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Production and Evaluation of the Nutritional and Functional Qualities of "Adakwa" Enriched with Waste Biomass of Traditional Brewer's Spent Grain as a Functional Staple Food

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Abstract

Brewers' spent grains constitute a nutrient-rich valuable and highly under-utilized by-product of the beer industry produced in large amounts all through the year. This bio-resource is a very good candidate for valorization, due to environmental and economic concerns, using biotechnological processing, particularly for food enrichment. This study was undertaken to evaluate the effect of fortification of Adakwa with traditional brewers' spent grains (TBSG) on its physicochemical and nutritional properties as well as its acceptability using an experimental design. Four (4) samples of Adakwa were produced with TBSG incorporated rates of 0% (control sample), 10%, 20%, and 30% and evaluated. Using an experimental design, the effect of process parameters, including the TBSG incorporation rate, cooking time, and cooking temperatures on the physicochemical and nutritional properties of the Adakwa were evaluated while the 9-point hedonic scale was used to evaluate the sensory properties and its overall acceptability: carbohydrate, protein, crude fibre, cellulose, polyphenol, antioxidant activity (FRAP and DPPH). The water absorption activity values were 81.2 ± 0.04, 4.55 ± 0.05, 9.73 ± 0.23, 3.31 ±

0.05, 6.73 ± 0.23, 1.60 ± 0.09, 28.85 ± 0.8 and 117 ± 3.54 respectively for 0% TBSG (control); 86.8 ± 0.01, 1.81± 0.20, 16.22 ± 0.16, 5.54 ± 0.69, 6.01 ± 0.16, 6.59 ± 0.03, 25.89 ± 0.94 and 475.0 ± 21.21 respectively for 30% TBSG. The sample with a high nutrient content was further produced using a central composite design and the factors studied were temperature and time, with responses, crude fiber, and FRAP content. The optimum production condition was: % TBSG: 47.06%; temperature: 123.17˚C; Time: 30.34 mins. The sample with 47% TBSG had the best overall acceptability after sensory evaluation with sensory scores of: 5.45 ± 0.76, 7.9 ± 0.79, 8.0 ± 1.0, 7.10 ± 0.16, 8.5 ± 1.6, 7.6 ± 0.98 for color, taste, aroma, mouthfeel, texture and overall acceptability respectively. Thus TBSG can be used to improve the physicochemical and nutritional properties of adakwa.

Keywords

Biomass, Brew-Waste, Spent Grain, Valorisation, Adakwa, Enrichment

1. Introduction

Among agro-industries, the brewery sector accounts for the production of an abundant amount of low-cost bio-waste which are largely underutilized despite their potential nutritional value and functional properties, and their disposal entails high costs for the brewery [1] [2]. Traditional brewing methods have remained an important activity throughout Africa despite commercial breweries producing variations of traditional African beers. The production of indigenous alcoholic beverages in a rural village of Cameroon from cereals and tubers using local techniques plays a major role in the economy of these communities. Traditional alcoholic beverages in Cameroon are principally produced from millet, sorghum, maize, rice, and cassava, with examples being "bilibili" produced from sorghum and corn-beer produced from maize [3]. The brewers spent grain is the major waste produced in brewery, after mashing process, and represents 85% of the total dry waste from brewery while the hot trub, generated during wort boiling as a result of thermal denaturation and precipitation of high molecular weight proteins, represents 15% - 20% of the dry matter content [4] [5] [6]. The chemical composition of these waste vary which depend on the type and quality of the ingredients used and the conditions prevailing during each step of the brewing process; nevertheless, they always have a high nutritional value [7] [8].

Brewers spent grain is a massively overlooked potential source of human nutrition as it has been reported to be very rich in fiber, protein and essential amino acids, minerals, polyphenols, vitamins, and lipids [9] [10]. BSG is a heterogeneous biomaterial composed of lignocellulosic biomass and has been reported to be rich in proteins (20% - 30%), fiber (30% - 70%), lipids, vitamins, and minerals [9] [11]. The traditional use of BSG is in animal nutrition, but more re-

cently it has been used in biogas production [12] [13], bioethanol production [14], and other applications as reviewed by [9] and [11]. Recent research suggests diverse applications of BSG as a substrate for the cultivation of microorganisms [15], the production of protein concentrates [16] [17], enzymes [18] [19], as well as for human food products [20] [21].

