texture (1-9)	0.3838	8.041	8.000	0.939	NS
Flavour (1-9)	0.1327	8.159	8.250	1.739	NS
Overall acceptability (1-9)	0.4279	8.023	8.086	0.850	NS
Hardness (N)	0.6323	21.694	21.109	0.504	NS
Cohesiveness	0.442	0.283	0.291	0.823	NS
Springiness (mm)	0.5574	9.454	9.769	0.621	NS
Gumminess (N)	0.8622	6.087	6.149	0.181	NS
Chewiness (Nmm)	0.8317	59.411	59.822	0.222	NS

* Predicted values of Design Expert 10.0.1 package; @ Actual values are average of seven trials for optimized product; # t-values found non-significant at 5% level of significance NS = Non Significant; Tabulated t-value = 2.447 (cal. t-value less than tabulated value)

Table 9: Standardized sorghum incorporated *chhana* cake recipe

Ingredients	Quantity (g)	Rate of Addition (% w/w of <i>chhana</i>)
<i>Chhana</i>	1000.0	-
Sorghum flour	253.1	25.31
WPC-80	97.8	9.78
Skimmed milk powder	150.0	15.00
White Butter	153.1	15.31
Cottonseed oil	102.1	10.21
Sugar	171.5	17.15
FOS-Sucralose	108.0	10.80
Isomalt-Sucralose	120.5	12.05
Baking powder	20.0	2.00
Baking soda	10.0	1.00

**Fig 1:** Influence of level of FOS-Sucralose and Isomalt-Sucralose on the flavour score of *chhana* based cake

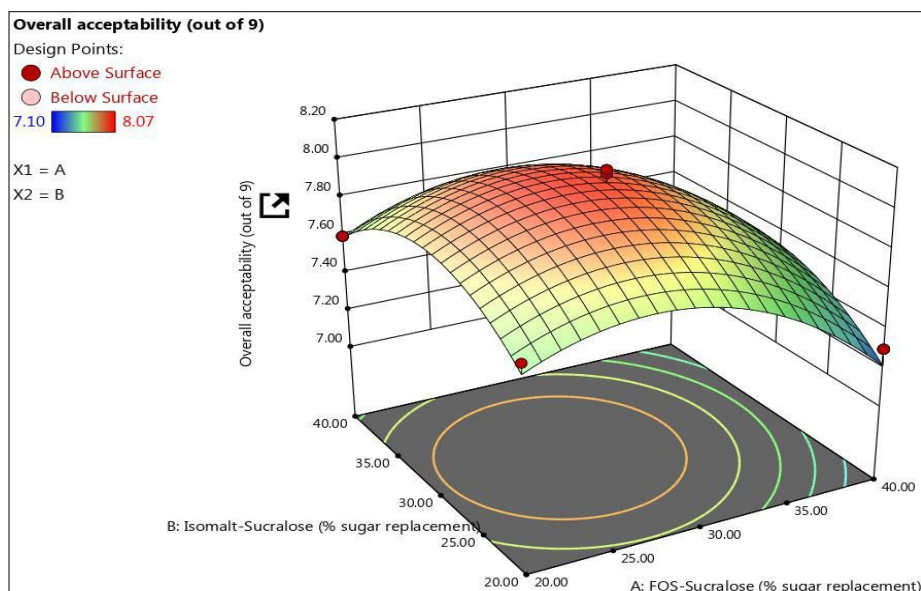


Fig 2: Influence of level of FOS-Sucralose and Isomalt-Sucralose on the overall acceptability score of *chhana* based cake

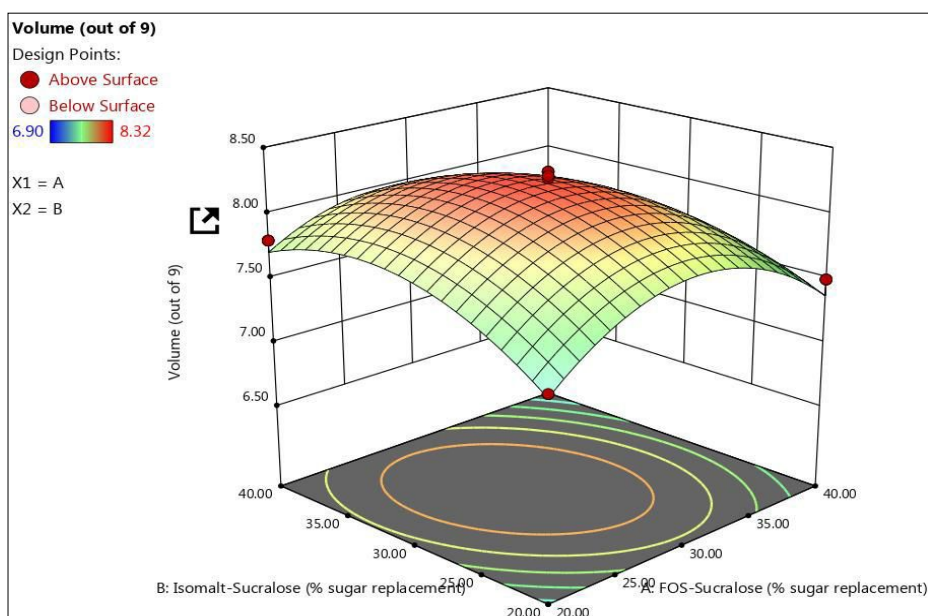


Fig 3: Influence of level of FOS-Sucralose and Isomalt-Sucralose on the volume score of *chhana* based cake

