

Effect of level of sorghum and WPC-80 on quality of sorghum incorporated chhana cake

Abstract

The objective of the present investigation was to develop a technology for manufacture of a millet based chhana cake. Sorghum incorporated chhana cake (SCC) was prepared using chhana as base material. Sorghum flour was added @ 20 % (w/w of chhana). Four batches of chhana were prepared from milk using different levels of milk fat, viz. 4.5, 5.0, 5.5 and 6.0%. It was found that chhana prepared from milk containing 6.0% milk fat was most suitable for preparation of SCC. The proportion of sorghum flour, blend of white butter and cottonseed oil (1.5:1.0 w/w) and WPC-80 in the formulation was optimized using Response Surface Method. The suggested solution was 25.31% sorghum flour, 25.52% blend of white butter and cottonseed oil (1.5:1.0 w/w) and 9.78% WPC-80 (w/w of chhana) and the desirability of the model was found to be 0.837. The proximate composition of the developed product was: moisture 25.0 %, protein 13.8 %, fat 18.90 %, total carbohydrate 40.60 % and ash 1.68%. The protein content of SCC was 14.5 % which was 2.9 times higher than commercial cakes.

Keywords: SCC, chhana cake, sorghum, WPC-80, gluten-free, bakery product, nutri-cereals

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 and sugar. It contains around 15.0 to 16.0% protein making it a rich source of milk proteins compared to around 5.0% protein in commercially available plain cakes.

Sorghum (*Sorghum bicolor* L. Moench) or “Jowar” is an important coarse-grained food crop widely known as nutri-cereal. It has a nutritional profile that is better than rice. Considering colour and genotype, there are five types of sorghum i.e. white, yellow, red, brown and black. Amongst them, majorly white and yellow types of sorghum are used in food preparations. 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 (Rao *et al.*, 2018). It is an excellent source of polyphenols, flavonoids and condensed tannins which are antioxidant potent in nature (McDonough *et al.*, 1986). Sorghum contains slow digestible starch in good amounts, which has functional property, prolongs digestion and absorption of carbohydrates in intestine (Wursch, 1997). Sorghum also contains good amount of dietary fiber that is 9.7-14.3 g/100 g and plays the role of bulking agent, binding agent of cholesterol, increases transit time and retards carbohydrates absorption (Rao, 2003), which has a significant positive effect on preventing and managing the diseases like constipation, irritable bowel syndrome and obesity. Sorghum lipid has potential to lower the cholesterol. Sorghum contains components that could be used as dietary supplements to manage cholesterol levels in humans (Carr *et al.*, 2005). Sorghum is considered as a gluten free grain for development of novel baked goods (Rao *et al.*, 2018; Jambukiya *et al.*, 2022; Cairns *et al.*, 2023)

In a study it was reported that substitution of 25% of wheat flour with sorghum flour in short and hard dough biscuits and wafers was cost effective without affecting quality, breakages, and plant efficiency. It was suggested that improved milling techniques to produce sorghum flour with particle size comparable to that of wheat flour can increase the possibility of higher substitution (Ratnavathi and Patil, 2013). The special taste property of sorghum in bakery products is its non-stickiness to the mouth. Preparation of cakes is similar to that of

cakes prepared from wheat maida. Sorghum flour is comparatively superior to the wheat flour for cake preparation (Rao *et al.*, 2018).

WPC 80 can effectively replace eggs in dry goods such as cookies and biscotti since they excel in providing emulsification, foaming, solubility, thickening, browning, gelation, nutritional fortification, water binding, and a clean flavor profile (De Wit, 2001; Komerowski and Oliveira, 2023). Cakes supplemented with whey protein showed a protein content increase of more than 50% compared to the standard recipe (Camargo *et al.*, 2018).

Products prepared replacing wheat with sorghum can be considered as gluten-free suitable for persons suffering from celiac disease. Celiac disease is autoimmune system illness intolerance to the gliadin fraction of wheat and the prolamins of rye (secalins), barley (hordeins) and possibly oats (avidins) (Rao *et al.*, 2018). Therefore, the present project was contemplated to evaluate the effect of sorghum, in the formulation of acceptable quality chhana based cake to develop a chhana based cake using sorghum in place of wheat flour.

Materials and methods:

Whole milk, skim milk and cream used for manufacturing chhana and white butter were procured from Vidya Dairy, Anand. 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. Finely ground sorghum flour was collected from Me-to-millet store, Anand. Cottonseed oil (Tirupati cottonseed oil of N K Proteins Pvt. Ltd.) used in this study was procured from local market from Anand. Sugar used in this study was of Madhur Sugars and Chemicals Pvt. Ltd., Maharashtra. Citric acid was procured from local commercial supplier of Anand city. Baking powder and baking soda of Blue bird brand, Mumbai was used in this study.

Preparation of chhana

Milk was standardized to desired level of fat and pasteurized. It was heated to 90°C for 5 min. and cooled to 70°C. A 1% citric acid solution at 70°C was slowly introduced into the milk while gently stirring with a ladle until the milk coagulated. The coagulum was left in the whey for 5 minutes, after which the whey was strained through muslin cloth. The coagulated mass was then hung to drain completely, resulting in chhana.