To date, the brewers spent grains generated from traditional brewing processes are either discarded or sold as animal feed. However, because of its nutritional content, traditional brewer spent grain (TBSG) is of interest for application in the fortification of human food products, particularly given its low cost and availability in large amounts. Using the brewer's spent grain, which has a low monetary value, as a high-nutrient functional ingredient may enhance the economic potential of the brew house and improve the dietary attributes of different food formulations [22] [23] [24]. However, it also changes the processing technological, mechanical, and physiochemical properties of the food including visual appearances such as color, compact texture in addition to acceptability [25]. Therefore, because of its nutritional content, TBSG is of interest for the application in the fortification of human food products to fight against malnutrition.

To address the high rate of nutritional deficiency which is prevalent in many African countries due to malnutrition and hidden hunger [26] [27], traditional food-based strategies, such as fortification in combination with public health interventions can be used. In 2008 and 2012, the Copenhagen Consensus ranked food fortification as one of the most cost-effective development priorities [28] [29]. While food fortification has successfully used to prevent micronutrient deficiencies in high-income countries, it is still less common in low and medium income countries as Cameroon where the food system is not delivering nutritionally adequate diets due the production and consumption of just a few major starchy food crops (maize, rice, wheat) with low nutritional quality.

The food industry is seeking to find new added-value applications that will change the traditional view on "waste" products and re-classify them as "co-products". Using the brewer's spent grain by-product, which has a low monetary value, as a high-nutrient functional ingredient may enhance the economic potential of the brew house and improve the dietary attributes of different food formulations [24]. To date, this material is either discarded or sold as animal feed. An excellent review [30] mentioned that BSG has considerable potential to be used for several purposes, such as animal feed, food ingredients, polymer production, microbial products, and nutritional application. This material consists of the grain husks obtained as solid residue and other residual compounds not converted into fermentable sugars in the mashing process after the production of wort [31].

The investigation of alternative uses of BSG is pertinent, not only from the perspective of the brewer who can benefit from the valorisation of this by-product but also from an environmental perspective as the recycling and re-use of industrial wastes and by-products have become increasingly important [9].

The bio-economy addresses the possibilities of transforming renewable biological resources into economically and bio-energetically viable products [31]. For better environmental and economic performance, these by-products should be converted into valuable products instead of being considered useless wastes. Utilization thereof will reduce the costs of food and feed production and will allow taking full advantage of the nutritional value of this waste. While some attempts have been made to incorporate the bioactive components of BSG and BSY into foodstuffs, further research in this area should be conducted [4].

Fortification of staple foods such as rice, maize and wheat flour in sub-Sahara Africa has been reported as a strategy for combating micronutrient malnutrition [32] [33] [34] [35]. Most studies on food fortification don't target traditional indigenous African staple dishes. Adakwa is a local traditional indigenous snack that got its origin from west Africa and expanded to other places via migration and its highly consumed in Bamenda of the North west region of Cameroon. It is produced principally from mixture of corn flour and groundnut paste with pepper enhance the taste.

Maize (*Zea mays* subsp. *May* L.) is widely consumed cereal crop grown globally. They are good sources of carbohydrates, vitamins and minerals. [36] reported that 100 g of edible portion of maize contains 71.88 g carbohydrate, 8.84 g protein, 4.57 g fat, 2.15 g crude fibre and 2.33 g ash. In different cultures and societies, they are use as compliments for soups, gravies and stews and supply the basic energy requirement of the consume. Maize grains are predominantly used for the production of different snack foods some of which may be eaten mainly to prevent hunger such as Adakwa.

Groundnut (*Arachis hypogaea*), also known as peanut is a legume exhibiting almost all the qualities of popular edible kernels such as pistachio, almonds etc., and they are the world's fourth most important source of edible vegetable oil, and third most important source of vegetable protein [37]. Groundnuts are also rich in polyphenols and chief of the antioxidant group. They contain magnesium, folate, vitamin E, organic fibre; all of which helps to lessen the risk of cardiovascular disease [38]. Due to its high nutritional value, it offers some health benefits, like prevention of chronic disease attributed to important soluble and insoluble fibre, slow digestive starch, prebiotic, oligosaccharide and phenolic compound. The slow starch digestion helps to regulate glycaemia; fibre helps on gastrointestinal function, while the phenolic compounds provide antioxidant properties [39].

In most developing countries of the world including Cameroon, where diets are more of carbohydrate origin; the occurrence of protein-energy malnutrition is common especially among children [40]. Traditional brewer spent grain (TBSG) are of interest and handy, as they could provide high been reported to be rich in fiber, protein and essential amino acids, minerals, polyphenols, vitamins, and lipids [41] [42] for incorporation into high carbohydrate-based foods. While a fairly large number of research works has been carried out on cereal products and its enrichment [43], no reports exit on enrichment of Adakwa. The objective

of this research was aimed at evaluating the effect of enrichment of "Adakwa" with traditional brewer's spent grain and process parameters on its physico-chemical, nutritional, and functional properties, and on the acceptability of the "adakwa".

