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Effect of Level of Sorghum and WPC-80 on Quality of Sorghum Incorporated Chhana Cake

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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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

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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 Hardness (N), Cohesiveness, Springiness (mm), Guminess (N) and Chewiness (Nmm) of SCC was found to be 17.48, 0.26, 8.13, 4.28 and 35.02 respectively. 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.

1. 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 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” 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 [1]. Sorghum contains slow digestible starch in good amounts, which has functional property, prolongs digestion and absorption of carbohydrates in intestine [2]. 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 [3]. 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 [4]. Sorghum is considered as a gluten free grain for development of novel baked goods (Rao et al., 2018; [5,6]

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 [7]. 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 [8,9]. Cakes supplemented with whey protein showed a protein content increase of more than 50% compared to the standard recipe [10].

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.

2. 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.

2.1 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.

2.2 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±2°C.

2.3 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.

2.4 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%) [11] (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.

2.5 Evaluation of Sensory Attributes

Samples were taken from the refrigerator, which was maintained at 7±2°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±2°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.

2.6 Chemical Analysis of SCC

Moisture content was measured according to IS: SP 18 (Part XI), 1981. Fat content was determined following AOAC [12] 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 [13]. The specific volume of gluten-free SCC was measured using the rapeseed displacement method [14]. 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 (cm³) divided by weight (g).

2.7`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±1°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.

2.8 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 [15]. For the optimization of selected parameters, the advanced statistical software Design Expert (version 13.0.5.0) was used.

3. RESULTS AND DISCUSSION

3.1 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 chhana making. Flavour wise, the order of preference was F4>F3>F2>F1. F3 and F4 had richer flavor with smoother and creamier mouthfeel compared to F1 and F2. The colour and appearance score of F4 was the significantly (P<0.05) higher compared to F1, F2 and F3. The colour and appearance score was in the order of F4>F3>F2>F1. Samples F1 and F2 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 F4 was significantly (P<0.05) higher compared to all the other samples. F4 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.

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

Table 3. 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	0.0782ns	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	A^2	-0.3557 #	-0.4585 #	-0.3036 #	-0.3050 #	-0.4199 #	-0.4225 #	-0.3952 #
	B^2	-0.3233 #	-0.2817 #	-0.3390 #	-0.3492 #	-0.1901 #	-0.2104 #	-0.2361 #
	C^2	-0.2555 #	-0.1226 ns	-0.3213 #	-0.3227 #	-0.1017 ns	-0.0866 ns	-0.1830 #
R^2		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;* R^2 *= Coefficient of determination*

3.2 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 values advocate a better fit of the selected quadratic model. The adequate precision measures 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.

3.3 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≥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 [16] 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. Jambukiya et al. [17] 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. [18] reported that 4 % ragi flour had a comparable (P>0.05) colour and appearance score in a functional chhana podo compared to control prepared using refined wheat flour. These differences in results could be attributed to difference in material used and processing methods.

3.4 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≥0.1) interactive effect (A×B, B×C and A×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 [16] 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. [17] also had reported the results with the use of barnyard millet in chhana based gluten free cake. On the other hand, Camargo et al., [10] found that 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 [19].

3.5 Crust Colour Score

Sorghum flour and butter+oil didn't show any significant (P≥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×B, A×C, and B×C (P≥0.1). All three factors had significant negative changes at quadratic terms (P<0.05) on crust colour score. Patel [16] 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. [17] 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.

3.6 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≥0.1). All Interactions i.e. A×B, B×C and A×C (P≥0.1) had non-significant effect (P≥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 [16] reported that WPC-80 didn't show any significant changes at linear terms in chhana cake. However, Jambukiya et al. [17] 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 [20-22] reported that crumb colour score improved with increasing the level of WPC in cake.

3.7 Body and Texture Score

Sorghum flour and butter+oil didn't show any significant changes (P≥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×B, B×C and A×C (P≥0.1). Sorghum flour and butter+oil had significant changes (P<0.05) at quadratic terms while WPC-80 had non-significant changes (P≥0.1) at quadratic terms. Jambukiya et al. [17] 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.

3.8 Flavour Score

Sorghum flour and butter+oil didn't show any significant changes (P≥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≥0.1) on flavour score was observed with interactive effect A×B and A×C respectively while interaction effect of B×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≥0.1) at quadratic terms. Jambukiya et al. [17] reported that barnyard millet and amaranth millet had a significant and non-significant negative effect on flavour score of chhana cakes at linear terms.