Preparation of sorghum incorporated chhana cake (SCC)

Chhana was used as the base for making SCC. It was kneaded in a Hobart mixer for about 1.5 to 2.0 min. Sucrose, at 40% (w/w of chhana), was added to the chhana paste and kneaded for an additional minute. The dry ingredients (calculated on the basis of w/w of chhana) i.e. sorghum flour (20.00%), skim milk powder (15%), baking powder (2.0%), and baking soda (1.0%)—were mixed together and sieved. This dry blend was then added to the mixture in the Hobart mixer and kneaded for another 1.5 to 2.0 min. to form smooth dough. Approximately 400 g of dough were placed into aluminum molds and baked at 130°C for 80 min. After cooling, the SCC was packed in LDPE pouches (50 μ thickness) and placed in PVC trays and stored in refrigerator at $7\pm 2^\circ\text{C}$.

Selecting the Appropriate Fat Level in milk used for chhana making

To determine the optimal fat level for milk used in chhana production, four batches of SCC were prepared using chhana derived from milk with varying fat levels: 4.5% (F1), 5.0% (F2), 5.5% (F3), and 6.0% (F4). These fat levels were selected based on preliminary screening. Milk with fat content higher than 6.0% was excluded due to logistical constraints and limited market availability. Each treatment was replicated four times.

Optimization of Sorghum Flour, Butter-Vegetable Oil Blend, and WPC-80 Levels

Three parameters were optimized using a Phase Centered Rotatable Design, involving 20 experiments. These parameters included the level of sorghum flour (ranging from 20.0% to 30.0%) (A), the level of white butter combined with cottonseed oil (in a 1.5:1 ratio, ranging from 20.0% to 30.0%) (B) and the level of WPC-80 (ranging from 7.5% to 12.5%)

(C). The experiments tested various combinations of these ingredients within the specified ranges to ensure the production of SCCs with acceptable quality. The Phase Centered Rotatable Design was used to precisely determine the optimal values for these variables, while also analyzing their combined effects on sensory attributes, rheological properties, and specific volume.

Evaluation of Sensory Attributes

Samples were taken from the refrigerator, which was maintained at $7\pm 2^{\circ}\text{C}$, and microwaved at a frequency of 2450 MHz for 12 seconds before being assessed for sensory evaluation. Sensory analysis was performed 24 hours after the manufacturing of the SCC, at a temperature of $23\pm 2^{\circ}\text{C}$. The sensory panel, consisted of 10 participants using a 9-point hedonic scale to evaluate various parameters. The evaluated sensory attributes included color and appearance, volume, body and texture, flavor, crumb color, crust color, and overall acceptability.

Chemical analysis of SCC

Moisture content was measured according to IS: SP 18(Part XI), 1981. Fat content was determined following AOAC (2005) standards. Protein content was analyzed using the semi-micro Kjeldahl method (IS: 1479, 1961) with the Kjel-plus digestion system (Model KES 20LVA DLS) and semi-automatic distillation system (Model Distil M) from M/s Pelican Instruments, Chennai. Ash content was assessed using the method outlined in IS: 1547 (1985). Total carbohydrate content was calculated by difference, as per FSSAI (2011). The specific volume of gluten-free SCC was measured using the rapeseed displacement method (AACC, 2000). After baking, the volume and weight of the SCC were recorded. To determine the specific volume, the SCC was placed in a known volume container and rapeseeds were added until the container was full. The volume of the SCC was represented by the volume of displaced rapeseeds. Specific volume was calculated as the volume (cm^3) divided by weight (g).

Texture profile analysis of chhana based cake

Four samples of each SCC were subjected to uniaxial compression to 50% of their initial height using a Food Texture Analyzer from Lloyd Instruments, England, model LRX Plus, equipped with a 0-500 kg load cell. The force-distance curve was recorded during a two-bite deformation cycle with a Cross Head speed of 20 mm/min, a Trigger force of 10 gf, and a 60% compression of the samples. The tests were conducted on Chhana-based cakes held for 1 hour at $25\pm 1^{\circ}\text{C}$ and 55% relative humidity. Data analysis, including calculations of the area under the force-distance curve and conversion into various textural attributes, was performed using Lloyd Instruments' NEXYGEN data analysis and applications software. The rheological parameters assessed included hardness, cohesiveness, springiness, gumminess, and chewiness.

Statistical analysis

The mean values from the analysis of duplicate SCC samples, obtained across four replications, were statistically analyzed using a completely randomized design (CRD) with the WASP software (the first web-based agricultural statistics software package, available at <https://ccari.icar.gov.in/waspnew.html>) and the OPSTAT website for free online analysis (Sheoran et al., 1998). For the optimization of selected parameters, the advanced statistical software Design Expert (version 13.0.5.0) was used.

Results and discussion

Effect of level of fat in milk

The effect of level of fat in milk used for chhana making on acceptability of SCC is presented in Table 1. As seen in Table 1 that the flavor score of F4 was the highest which was at par ($P>0.05$) with that of F3. There was a progressive increase in flavor score of SCC with increase in level of fat in milk used for chhanamaking. Flavour wise, the order of preference

was $F_4 > F_3 > F_2 > F_1$. F_3 and F_4 had richer flavor with smoother and creamier mouthfeel compared to F_1 and F_2 . The colour and appearance score of F_4 was significantly ($P < 0.05$) higher compared to F_1 , F_2 and F_3 . The colour and appearance score was in the order of $F_4 > F_3 > F_2 > F_1$. Samples F_1 and F_2 had a dry appearance. The samples prepared from milk with lower fat content viz. 4.5, 5.0 and 5.5 were not liked by the panel since they had a lacked richness, smooth mouth feel and flavor. The overall acceptability score of F_4 was significantly ($P < 0.05$) higher compared to all the other samples. F_4 had as moist body and richer mouthfeel with a balance of moistness and crumb structure.