2. Materials and Method

2.1. Materials

Fresh traditional brewers spent grain (TBSG) used in this study was obtained from a local traditional alcoholic beverage, corn beer, (Sha) producer from Bambili, Bamenda. All the other raw materials for the Adakwa preparation were obtained from the local market in Bambili, Bamenda. All chemicals used in the study were of analytical grade. The Food Science and Technology Laboratory of the National Polytechnic University Institute Bamenda was used to carry out the production, physiochemical, functional, and sensory analysis.

2.2. Methodology

2.2.1. Sample Preparation

The fresh TBSG were processed and preserved as described by [44] before application in Adakwa enrichment. The fresh TBSG samples were oven-dried at 78˚C for 12 hours to a moisture content of 26%. The dried TBSG were then ground into flour using a blender, packaged in bags, sealed, and stored at room temperature until use.

2.2.2. Preparation of Adakwa

Adakwa was produced following the traditional method by mixing corn flour (50 g), groundnut paste (35 g), pepper and oil, with enrichment using the prepared TBSG flour as illustrated in **Figure 1**. The Adakwa prepared from corn flour and groundnut paste without TBSG substitution served as control. After mixing, the mixture was kept in a tray for shaping before cooking. All samples were prepared under the same cooking condition of 25 minutes at 140˚C.

2.3. Experimental Design to Study the Effect of TBSG Incorporation on Physicochemical, Nutritional, and Functional Properties of Adakwa

The effect of TBSG on the physicochemical, nutritional, and functional properties of Adakwa was studied by the substitution method the in with the TBSG incorporated in the Adakwa at rates of 10% (NA + TBSG (10%)), 20% (NA + TBSG (20%)) and 30% (NA + TBSG (30%)) as indicated in **Figure 2**. All other ingredients were maintained the same. The Adakwa prepared from corn flour and groundnut paste without TBSG substitution NA (100%), served as control. All samples were prepared under the same condition of 25 minutes at 140˚C. After the preparation of the Adakwa, as shown in **Figure 2**, all samples were analyzed for their physicochemical, nutritional, and functional properties.

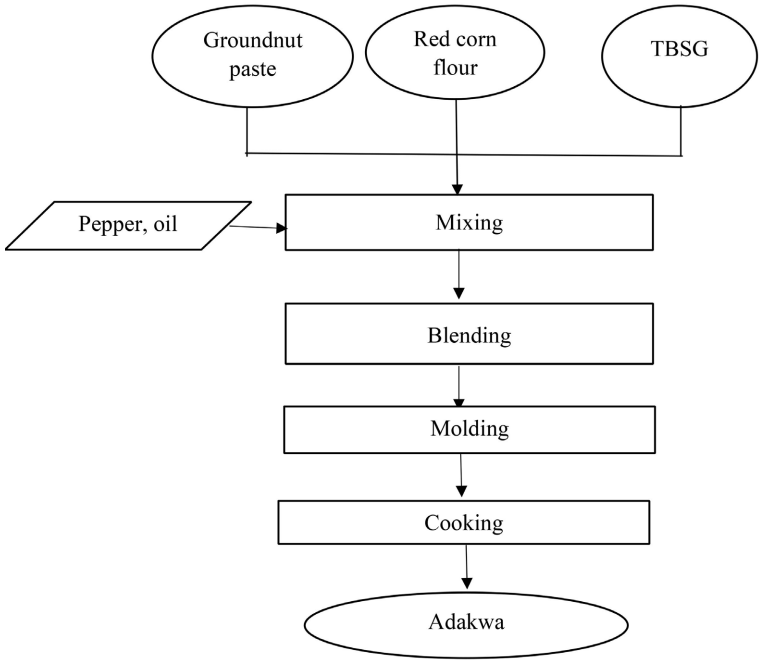

Figure 1. Block diagram for production of Adakwa enriched with TBSG.

Figure 2. Adakwa enriched with (left to right) 10%, 20% and 30% TBSG.

2.4. Effect of Process Parameters on the Fiber Content and % FRAP the TBSG Enriched Adakwa

Experimental Design

A response surface methodology (Central Composite Design) was used to study the effect of the process parameters on the fiber content and % FRAP of the adakwa enriched with TBSG. The experimental factors studied included the% of TBSG to ground nut and corn flour (%), (X_1), cooking temperature (˚C) (X_2), and the cooking time (min) (X_3) The experimental matrix with coded experimental values were transformed into real experimental values as presented on Table 1 below. The experiments were conducted in a randomized order to minimize the effect of unexpected variability in the observed responses due to extraneous factors.