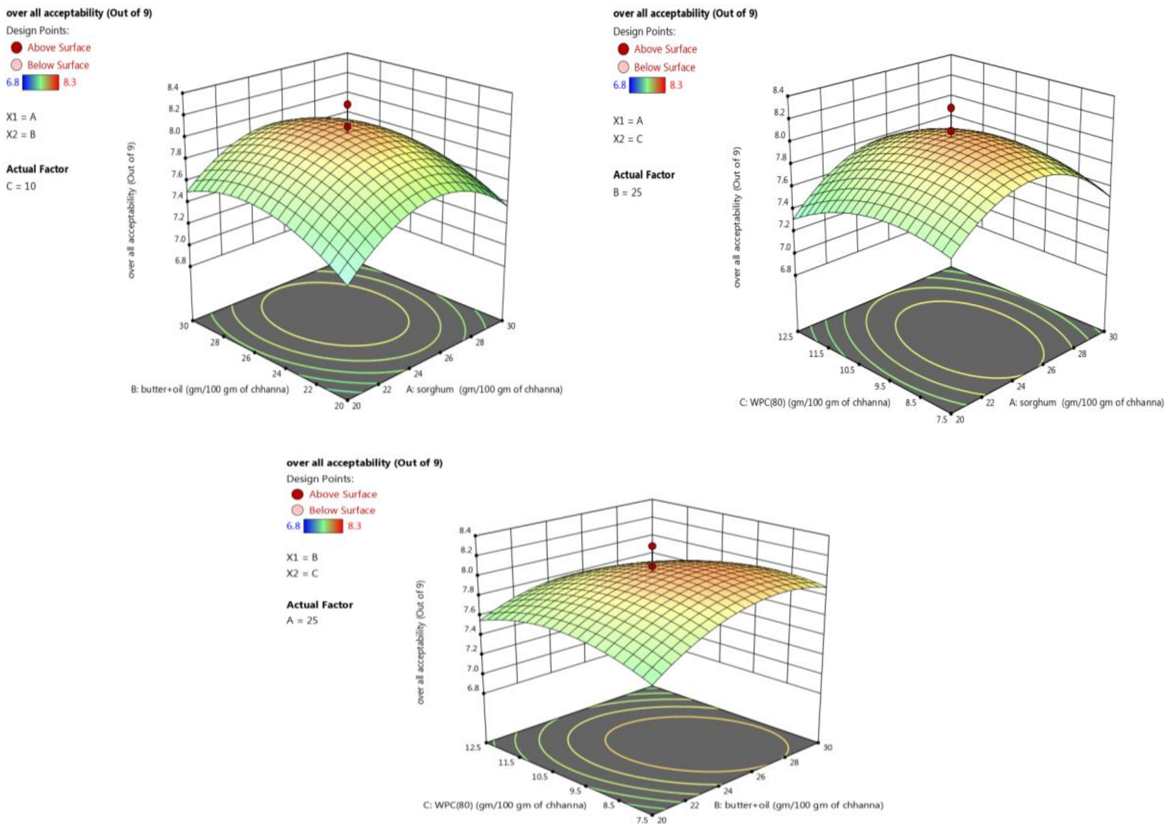

Fig. 1. Influence of level of sorghum flour, WPC-80 and butter+oil on the overall acceptability score of SCC

3.9 Overall Acceptability Score

The Overall acceptability score of SCC was observed in the range from 6.80 to 8.30. Interaction among variables and their effects on overall acceptability scores of SCC are presented in the form of three dimensional response surface plots (Fig. 1) with varying level of three variables within the experimental range. All the factors, sorghum flour, butter+oil and WPC-80 didn't show any significant changes (P≥0.1) on overall acceptability score at linear terms. A non-significant interactive effect on overall acceptability score was observed with all interactions A×B, B×C and A×C. Sorghum flour, butter+oil and WPC-80 had significant changes (P<0.05) at quadratic terms.

Jambukiya et al. [17] reported that Barnyard millet and amaranth millet had significant negative and positive linear impact on overall acceptability score of chhana cake.

4. 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 (N mm). 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 (N mm) 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 (N mm) were greater than 4, hence, it is considered to be assisting the suitability of the model to navigate the design.

4.1 Specific Volume

Butter+oil showed non-significant effect while WPC-80 (P<0.05) and sorghum flour (P<0.01) 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×B, B×C and A×C (P≥0.1). WPC-80 (P≥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≥0.05). Patel [16,23] reported that WPC-80 and maida showed a significant positive effect on specific volume at linear terms in chhana cake. WPC-80 (P<0.05) and sorghum flour (P<0.01) showed a significant positive change on specific volume at linear terms. The possible reason for the observed improvements in specific volume in the presence of sorghum flour with WPC might be attributed to the more air incorporated due to good emulsification properties of WPC, resulting in a product with high specific volume. WPC-80 (P≥0.05) had significant negative changes at quadratic terms. This could be possibly because the addition of excessive WPC-80 reduced available water due to its high water binding ability, weakening sorghum flour interactions reducing foam stability and thus impacting specific volume.