Results concluded that use of chhana prepared with 6 % fat in milk for manufacture of sorghum incorporated chhana cake (SCC) had higher acceptability over chhana prepared from milk with lower fat percentage viz. 4.5, 5.0 and 5.5%. There chhana prepared from whole milk having 6.0% fat and was selected and used in the formulation of SCC.

Influence of varying the level of sorghum flour, butter+oil and WPC-80 on the sensory properties

The quadratic model for sensory parameters namely were colour & appearance, volume, crust colour, crumb colour, body & texture, flavour and overall acceptability were obtained through successive regression analysis. The design matrix with the experimental data on sensory attributes of SCC for response analysis is presented in Table 2. The coefficient of determination (R^2) is shown in Table 3. It reflects the proportion of variability in data explained or accounted by the model. A larger R^2 value advocates a better fit of the selected quadratic model. The adequate precision measure is the signal to noise ratio, the value of which should be greater than 4.0. The adequate precision value (Table 3) of all the responses were greater than 4, hence, it is considered to be assisting the suitability of the model to navigate the design.

Colour & appearance score

From Table 3, it can be seen that all the factors, sorghum flour, butter+oil and WPC-80 didn't show any significant changes on colour and appearance score at linear terms ($P \geq 0.1$). Varying levels of sorghum flour, butter+oil and WPC-80 resulted in negative significant changes on colour and appearance scores at quadratic level ($P < 0.05$).

There are no available references in the literature regarding the impact of different levels of sorghum combined with WPC and butter+oil on the color and appearance scores of SCCs. However, Patel (2020) conducted similar research and found that ghee residue, maida, and WPC-80 did not produce significant changes in color and appearance in chhana cakes at linear terms. Additionally, his study indicated that WPC-80 had non-significant changes ($P > 0.05$) at quadratic terms. Jambukiyat *et al.* (2023) also reported that barnyard millet had a non-significant ($P > 0.05$) negative effect. However in his studies, amaranth had significant ($P < 0.05$) positive and negative effect on colour and appearance score at linear and quadratic terms in chhana based gluten free cake respectively. On the other hand, Parwez *et al.* (2022) reported that 4 % ragi flour had a comparable ($P > 0.05$) colour and appearance score in a functional chhana poddo compared to control prepared using refined wheat flour. These differences in results could be attributed to difference in material used and processing methods.

Volume score

Butter+oil showed significant ($P < 0.1$) changes on volume score at linear terms. The positive value of co-efficient indicates the significantly ($P < 0.05$) positive linear effect of butter+oil on volume scores at linear level. A non-significant ($P \geq 0.1$) interactive effect ($A \times B$, $B \times C$ and $A \times C$) was observed on volume score. Sorghum flour ($P < 0.05$) and butter+oil ($P < 0.05$) had significant changes at quadratic terms while WPC 80 ($P < 0.1$) had non-significant changes at quadratic terms.

In similar studies while working on chhana cakes using ghee residue and maida, Patel (2020) reported that WPC-80 didn't show any significant changes at linear and quadratic terms on volume score of chhana cake added with ghee residue. Similarly Jambukiya *et al.* (2023) also had reported the results with the use of barnyard millet in chhana based gluten free cake. On the other hand, Camargo *et al.*, (2018) found that an increase in WPC increased the volume of banana cake which in turn reflected in positive effect of volume score. WPC incorporation produced highest cake volume with a decrease in baking loss (Ammar *et al.*, 2021).

Crust colour score

Sorghum flour and butter+oil didn't show any significant ($P \geq 0.1$) changes on crust colour score while WPC-80 showed positive significant ($P < 0.05$) changes at linear terms. A non-significant negative interactive effect on crust colour score was observed with all interactions i.e. $A \times B$, $A \times C$, and $B \times C$ ($P \geq 0.1$). All three factors had significant negative changes at quadratic terms ($P < 0.05$) on crust colour score.

Patel (2020) reported that WPC showed non-significant effect on crust colour score at linear terms. In his studies level of WPC ranged from 5 to 15 %w/w of chhana. Jambukiya *et al.* (2023) reported that barnyard millet had non-significant negative and amaranth had a significant ($P < 0.05$) positive effect on crust colour score at linear terms in chhana based cake.

Crumb colour score

Except WPC-80 with significant ($P < 0.1$), all other factors i.e. sorghum flour, butter+oil didn't show any significant changes on crumb colour score at linear terms ($P \geq 0.1$). All Interactions i.e. $A \times B$, $B \times C$ and $A \times C$ ($P \geq 0.1$) had non-significant effect ($P \geq 0.1$) on crumb colour scores. All three factors had significant changes at quadratic terms ($P < 0.05$).

In his studies while reporting on effect of ghee residue and WPC-80 on chhana podo or chhana cake, Patel (2020) reported that WPC-80 didn't show any significant changes at linear terms in chhana cake. However, Jambukiya *et al.* (2023) reported that barnyard millet had a significant negative effect on crumb colour score at linear terms in chhana based gluten free cake. Suliman and Mohammed (2018) reported that crumb colour score improved with increasing the level of WPC in cake.

Body and texture score

Sorghum flour and butter+oil didn't show any significant changes ($P \geq 0.1$) while WPC-80 showed significant changes ($P < 0.05$) on body and texture score at linear terms. All interactions were having non-significant interactive effect on body and texture score i.e. $A \times B$, $B \times C$ and $A \times C$ ($P \geq 0.1$). Sorghum flour and butter+oil had significant changes ($P < 0.05$) at quadratic terms while WPC-80 had non-significant changes ($P \geq 0.1$) at quadratic terms.