The results obtained were fitted in the general quadratic model equation (Equation (1)) with three factors and interactions to obtain the model equation for the responses fiber content (Y_1) and % FRAP (Y_2)

Table 1. Experimental matrix with real values to study the effect of process parameters on the physicochemical, nutritional, and functional properties of the Adakwa.

RUNS	X_1	X_2	X_3
	% of TBSG to ground nut and corn flour (%),	Temperature (˚C)	Time (mins)
1	25	109.77	25
2	25	160.23	25
3	40	120	20
4	40	150	30
5	25	135	33.41
6	25	135	25
7	25	135	25
8	25	135	16.59
9	50.23	135	25
10	10	150	30
11	0	135	25
12	10	120	30
13	40	150	20
14	40	120	30
15	10	120	20
16	10	150	20

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_{12} X_1 X_2 + \beta_{13} X_1 X_3 + \beta_{23} X_2 X_3 + \beta_{11} X_1^{\,2} + \beta_{22} X_2^{\,2} + \beta_{33} X_3^{\,2} + E \quad (1)$$

Optimized condition for the various factors in the design was obtained and the effect of various parameters was studied.

2.5. Analytical Methods

2.5.1. Effects of TBSG on the Physicochemical Properties of Adakwa

1) Effect on pH

The pH of the samples was determined with the help of a pH meter (Model PHS-3C) using 2 grams of the sample mixed with 20 ml of distilled water.

2) Effect on Fibre content, Cellulose, Hemicellulose, and Lignin

The crude fiber content was determined using the AOAC 2005 method [45] by boiling the sample in sulphuric acid followed by sodium hydroxide and the obtained residue was incinerated and weighed. The three components of ligno-cellulosic biomass (cellulose, hemicellulose, and lignin) in the enriched Adakwa samples were determined by the method described by [46] using Acetone, Sodium hydroxide (NaOH, 0.5 mol/L), Sulphuric acid (98%) and Barium chloride solution.

2.5.2. Effects of TBSG on the Nutritional Properties of Adakwa

1) Effect on Lipid, carbohydrates, and protein

The lipid content was determined following soxhlet extraction with hexane and evaluated according to the method described by [47] using two grams of the enriched Adakwa samples which were previously dried at 105˚C for 24 h. Total carbohydrate was determined by a spectrophotometer according to the [48] method using five grams samples while the protein content was determined with the help of a spectrophotometer by the biuret method using standard dilutions of BSA containing 0.006, 0.012, 0.018, 0.022, and 0.024 mg/ml protein. The concentration of vitamin C was obtained by titration (redox titration of iodine solution) against a 0.005 M iodine solution to a dark blue-black color as described by the [48] method.

2.5.3. Effects of TBSG on the Functional Properties of Adakwa

1) Effect on water absorption capacity (WAC)

The WAC was evaluated according to the method described by [49] in which 0.1 g samples were mixed with 10 ml of distilled water and kept in a water bath at 30˚C for 30 min, then centrifuged at 5000 rpm for 15 min and the weight of pellet determined. The excess water absorbed by the samples was expressed as the percentage of water bound by a 100 g sample.

2) Effect on total polyphenol and Antioxidant activity

The total polyphenol content was determined using Folin–Ciocalteu reagent and gallic acid (0.2 g/l) as the standard according to the method reported by [50]. During this reaction, the polyphenols are oxidized to give a mixture of blue tungsten oxide (W8O23) whose maximum absorption at 725 nm is proportional to the number of phenolic compounds. The antioxidant activity was determined via the DPPH method as reported by Blois (1958 by studying the effect of adakwa extract on DPPH radicals with some modifications. A solution of DPPH (0.5 mmol/L) in ethanol and 0.05 mol/L acetate buffer (pH 5.5) was prepared. Extract in solution (0.1 ml) at different concentrations was mixed with 2 ml of acetate buffer, 1.9 ml of absolute ethanol, and 1 ml DPPH• solution. The mixture was shaken immediately after adding DPPH• and allowed to stand at room temperature in dark for 30 min. The decrease in absorbance at 517 nm was measured using a spectrophotometer. BHT was used as positive control and the sample solution without DPPH• was blank. The radical scavenging activity was measured as a decrease in absorbance of DPPH and calculated as:

$$\text{Scavenging activity}(\%) = \left(\text{Abs control} - \frac{\text{Abs Sample} - \text{Abs blank}}{\text{s Control}} \right) \times 100$$

where Abs control, is the absorbance of 517 nm of DPPH without any sample extracts, Abs sample is the absorbance of the different sample extracts with DPPH and Abs blank is the absorbance of respective extracts without DPPH.