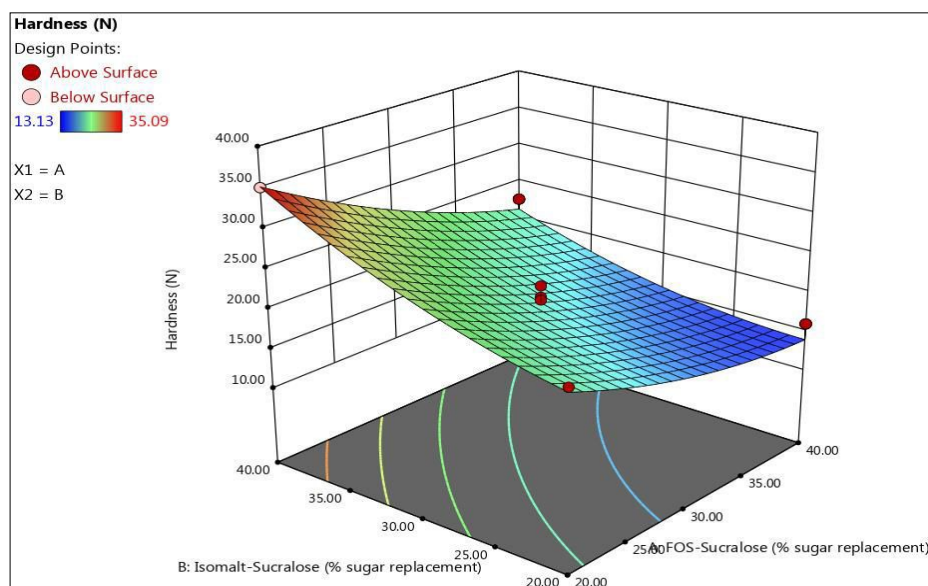


Fig 4: Influence of level of FOS-Sucralose and Isomalt-Sucralose on the Hardness of *chhana* based cake

Conclusion

Good quality chhana based cake incorporating sorghum can be prepared from chhana with sorghum as a binder in place of maida or suji. The protein content of sorghum incorporated chhana cake was 14.5% which was 2.9 times higher than commercially available cake. The reduced sugar formulation contained 17.1% added sugar (w/w of chhana) whereas added sugar in product formulation without sugar replacers viz. blend of FOS-Sucralose and Isomalt-Sucralose was 40% w/w of chhana. Hence, it had 57.1% lower sugar content compared to product formulation without sugar replacer.

References

1. Adiamo OQ, Fawale OS, Olawoye B. Recent trends in the formulation of gluten-free sorghum products. *Journal of Culinary Science & Technology*. 2018;16(4):311-325.
2. Barndt RL, Jackson G. Stability of sucralose in baked goods. *Food Technology*. 1990;44:62-66.
3. Barot A. Development of technology for reduced sugar chhana based cake incorporating sorghum [Doctoral dissertation]. Anand (Gujarat): Kamdhenu University; 2024.
4. Bornet FRJ. Undigestible sugars in food products. *The American Journal of Clinical Nutrition*. 1994;59(3):763S-769S.
5. Cairns A, Brazington S, Gragg E, Holmes A, Vavra C, Whitehair K, Getty K. Development and scale-up of gluten-free sorghum-based bakery goods for K-state Dining Services. *Journal of Agriculture and Food Research*. 2023;14:100840.
6. Curti MI, Belorio M, Palavecino PM, Camiña JM, Ribotta PD, Gómez M. Effect of sorghum flour properties on gluten-free sponge cake. *Journal of Food Science and Technology*. 2022;59(4):1407-1418.
7. Giese JH. Alternative sweeteners and bulking agents. *Food Technology*. 1993;47:113-126.
8. Jambukiya H, Pinto S, Gokhale A, Patel S. Physico-chemical, sensory and microbial changes during storage of gluten-free chhana cake. *The Pharma Innovation Journal*. 2022;11(10):21-25.
9. Kherade M, Solanke S, Tawar M, Wankhede S. Fructooligosaccharides: A comprehensive review. *Journal of Ayurvedic and Herbal Medicine*. 2021;7:193-200. DOI: 10.31254/jahm.2021.7305.
10. Kroger M, Meister K, Kava R. Low-calorie sweeteners and other sugar substitutes: A review of the safety issues. *Comprehensive Reviews in Food Science and Food Safety*. 2006;5(2):35-47.
11. Kumar R. Technology of dietetic chhana podo production [Doctoral dissertation]. Karnal: NDRI; 2008.
12. Martinez-Cervera S, Sanz T, Salvador A, Fiszman SM. Rheological, textural and sensorial properties of low-sucrose muffins reformulated with sucralose/polydextrose. *LWT-Food Science and Technology*. 2012;45:213-220.
13. McDonough CM, Rooney LW, Earp CF. Structural characteristics of Eleusine coracana (finger millet) using scanning electron and fluorescence microscopy. *Food Microstructure*. 1986;5(3):247-256.
14. Rao BS. Bioactive phytochemicals in Indian foods and their potential in health promotion and disease prevention. *Asia Pacific Journal of Clinical Nutrition*. 2003;12(1):9-22.
15. Sahay BK, Sahay RK. Lifestyle modification in management of diabetes mellitus. *Journal of the Indian Medical Association*. 2002;100(3):178-180.
16. Sentko A, Willibald-Ettle I. Isomalt. In: O'Donnell K, Kearsley MW, editors. *Sweeteners and Sugar Alternatives in Food Technology*. Chichester, UK: Wiley-Blackwell; c2012. p. 243-274.
17. Zumbe A, Lee A, Storey D. Polyols in confectionery: the route to sugar-free, reduced sugar and reduced calorie confectionery. *British Journal of Nutrition*. 2001;85(S1)