Jambukiya *et al.* (2023) reported that barnyard millet and amaranth had a significant negative and positive effect on body and texture score at linear terms respectively in chhana based gluten free cake.

Flavour score

Sorghum flour and butter+oil didn't show any significant changes ($P \geq 0.1$) on flavour score at linear terms while WPC-80 had significant effect ($P < 0.05$) on flavour score at linear terms. A non-significant negative and positive interactive effect ($P \geq 0.1$) on flavour score was observed with interactive effect $A \times B$ and $A \times C$ respectively while interaction effect of $B \times C$ had significant negative effect ($P < 0.1$) on flavour score. Sorghum flour and butter+oil had significant changes ($P < 0.05$) while WPC-80 had non-significant changes ($P \geq 0.1$) at quadratic terms.

Jambukiya *et al.* (2023) reported that barnyard millet and amaranth millet had a significant and non-significant negative effect on flavour score of chhana cakes at linear terms.

Overall acceptability score

The Overall acceptability score of SCC was observed in the range from 6.80 to 8.30. All the factors, sorghum flour, butter+oil and WPC-80 didn't show any significant changes ($P \geq 0.1$) on overall acceptability score at linear terms. A non-significant interactive effect on overall acceptability score was observed with all interactions $A \times B$, $B \times C$ and $A \times C$. Sorghum flour, butter+oil and WPC-80 had significant changes ($P < 0.05$) at quadratic terms.

Jambukiya *et al.* (2023) reported that Barnyard millet and amaranth millet had significant negative and positive linear impact on overall acceptability score of chhana cake.

Influence of varying the level of Sorghum flour, Butter+oil and WPC-80 on specific volume and rheological properties of SCC

The instrumental method of rheology assessment aims at quantifying objectively the rheological characteristics to the maximum extent possible. The rheological characteristics of SCC are greatly influenced by its type and quality of raw material used and manufacturing practices/parameters followed. Rheological properties chosen as responses for SCC to monitor its quality are Hardness (N), Cohesiveness, Springiness (mm), Gumminess (N) and Chewiness (Nmm). The values of these responses along with their factors as per run order are given in Table 4. The regression analysis of the data is presented in Table 5. The quadratic model for specific volume and rheological parameters namely Hardness (N), Cohesiveness, Springiness (mm), Gumminess (N) and Chewiness (Nmm) were obtained through successive regression analysis. The coefficient of determination (R^2) shown in Table 5 reflects the proportion of variability in data explained or accounted by the model. The adequate precision value for specific volume, Hardness (N), Cohesiveness, Springiness (mm), Gumminess (N) and Chewiness (Nmm) were greater than 4, hence, it is considered to be assisting the suitability of the model to navigate the design.

Specific volume

Only butter+oil showed non-significant effect while Whey protein concentrate (WPC-80) ($P < 0.05$) and sorghum flour ($P \geq 0.05$) showed a significant positive change on specific volume at linear terms indicating positive linear effect of WPC-80 and sorghum flour on specific volume. Table 5 reveal that a non-significant interactive effect on specific volume was observed with all interactions $A \times B$, $B \times C$ and $A \times C$ ($P \geq 0.1$). WPC-80 ($P \geq 0.05$) had significant negative changes at quadratic terms while Sorghum flour and butter+oil had non-significant changes at quadratic terms. The negative value of sorghum flour and WPC-80 indicates the negative effect on specific volume of SCC. WPC-80 had significant positive changes at quadratic terms ($P \geq 0.05$).

Hardness

Only butter+oil showed non-significant effect while WPC-80 and sorghum flour showed a significant negative and positive changes on Hardness at linear terms respectively ($P < 0.05$) indicating negative and positive linear effect of WPC-80 and sorghum flour on Hardness. A non-significant interactive effect on Hardness was observed with all interactions i.e. $A \times B$, $B \times C$ and $A \times C$ ($P \geq 0.1$). Sorghum flour ($P \geq 0.05$) had significant positive changes at quadratic terms while WPC-80 and butter+oil had non-significant changes at quadratic terms. The positive value of sorghum flour indicates the positive effect on Hardness of SCC.

Cohesiveness

Only WPC-80 showed positive significant effect ($P < 0.05$) while butter+oil and sorghum flour showed a non-significant negative change on cohesiveness at linear terms respectively ($P \geq 0.1$) indicating negative linear effect of butter+oil and sorghum flour on cohesiveness. A non-significant effect on cohesiveness was observed with all interactions i.e. $A \times B$, $B \times C$ and $A \times C$ ($P \geq 0.1$). Sorghum flour ($P \geq 0.05$) had significant negative changes at quadratic terms while WPC-80 and butter+oil had non-significant changes at quadratic terms.

Springiness

Only WPC-80 showed negative significant effect ($P < 0.05$) while butter+oil and sorghum flour showed a non-significant positive change on springiness at linear terms respectively ($P \geq 0.1$) indicating positive linear effect of butter+oil and sorghum flour on cohesiveness. A non-significant interactive effect on springiness was observed with all interactions i.e. $A \times B$, $B \times C$ and $A \times C$ ($P \geq 0.1$). Sorghum flour ($P \geq 0.05$) had significant positive changes at quadratic terms while WPC-80 and butter+oil had non-significant changes at quadratic terms.