The reducing power of adakwa extract was determined by the FRAP method as described by [51] with some modifications. Briefly, extracts (2 ml) in PBS (2.5 ml, 0.2 mol/L, pH 6.6) was added to potassium ferricyanide (2.5 ml, 10 mg/ml)

and the mixture was incubated at 50˚C for 20 min. 2.5 ml of 10 mg/ml trichloroacetic acid (TCA) was added and centrifuged at 1160 g for 10 min. De-ionized water (2.5 ml) was added to 2.5 ml of the supernatant and 0.5 ml of 1.0 mg/ml ferric chloride ($FeCl_3$). The absorbance was measured at 700 nm against a blank using a spectrophotometer. The blank of each sample was prepared by adding distilled water instead of $FeCl_3$. Ascorbic acid was used as a control. Higher absorbance of the reaction indicates a higher reducing power.

2.6. Sensory Analysis

Sensory analysis on taste, texture, color, flavor, aroma, and overall acceptability was done on the adakwa prepared from the optimized adakwa prepared traditionally incorporated with TBSG. Coded samples were presented to 30 panelists who were familiar with adakwa for sensory evaluation using a 9-point hedonic scale ranging from extremely dislike to excellent was used.

2.7. Data Analysis

Adakwa samples were analyzed in triplicate, and the mean values, standard deviations (SD), and correlation values (r^2) were calculated. Statistical analysis was conducted on data using ANOVA and the general linear model, with Excel and STATGRAPHICS centurion version XVII. Mean separations were examined using the t-test. The P-value ≤ 0.05 was used for significant effect or difference, R-squared value > 70%, and/or standard error < 10% was used for model validation. Results were expressed in tables as mean ± standard deviation of the mean. The graphs were plotted using the same software.

3. Results and Discussion

3.1. Effects of TBSG on the Physicochemical Properties of Adakwa

The effect of TBSG incorporation on the pH and the water absorption capacity is presented in **Table 2**.

3.1.1. Effect on pH

The F-ratio, which equals 6.42, is a ratio of the between-group estimate to the within-group estimate. Since the P-value of the F-test is greater than 0.05, there is no statistical significant difference between the means of the 4 samples at the 5% significance level. The Multiple Range Tests effectively show a statistical significant difference in the pH values amongst the samples, NA (100%) and NA + TBSG (30%) compared to NA + TBSG (20%) and NA + TBSG (10%) at $P < 0.05$. There was no statistical significant difference between NA + TBSG (10%) and NA + TBSG (20%). It also became more acid because the spent grain has an acid pH [52].

3.1.2. Effect on Water Absorption Capacity (WAC)

The F-ratio, which equals 181.58, is a ratio of the between-group estimate to the within-group estimate. Since the P-value of the F-test is less than 0.05, there is a

Table 2. Effect of TBSG on pH and the Water absorption capacity (WAC) of Adakwa.

SAMPLES	pH	WAC (gH_2O/100 g)
NA (100%)	5.76 ± 0.21^a	117 ± 3.54^a
NA + TBSG2 (10%)	6.66 ± 0.15^c	195.0 ± 7.07^b
NA + TBSG (20%)	6.59 ± 0.025^c	194.5 ± 4.95^b
NA + TBSG (30%)	6.72 ± 0.25^b	475.0 ± 21.21^c

Each value is a mean of 3 trials ± standard deviation. Values with different superscripts along the column are significantly different ($P < 0.05$).

statistical significant difference between the means of the 4 samples at the 5% significance level. The Multiple Range Tests equally show a statistical significant difference in the WAC amongst the products, NA (100%) and NA + TBSG (30%) compared to NA + TBSG (20%) and NA + TBSG (10%) at $P < 0.05$. There was no statistical significant difference between NA + TBSG (10%) and NA + TBSG (20%).

The change in WAC might be due to the loosening of the dietary fiber structure, consequently exposing hydrophilic groups [53]. The increase in the water-absorption capacity is beneficial for inhibiting syneresis and modifying viscosity and texture [54]. WAC contributes to textural (hardness) properties of the utilization of byproducts as food ingredients [55].

3.1.3. Effect on Fibre Content, Cellulose, Hemicellulose, And Lignin

The effect of TBSG incorporation on the fiber content, Cellulose, Hemicellulose, and Lignin is presented in **Table 3**.