4.2 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×B, B×C and A×C (P≥0.1). Interaction among variables and their effects on Hardness of SCC are presented in the form of three dimensional response surface plots (Fig. 2) with varying level of three variables within the experimental range. Sorghum flour (P≥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. Patel [16,24] reported that only WPC-80 being non-significant (P>0.05), maida showed significant (P≤0.01), changes on hardness at linear and quadratic terms. Sorghum flour (P<0.01) had significant positive changes at quadratic terms. The increment of hardness of sorghum could be due to its high water holding capacity which could have reduced the free water resulting in increased hardness of the cake.

4.3 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≥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×B, B×C and A×C (P≥0.1). Sorghum flour (P<0.05) had significant negative changes at quadratic terms while WPC-80 and butter+oil had non-significant changes at quadratic terms. However, Patel [16] reported that Only WPC-80 being non-significant (P>0.05), maida showed significant changes at 1 and 5 per cent level on cohesiveness at linear terms. The addition of WPC also increased the cohesiveness and cohesiveness at linear level. This effect could possibly be due to increased protein aggregation which is associated with cohesiveness. The decreases in cohesiveness with increase in sorghum at quadratic level could be attributed to higher contents of fiber and/or resistant starch as sorghum flour levels increased.

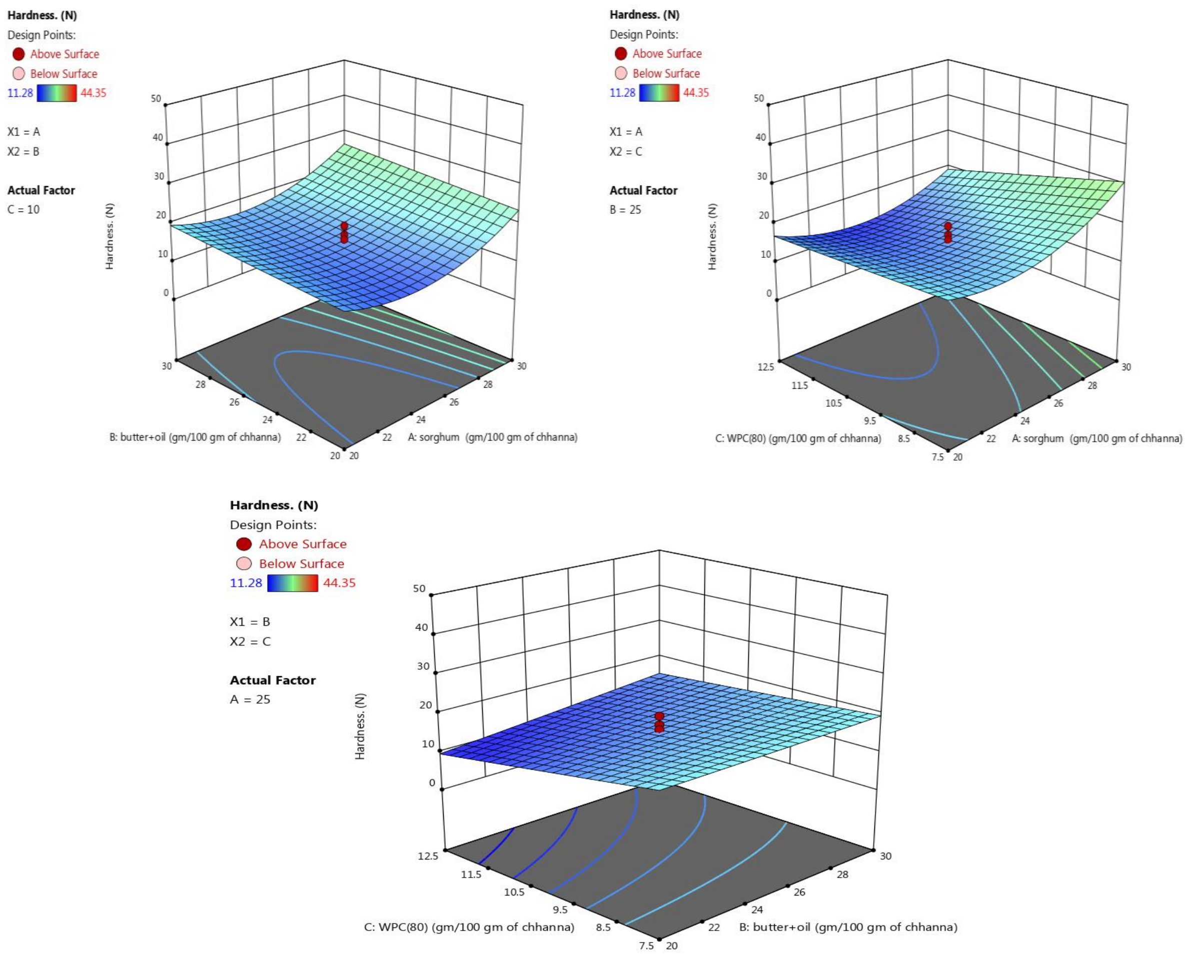

Fig. 2. Influence of level of sorghum flour, butter+oil and WPC-80 on the hardness of SCC

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 levels of ingredients of SCC

Parameters		**Specific Volume (cm^3/g)**	**Rheological Attributes**				
			Hardness (N)	**Cohesiveness**	**Springiness (mm)**	**Guminess (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	A^2	-0.0154 ns	5.77 #	-0.0340 #	0.7236 #	1.13 #	11.08 #
	B^2	0.0288 ns	0.0357 ns	-0.0052 ns	0.0660 ns	-0.1091 ns	1.00 ns
	C^2	-0.0402 *	0.0587 ns	-0.0071 ns	0.1544 ns	-0.0313 ns	-0.7329 ns
R^2		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; R^2 = Coefficient of determination*

4.4 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 ($P\geq0.1$) 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×B, B×C and A×C ($P\geq0.1$). Sorghum flour ($P<0.05$) had significant positive changes at quadratic terms while WPC-80 and butter+oil had non-significant changes at quadratic terms. In one study, Patel (2020) reported that WPC-80 and maida showed significant changes on springiness at linear terms ($P<0.05$). In his study, he also reported that WPC-80 had non-significant changes ($P>0.05$) while maida had significant changes ($P<0.01$) at quadratic terms on springiness of chhana cake.

4.5 Gumminess