Gumminess

Only Sorghum flour showed positive significant effect ($P \geq 0.05$) while butter+oil and WPC-80 showed a non-significant positive and negative change on gumminess at linear terms respectively ($P \geq 0.1$) indicating positive and negative linear effect of butter+oil and WPC-80 on gumminess. A significant negative interactive effect on gumminess was observed with $A \times C$ on SCC ($P < 0.05$). A non-significant negative and positive interactive effect on gumminess was observed with interactive effect $A \times B$ and $B \times C$ ($P \geq 0.1$). Sorghum flour ($P \geq 0.05$) had significant positive changes at quadratic terms while WPC-80 and butter+oil had non-significant ($P \geq 0.1$) changes at quadratic terms.

Chewiness

Sorghum flour and WPC-80 showed positive ($P < 0.05$) and negative ($P < 0.1$) significant effect while butter+oil only showed a ($P \geq 0.1$) non-significant positive change on chewiness at linear terms respectively indicating positive and negative linear effect of sorghum flour and WPC-80 on chewiness. A significant negative interactive effect on chewiness was observed with interactive effect ($A \times C$) on SCC ($P \geq 0.1$). The positive interaction indicates that both the factors are positively correlated and by increasing the level of one factor, the level of another factor has to be increased and vice versa. Sorghum flour ($P \geq 0.05$) had significant positive changes at quadratic terms. The positive value of sorghum flour indicates the positive effect on chewiness of SCC.

Optimization of product formulation for SCC manufacture

Considering the parameters and their limits, the RSM suggested the one most suited solution. Criteria/responses chosen for process optimization of SCC manufacture is presented in Table 6. The predicted sensory scores and rheological attribute of optimized SCC from RSM analysis are depicted in Table 7.

The final product was manufactured employing this suggested formulation and the actual results were obtained from SCC manufacture. The predicted values of the criteria/responses selected for process 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 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. The suggested proportion from RSM of sorghum flour (w/w of chhana), blend of white butter and cottonseed oil (1.5:1.0 w/w of chhana) and WPC-80 (w/w of chhana) was 25.31, 25.52 and 9.78 % respectively and the desirability of the model was found to be 0.837.

In the final formulation chhana was used as base material. Other 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 @ 40.00 %, baking soda @ 1.00 % and baking powder @ 2.00 %. The developed product was analysed for its proximate chemical composition. It was found to have 25.0 ± 2.28 % moisture, 18.90 ± 1.02 % fat, 13.8 ± 0.98 % protein, 40.60 ± 2.15 % carbohydrate and 1.68 ± 0.05 % ash. The protein content of SCC was 13.8% which

was 2.7 times higher than commercially available cake. The flavour, body and texture, colour and appearance and overall acceptability score of the developed product was found to be 8.03, 8.01, 7.88, 7.93, 7.90, 8.14 and 8.04. The product was found to be highly acceptable having an overall acceptability score of 8.04 on a 9-point hedonic scale.

Conclusion

Based on the results obtained in this study it can be concluded that an acceptable quality SCC can be prepared using sorghum flour in place of wheat flour. Chhana prepared from milk containing 6.0% milkfat was most suitable for preparation of SCC. The suggested proportion from RSM of sorghum flour (w/w of chhana), blend of white butter and cottonseed oil (1.5:1.0 w/w of chhana) and WPC-80 (w/w of chhana) was 25.31, 25.52 and 9.78 % respectively and the desirability of the model was found to be 0.837. The protein content of SCC was 13.8 % which was 2.7 times higher than commercially available cake. The developed product was “liked very much” having an overall acceptability score of 8.04 on a 9-point hedonic scale.

References:

- AACC (2000). American Association of Cereal Chemists, Method 10-05.01 Guidelines for Measurement of Volume by Rapeseed Displacement.
- Ammar I., Gharsallah H., Brahim A. B., Attia H., Ayadi M., Hadrich B. & Felfoul I. (2021). Optimization of gluten-free sponge cake fortified with WPC using mixture design methodology, *Food Chemistry*. 343, article 128457, <https://doi.org/10.1016/j.foodchem.2020.128457>.
- AOAC (2005). Official methods of analysis. Washington, DC: Association of Official Analytical Chemists.
- Cairns, A., Brazington, S., Gragg, E., Holmes, A., Vavra, C., Whitehair, K. & Getty, K. (2023). Development and scale-up of gluten-free sorghum-based bakery goods for K-state Dining Services. *Journal of Agriculture and Food Research*, 14, 100840.
- Camargo, L. R., Silva, L. M., Komerowski, M. R., Kist, T. B., Rodrigues, C. E., Rios, A. D. O., Silva, M. M., Doneda, D., Schmidt, H. O., & Oliveira, V. R. (2018). Effect of whey protein addition on the nutritional, technological and sensory quality of banana cake. *International Journal of Food Science & Technology*, 53(11), 2617-2623.
- Carr, T. P., Curtis, L. W., Vicki, S., Susan, L. C., David, M. G., & Kyle, R. J. (2005). Grain sorghum lipid extract reduces cholesterol absorption and plasma non-HDL cholesterol concentration in hamsters. *Journal of Nutrition*, 135(9), 2236-2240.
- De Wit, J. N. (2001). Lecturer's handbook on whey and whey products. European whey products association, (1st ed. Pp.14-19) Brussels. Retrieved from: <http://ewpa.euromilk.org/publications.html>.
- FSSAI (2011) Food safety and standards (Food products standards and food additives) regulations, 2011, Ministry of health and family welfare (Food safety and standards authority of India).
- Indian Standard: 1479 (Part II) (1961). Methods of test for dairy industry, (Part II). Chemical analysis of milk, Indian Standards Institution, Manak Bhavan, New Delhi.
- Indian Standard: 1547 (1985). Specifications for Infant Milk Foods. Bureau of Indian Standards, Manak Bhavan, New Delhi.
- IS: SP: 18 (Part XI) (1981). Handbook of Food analysis, Dairy Products. Indian Standards Institution, Manak Bhavan, New Delhi.
- Jambukiya, H., Pinto, S. & Patel, S. (2023). Development of technology for manufacture of millet based SCC. *Research Journal of Agricultural Sciences* 14(1): 28-34.