1) Fibre content

The F-ratio, which equals 73.27, is a ratio of the between-group estimate to the within-group estimate. Since the P-value of the F-test is less than 0.05, there is a statistical significant difference between the means of the 4 variables at the 5% significance level. The Multiple Range tests as well show a statistical significant difference in the fiber content between the product NA + TBSG (10%) and NA + TBSG (20%) compared to that of NA + TBSG (30%) and NA (100%) at $P < 0.05$. Whereas, NA + TBSG (20%) and NA + TBSG (30%) showed no significant difference.

Thus, BSG-enriched bread may be considered a good source of dietary fiber to attain the necessary daily fiber intake (28 - 36 g/day) required for healthy nutrition[56]. [57] reported that the addition of BSG in extruded snacks increased the fiber content of the snacks from 4.8% in the control sample (0% TBSG) to 19.8% in samples containing 30% TBSG. This, therefore, suggest that the incorporation of BSG to supplement corn flour for adakwa production would enrich dietary fiber values as well.

2) Cellulose

The F-ratio in the ANOVA table, for the mean values of cellulose, equals 2.98, between-group estimate to the within-group estimate. Since the P-value of the

Table 3. Effects of TBSG on Fiber Content, Cellulose, Hemicellulose, and Lignin content of Adakwa.

SAMPLES	Fiber content	cellulose	Hemicellulose	Lignin
NA (100%)	9.73 ± 0.23[a]	3.31 ± 0.05[a]	4.24 ± 0.04[a]	0.38 ± 0.02[a]
NA + TBSG (10%)	13.75 ± 0.00[b]	4.60 ± 0.11[c]	7.58 ± 0.25[b]	0.47 ± 0.02[b]
NA + TBSG (20%)	13.68 ± 0.02[b]	5.47 ± 0.15[b]	8.44 ± 0.11[b]	0.45 ± 0.02[b]
NA + TBSG (30%)	16.22 ± 0.16[c]	5.54 ± 0.69[b]	9.13 ± 0.51[c]	0.67 ± 0.02[c]

Each value is a mean of 3 trials ± standard deviation. Values with different superscripts along the column are significantly different ($P < 0.05$).

F-test is greater than 0.05, there is no statistical significant difference between the means of the 4 samples at the 5% significance level. In the same light, the Multiple Range tests show a statistical significant difference between the product NA (100%) and NA + TBSG (10%) compared to cellulose content of NA + TBSG (20%) and NA + TBSG (30%). But no statistical significant difference in cellulose content of NA + TBSG (20%) and NA + TBSG (30%) at $P < 0.05$.

3) Hemicellulose

The F-ratio in the ANOVA, for the mean values of hemicellulose, equals 16.14, between-group estimate to the within-group estimate. Since the P-value of the F-test is less than 0.05, there is a statistical significant difference between the means of the 4 samples at the 5% significance level. The Multiple Range tests as well show a statistical significant difference in the hemicellulose between the product, NA + TBSG (10%) and NA + TBSG (20%) compared to NA (100%) and NA + TBSG (30%) at $P < 0.05$. Whereas, NA + TBSG (10%) and NA + TBSG (20%) showed no significant difference.

4) Lignin

The F-ratio, for the mean values of lignin, equals 49.88 between-group estimates to the within-group estimate. Since the P-value of the F-test is less than 0.05, there is a statistical significant difference between the means of the 4 samples at the 5% significance level. In the same light, the Multiple Range tests show a statistical significant difference in the lignin content between the product, NA (100%) and NA + TBSG (30%) compared to NA + TBSG (20%) and NA + TBSG (10%) at $P < 0.05$. Whereas, NA + TBSG (20%) and NA + TBSG (10%) showed no significant difference.

3.2. Effects of TBSG on the Chemical and Nutritional Properties of Adakwa

Effect on Lipid, Carbohydrates, and Protein

The effect of TBSG incorporation on the Lipid, carbohydrates, protein, and vitamin C is presented in **Table 4**.

1) Lipid content

The value of total lipids for the four samples varies from 5.2 ± 0.14 for sample NA+TBSG (10%) to 8.75 ± 0.35 for sample NA (100%), thus total lipids are

Table 4. Effects of TBSG on Lipid, carbohydrates, protein, and vitamin C content of Adakwa.