Only Sorghum flour showed positive significant effect ($P<0.05$) while butter+oil and WPC-80 showed a non-significant positive and negative change on gumminess at linear terms respectively ($P\geq0.1$) 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×C on SCC ($P<0.05$). A non-significant negative and positive interactive effect on gumminess was observed with interactive effect A×B and B×C ($P\geq0.1$). Sorghum flour ($P<0.05$) had significant positive changes at quadratic terms while WPC-80 and butter+oil had non-significant ($P\geq0.1$) changes at quadratic terms. Similarly Patel [16] reported that WPC-80 didn't show any significant ($P>0.05$) while maida, ghee residue showed significant ($P<0.01$) changes at linear terms.

4.6 Chewiness

Sorghum flour and WPC-80 showed positive ($P<0.05$) and negative ($P<0.1$) significant effect while butter+oil only showed a ($P\geq0.1$) 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×C) on SCC ($P\geq0.1$). 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 ($P<0.05$) had significant positive changes at quadratic terms. The positive value of sorghum flour indicates the positive effect on chewiness of SCC. Patel [16] reported that maida had significant ($P\leq0.01$), WPC-80 had non-significant ($P>0.05$) changes on chewiness at linear terms in chhana cake. However, he also reported for non-significant ($P>0.05$) effect of ghee residue, WPC-80 and maida on chewiness of chhana cake at quadratic terms. A significant increase in chewiness at linear levels with increase in sorghum flour could be attributed to its high water holding capacity which was also responsible for increase in hardness of the product.

5. 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 all the parameters are reported in Table 7. 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 7. 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

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/s 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)*

% (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.

6. CONCLUSION

Based on the results obtained in this study it can be concluded than an acceptable quality SCC can be prepared using sorghum flour in place of wheat flour. Chhana prepared from milk containing 6.0% milk fat 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.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that the following AI technology has been used during the writing or editing some portions of the manuscripts.

Name: ChatGPT (free access available online at https://chatgpt.com)
Version: GPT-4

Model: Developed by OpenAI, GPT-4 is the underlying language model that powers this AI. It offers improvements in language understanding, generation, and reasoning over prior versions.

Source: This generative AI technology is provided by OpenAI, a leading research organization in AI development.

The AI has the capability to process both text and image inputs and offers enhanced features such as real-time information retrieval via browsing tools, code execution via Python integration, and image generation with DALL·E.

1. This free ChatGPT online service has been utilized while writing this article to just ensure grammatical corrections and proper sentence formation for the proper article content.
2. Introduction
3. Abstract

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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