- Jambukiya, H., Pinto, S., Gokhale, A., & Patel, S. (2022). Physico-chemical, sensory and microbial changes during storage of gluten-free SCC. *The Pharma Innovation Journal*, 11(10), p. 21-25.
- Komerowski, M.R., & Oliveira, V.R. (2023). Influence of the Amount and Type of Whey Protein on the Chemical, Technological, and Sensory Quality of Pasta and Bakery Products. *Foods*. 12(14): 2801. doi: 10.3390/foods12142801. PMID: 37509893; PMCID: PMC10379415.
- McDonough, C. M., Rooney, L. W., & Earp, C. F. (1986). Structural characteristics of *Eleusine coracana* (finger millet) using scanning electron and fluorescence microscopy. *Food Microstructure*, 5(3), 247-256.
- Parwez, A., Venkatesh, M., Prabha, R., Praveen A.R., Shilpashree, B. G. and Kauser, H. (2022). Development of functional chhana podo. *The Pharma Innovation Journal*. SP-11(8): 1266-1272.
- Patel, D. (2020). *Development of technology to prepare chhana based cake using ghee residue and whey protein concentrate* [Doctoral dissertation, Anand Agriculture University, Anand (Gujarat), India]. Retrieved from <https://krishikosh.egranth.ac.in/handle/1/5810184227>.
- Puranik, D. B. & Gupta, S. K. (2017). Development of egg-less cake using whey protein concentrate as egg substitute. *International Journal of Science, Environment and Technology*, 6(4), 2343-2352.
- Rao, B. S. (2003). Bioactive phytochemicals in Indian foods and their potential in health promotion and disease prevention. *Asia Pacific Journal of Clinical Nutrition*, 12(1), 9-22.
- Ratnavathi, C. V., & Patil, J. V. (2013). Sorghum utilization as food. *Journal of Nutrition and Food Science*, 4, 247-251.
- Sheoran, O. P, Tonk, D. S, Kaushik, L. S, Hasija, R.C. and Pannu, R.S. (1998). Statistical Software Package for Agricultural Research Workers. Recent Advances in information theory, Statistics & Computer Applications by D.S. Hooda & R.C. Hasija Department of Mathematics Statistics, CCS HAU, Hisar (139-143).
- Suliman, S. A. & Mohammed, M. F. (2018). The Effect of Reducing Agent on Quality Characteristics of Flour and Cake (Glutathione). *International Journal of Science and Research*, 7(7), 340-346.
- Wursch, P. (1997). The role of viscous soluble fiber in the metabolic control of diabetes. *Diabetes Care*, 20(11), 1774-1780.

Table 1 Influence of level of fat in milk used for chhana making on acceptability of sorghum incorporated SCC (9-point hedonic scale)

Sample code (%fat in milk)	Flavour score	Colour and appearance score	Body and texture score	Overall acceptability score
F1 (4.5)	6.60 ^c ±0.13	6.56 ^c ±0.11	6.55 ^c ±0.09	6.59 ^c ±0.07
F2 (5.0)	6.83 ^{bc} ±0.16	6.72 ^{bc} ±0.13	6.75 ^{bc} ±0.06	6.75 ^{bc} ±0.14
F3 (5.5)	6.99 ^{ab} ±0.20	6.77 ^b ±0.18	6.79 ^b ±0.05	6.82 ^b ±0.11
F4 (6.0)	7.22 ^a ±0.11	7.05 ^a ±0.07	7.14 ^a ±0.25	7.11 ^a ±0.11
SEm±	0.09	0.06	0.07	0.06
CD(0.05)	0.27	0.20	0.21	0.17
CV (%)	2.53	1.89	2.03	1.63

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 SCC for

response analysis

Run	Variables (g/ 100 g of chhana)			Sensory attributes as response (9 point hedonic scale)						
	Sorghum flour (A)	Butter+oil (B)	WPC-80 (C)	Colour and appearance	Volume	Crust Colour	Crumb Colour	Body and Texture	Flavour	Overall acceptability
1	25.00	25.00	10.00	8.00	7.80	8.00	8.10	7.40	7.90	7.90
2	30.00	30.00	12.50	7.20	7.30	7.10	7.10	7.30	6.90	7.10
3	25.00	16.59	10.00	7.20	7.10	7.30	7.30	7.30	7.60	7.50
4	20.00	20.00	7.50	7.00	6.90	7.00	7.00	6.80	7.10	6.90
5	30.00	20.00	12.50	7.00	6.90	7.10	7.10	7.00	7.30	7.10
6	20.00	30.00	7.50	7.10	7.40	6.90	7.00	7.30	7.80	7.40
7	25.00	25.00	10.00	7.80	8.00	7.70	7.80	8.20	7.90	8.00
8	30.00	30.00	7.50	6.90	7.30	6.60	6.70	7.60	7.70	7.40
9	20.00	20.00	12.50	6.60	6.60	6.60	6.60	6.90	6.90	6.80
10	16.59	25.00	10.00	6.90	6.80	7.00	7.00	6.90	6.90	7.20
11	25.00	25.00	10.00	8.10	8.00	8.10	8.10	8.00	7.90	7.80
12	25.00	33.41	10.00	7.10	7.80	6.70	6.70	7.80	7.70	7.70
13	25.00	25.00	5.80	7.10	7.90	6.70	6.70	8.30	8.20	7.80
14	25.00	25.00	10.00	7.90	8.20	7.70	7.70	7.90	8.10	8.10
15	33.41	25.00	10.00	7.20	7.10	7.20	7.20	6.90	7.20	7.10
16	25.00	25.00	10.00	7.80	7.80	7.80	7.80	7.90	8.20	8.10
17	25.00	25.00	10.00	8.20	8.30	8.10	8.10	8.10	8.40	8.30
18	25.00	25.00	14.20	7.60	7.90	7.40	7.40	7.30	7.80	7.70
19	30.00	20.00	7.50	6.90	7.10	6.80	6.80	7.20	7.20	7.00
20	20.00	30.00	12.50	6.90	6.60	7.10	7.10	6.70	7.00	6.90