Samples	Lipid (g/100 g)	Carbohydrates (g/100 g)	Protein (g/100 g)
NA (100%)	8.75 ± 0.35^{a}	81.2 ± 0.04^{a}	4.55 ± 0.05^{a}
NA + TBSG (10%)	5.2 ± 0.14^{b}	82.0 ± 0.02^{b}	4.40 ± 0.3^{a}
NA + TBSG (20%)	5.61 ± 0.18^{b}	82.04 ± 0.06^{b}	4.46 ± 0.09^{a}
NA + TBSG (30%)	5.6 ± 0.14^{b}	86.8 ± 0.01^{c}	1.81 ± 0.20^{b}

Each value is a mean of 3 trials ± standard deviation. Values with different superscripts along the column are significantly different ($P < 0.05$).

minimal in sample NA + TBSG (10%) and highest in sample NA (100%). The difference in lipid content between sample NA (100%) and sample NA + TBSG (10%) is a result of incorporating BSG (10%) into NA. The F-ratio in the ANOVA table, for the mean values of lipid, equals 55.18, between-group estimate to the within-group estimate. Since the P-value of the F-test is less than 0.05, there is a statistical significant difference between the means of the 4 samples at the 5% significance level. However, the Multiple Range shows that the lipid content of NA+BSG (10%), NA + TBSG (20%) and NA + TBSG (30%) are not significantl different statistically but there exists a statistical significant difference between the product NA (100%) and NA + TBSG (10%), NA (100%) and NA + TBSG (20%), NA (100%) and NA + TBSG (30%) at P value < 0.05.

It was observed that as the level of substitution of BSG increased, fats extracted from cookies increased from 2.120 to 2.310g in 15% BSG supplement [58]. Fat is a source of energy that is needed in adakwa production, thus using BSG to supplement corn flour for adakwa formation would enhance its nutritional value.

2) Carbohydrates

The Multiple Range shows that the carbohydrate content of NA + TBSG (10%) and NA + TBSG (20%) is not statistical significantly different but there exists a statistical significant difference in the carbohydrate content between the product NA + TBSG (10%) and NA + TBSG (20%) compared to NA (100%) NA + TBSG (30%) at P value < 0.05.

The value of total carbohydrate for the four samples varies from 81.2 ± 0.04^{a} for sample NA (100%) to 86.8 ± 0.01^{c} for sample NA + TBSG (30%), therefore total carbohydrate is minimal in sample NA (100%) and highest in sample NA + TBSG (30%). This difference in carbohydrate content between sample NA (100%) and sample NA + BSG (30%) is a result of incorporating TBSG (30%) into NA. Total carbohydrates amount decreased (from 53.69% to 40.46%) as the content of TBSG in the samples increased. The main carbohydrate in wheat flour is represented by starch, while the BSG contains only residual amounts of starch, this compound being consumed by the extensive amylolysis during the mashing process [24] [59]. BSG is predominantly a fibrous material [2] [60] that is poor

in fermentable sugars. In addition, the washing until exhaustion of this residue for the recovery of the brewing wort extract reduces the sugar content to its minimum.

3) Protein content

Total protein value for the four samples varies from 1.81 ± 0.20^{b} for sample NA + TBSG (30%) to 4.55 ± 0.05 for sample NA (100%), therefore total protein content is lower in sample NA + TBSG (30%), and the highest in sample NA (100%). This difference in protein content between samples NA (100%) and sample NA + TBSG (30%) is a result of incorporating BSG (30%) into NA.

The F-ratio in the ANOVA table, for the mean values of protein, equals 63.88, between-group estimate to the within-group estimate. Given the P-value of the F-test is less than 0.05, there is a statistical significant difference between the means of the 4 samples at the 5% significance level. However, the Multiple Range shows no statistical significant difference between the product NA (100%), NA + TBSG (10%), and NA + TBSG (20%). But a statistical significantly different in protein content of NA (100%), NA + TBSG (10%), and NA + TBSG (20%) compared to that of NA + TBSG (30%) at $P < 0.05$.

3.3. Effect on Vitamin C and Mineral Content

The effect of TBSG incorporation on Vitamin C and Ca is presented in Table 5.

3.3.1. Effect on Vitamin C

There is no statistical significant difference between the means of the 4 samples at the 5% significance level. The Multiple Range Tests effectively show a statistical significant difference in the vitamin C content values amongst the samples; NA (100%), NA + TBSG (10%), NA + TBSG (20%), NA + TBSG (30%) at $P < 0.05$. The mineral and vitamin contents of the test bread relative to the control suggest their superiority over the control [61] [62].

3.3.2. Effect on Ca Content

There is no statistical significant difference between the means of the 4 samples at the 5% significance level. The Multiple Range Tests effectively show a statistical significant difference in the calcium content values amongst the samples; NA (100%), NA + TBSG (10%), NA + TBSG (20%), NA + TBSG (30%) at $P < 0.05$. The mineral and vitamin contents of the test bread relative to the control suggest their superiority over the control [61] [62]. The high ash content of the test bread and the control was an indication that the products are good sources of minerals [63].