Table3 Coefficient of the full second order polynomial model for coded sensory responses to different levels of ingredients of SCC

Parameters		Sensory score as response						
		Colour and appearance	Volume	Crust colour	Crumb colour	Body and Texture	Flavour	Overall acceptability
Intercept		7.95	8.03	7.90	7.93	7.93	8.08	8.05
Linear Level	A	0.0556 ^{ns}	0.1175 ^{ns}	0.0246 ^{ns}	0.0246 ^{ns}	0.1025 ^{ns}	0.0589 ^{ns}	0.0316 ^{ns}
	B	0.0230 ^{ns}	0.1667 [*]	-0.0592 ^{ns}	-0.0384 ^{ns}	0.1348 ^{ns}	0.0782 ^{ns}	0.0979 ^{ns}
	C	0.0501 ^{ns}	-0.0952 ^{ns}	0.1301 [#]	0.1155 [*]	-0.1964 [#]	-0.1737 [#]	-0.0709 ^{ns}
Interactive Level	A*B	-0.0458 ^{ns}	0.0125 ^{ns}	-0.0750 ^{ns}	-0.0750 ^{ns}	0.0500 ^{ns}	-0.0875 ^{ns}	-0.0250 ^{ns}
	A*C	0.1208 [*]	0.1125 ^{ns}	0.1250 ^{ns}	0.1250 ^{ns}	0.00 ^{ns}	0.0375 ^{ns}	0.0500 ^{ns}
	B*C	0.0458 ^{ns}	-0.0375 ^{ns}	0.1000 ^{ns}	0.0750 ^{ns}	-0.1000 ^{ns}	-0.1875 [*]	-0.1000 ^{ns}
Quadratic Level	A²	-0.3557 [#]	-0.4585 [#]	-0.3036 [#]	-0.3050 [#]	-0.4199 [#]	-0.4225 [#]	-0.3952 [#]
	B²	-0.3233 [#]	-0.2817 [#]	-0.3390 [#]	-0.3492 [#]	-0.1901 [#]	-0.2104 [#]	-0.2361 [#]
	C²	-0.2555 [#]	-0.1226 ^{ns}	-0.3213 [#]	-0.3227 [#]	-0.1017 ^{ns}	-0.0866 ^{ns}	-0.1830 [#]
R²		0.9201	0.8457	0.9069	0.9071	0.8135	0.8723	0.8252
Model F-value		12.79	6.09	10.82	10.84	4.85	7.59	5.25
APV		9.1280	7.2238	9.6489	9.3428	6.6236	7.9424	6.2027
Suggested Model		Quadratic	Quadratic	Quadratic	Quadratic	Quadratic	Quadratic	Quadratic

* : 0.05 ≤ P < 0.1; # : P < 0.05; ^{ns} : non-significant, P ≥ 0.1; APV = Adequate Precision Value; A = Sorghum flour; B = Butter+oil; C =

WPC-80; R² = Coefficient of determination

Table 4 Design matrix with the experimental data on specific volume and rheological

parameters of SCC for response analysis

Run	Variables (g/ 100 g of chhana)			Specific volume (cm ³ /g)	Rheological Attributes				
	Sorghum flour (A)	Butter +oil (B)	WPC -80 (C)		Hardness (N)	Cohesiveness	Springiness (mm)	Gumminess (N)	Chewiness (Nmm)
1	25	25	10	1.24	17.19	0.23	8.00	2.34	19.90
2	30	30	12.5	1.46	18.57	0.23	8.02	4.67	37.23
3	25	16.59	10	1.44	12.17	0.28	7.31	3.04	25.04
4	20	20	7.5	1.03	22.12	0.18	9.39	2.70	19.62
5	30	20	12.5	1.45	13.50	0.27	7.67	2.72	18.21
6	20	30	7.5	1.08	21.46	0.20	9.17	2.75	24.44
7	25	25	10	1.26	15.24	0.27	7.75	3.36	25.96
8	30	30	7.5	1.05	27.24	0.18	9.40	5.90	54.34
9	20	20	12.5	1.33	16.88	0.25	8.00	4.94	43.49
10	16.59	25	10	1.21	21.36	0.20	9.13	3.11	29.26
11	25	25	10	1.27	19.47	0.23	8.45	4.24	36.16
12	25	33.40	10	1.44	21.12	0.22	8.66	4.79	45.79
13	25	25	5.79	1.02	21.63	0.20	9.33	4.43	42.39
14	25	25	10	1.33	15.91	0.25	7.95	4.35	34.68
15	33.40	25	10	1.42	44.35	0.13	10.56	11.72	98.59
16	25	25	10	1.34	15.51	0.26	7.81	4.73	42.79
17	25	25	10	1.38	11.28	0.31	6.83	3.90	23.78
18	25	25	14.20	1.47	11.79	0.28	7.14	3.84	18.62
19	30	20	7.5	1.12	29.50	0.14	9.70	8.88	95.50
20	20	30	12.5	1.42	19.93	0.22	8.59	3.92	32.37

Table 5 Coefficient of the full second order polynomial model for coded specific volume and rheological responses to different level of ingredients of SCC

Parameters		Specific Volume (cm ³ /g)	Rheological Attributes				
			Hardness (N)	Cohesiveness	Springiness (mm)	Gumminess (N)	Chewiness (Nmm)
Intercept		1.31	15.81	0.2582	7.80	3.84	30.65
Linear Level	A	0.0420 [*]	3.45 [#]	-0.0115 ^{ns}	0.1497 ^{ns}	1.64 [#]	14.79 [#]
	B	0.0059 ^{ns}	1.48 ^{ns}	-0.0076 ^{ns}	0.1970 ^{ns}	0.0691 ^{ns}	0.4736 ^{ns}
	C	0.1565 [#]	-3.51 [#]	0.0300 [#]	-0.6636 [#]	-0.3641 ^{ns}	-7.51 [*]
Interactive Level	A*B	-0.0250 ^{ns}	0.0525 ^{ns}	-0.0001 ^{ns}	-0.0400 ^{ns}	-0.0075 ^{ns}	-1.98 ^{ns}
	A*C	0.0125 ^{ns}	-2.24 ^{ns}	0.0115 ^{ns}	-0.1800 ^{ns}	-1.35 [#]	-15.78 [#]
	B*C	0.0150 ^{ns}	1.38 ^{ns}	-0.0136 ^{ns}	0.1825 ^{ns}	0.4825 ^{ns}	5.53 ^{ns}
Quadratic Level	A²	-0.0154 ^{ns}	5.77 [#]	-0.0340 [#]	0.7236 [#]	1.13 [#]	11.08 [#]
	B²	0.0288 ^{ns}	0.0357 ^{ns}	-0.0052 ^{ns}	0.0660 ^{ns}	-0.1091 ^{ns}	1.00 ^{ns}
	C²	-0.0402 [*]	0.0587 ^{ns}	-0.0071 ^{ns}	0.1544 ^{ns}	-0.0313 ^{ns}	-0.7329 ^{ns}
R²		0.8874	0.8409	0.8343	0.8541	0.7858	0.8149
Model F-value		8.75	5.87	5.60	6.50	4.08	4.89
APV		11.0924	9.5302	7.9144	8.3091	7.9413	7.5455
Suggested Model		Linear	Quadratic	Quadratic	Quadratic	Quadratic	Quadratic

* : 0.05 ≤ P < 0.1; # : P < 0.05; ns : non-significant, P ≥ 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 SCC manufacture

Sr. No	Parameter	Units	Goal	Lower Limit	Upper Limit	Level of Importance
1	A: Sorghum flour	%	In range	20.00	30.00	3
2	B: Butter + oil	%	In range	20.00	30.00	3
3	C: WPC-80	%	In range	7.50	12.50	3
4	Colour and appearance	1- 9	Maximize	6.60	8.17	5
5	Volume	1- 9	Maximize	6.60	8.30	5

6	Crust colour	1 - 9	Maximize	6.60	8.10	5
7	Crumb colour	1 - 9	Maximize	6.60	8.10	5
8	Body and Texture	1 - 9	Maximize	6.70	8.30	5
9	Flavour	1 - 9	Maximize	6.90	8.40	5
10	Overall acceptability	1-9	Maximize	6.80	8.30	5
11	Specific volume	cm ³ /g	In range	1.02	1.47	3
12	Hardness	N	In range	11.28	44.35	3
13	Cohesiveness	-	In range	0.13	0.31	3
14	Springiness	mm	In range	6.83	10.56	3
15	Guminess	N	In range	2.34	11.72	3
16	Chewiness	Nmm	In range	18.21	98.59	3

Table 7 Comparison of predicted v/ actual values of responses used for process optimization of SCC manufacture

Response	P Value	Predicted Value *	Actual Value @	Cal. t-Value #	Level of Significance
Colour and appearance (1-9)	0.16	8.10	8.03	1.58	NS
Volume (1-9)	0.60	8.06	8.01	0.55	NS
Crust colour (1-9)	0.93	7.88	7.88	0.08	NS
Crumb colour (1-9)	0.82	7.91	7.93	0.23	NS
Body and Texture (1-9)	0.22	7.96	7.90	1.37	NS
Flavour (1-9)	0.25	8.10	8.14	1.26	NS
Overall acceptability (1-9)	0.72	8.06	8.04	0.37	NS
Specific volume (cm ³ / g)	0.30	1.30	1.31	1.12	NS
Hardness (N)	0.22	16.51	17.48	1.37	NS
Cohesiveness	0.60	0.25	0.26	0.56	NS
Springiness (mm)	0.21	7.89	8.13	1.41	NS
Guminess (N)	0.18	3.99	4.28	1.53	NS
Chewiness (Nmm)	0.13	32.37	35.02	1.75	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)