3.4. Effects of TBSG on the Functional Properties of Adakwa

3.4.1. Effect on Polyphenol Content and Antioxidant Activity

The effect of TBSG incorporation on the Polyphenol content and Antioxidant activity is presented in Table 6.

Table 5. Effects of TBSG on Vitamin C and Ca of Adakwa.

SAMPLES	Vitamin C	Ca (mg/100 g)
NA(100%)	25.23 ± 0.32^{a}	20.67 ± 0.44^{a}
NA + TBSG2 (10%)	21.49 ± 0.69^{b}	22.62 ± 0.19^{b}
NA + TBSG (20%)	23.76 ± 0.45^{c}	25.45 ± 0.25^{c}
NA + TBSG (30%)	30.18 ± 1.2^{d}	46.72 ± 1.2^{d}

Each value is a mean of 3 trials ± standard deviation. Values with different superscripts along the column are significantly different ($P < 0.05$)

Table 6. Effects of TBSG on Polyphenol content and Antioxidant activity of Adakwa.

SAMPLES	Polyphenol (mg/100 g)	FRAP (%)	DPPH (EC_{50} mg/mL)
NA (100%)	6.73 ± 0.23^{b}	1.60 ± 0.09^{a}	28.85 ± 0.82^{c}
NA + TBSG (10%)	5.75 ± 0.00^{a}	5.77 ± 0.11^{b}	20.03 ± 0.71^{a}
NA + TBSG (20%)	5.79 ± 0.00^{a}	5.65 ± 0.02^{b}	21.35 ± 0.73^{a}
NA + TBSG (30%)	6.01 ± 0.16^{c}	6.59 ± 0.03^{c}	25.89 ± 0.94^{b}

Each value is a mean of 3 trials ± standard deviation. Values with different superscripts along the column are significantly different ($P < 0.05$).

3.4.2. Polyphenol Content

The ANOVA table decomposes the variance of the data into two components: a between-group component and a within-group component. The F-ratio, which equals 7.25, is a ratio of the between-group estimate to the within-group estimate. Since the P-value of the F-test is less than 0.05, there is a statistical significant difference between the means of the 4 samples at the 5% significance level. The Multiple Range Tests show a statistical significant difference in the polyphenol content between the products NA (100%) and NA + TBSG (30%) compared to NA + TBSG (20%) and NA + TBSG (10%). But no statistical significant difference in cellulose content of NA (10%) and NA + TBSG (20%).

The supplementation of fermented BSG to pasta significantly enhanced the concentration of the phenolic compounds, especially after mimicked gastric digestion [64]. BSG is recognized as a carrier of valuable phenols whose antioxidant, antiradical, but also anti-carcinogenic, and anti-apoptotic properties, have been acknowledged [9]. Cooking methods have an essential role in the stability of phenolic compounds and their subsequent release during digestion. It is worth noting, however, that the fate of phenolic compounds during heat treatments varies greatly [64]. On the other hand, heat treatments are of paramount importance for the release of phenolic compounds from food matrices during digestion, consequentially increasing their bio-accessibility [65].

3.4.3. DPPH Activity

The F-ratio in the ANOVA, which equals 87.0568, is a ratio of the between-group estimate to the within-group estimate. Since the P-value of the F-test is

less than 0.05, there is a statistical significant difference between the means of the 4 samples at the 5% significance level.

The Multiple Range Tests equally show a statistical significant difference in the DPPH activity amongst the products NA (100%) and NA + TBSG (30%) compared to at $P < 0.05$. Whereas there was no significant difference between NA + TBSG (20%) and NA + TBSG (10%). Cooking led to a decrease in antioxidant activity, as determined by DPPH, while digestion amplified the radical scavenging activity. Whilst some of the peptides and phenolic compounds responsible for the scavenging properties against DPPH might have leached in the cooking water, it is also known that food processing affects its antioxidant properties [66].

3.4.4. FRAP

The F-ratio, which equals 903.90, is a ratio of the between-group estimate to the within-group estimate. Since the P-value of the F-test is less than 0.05, there is a statistical significant difference between the means of the 4 samples at the 5% significance level. The Multiple Range Tests equally show a statistical significant difference in the FRAP amongst the products, NA (100%) and NA + TBSG (30%) compared to NA + TBSG (10%) and NA + TBSG (20%) at $P < 0.05$. There was no statistical significant difference between NA + TBSG (10%) and NA + TBSG (20%).

Bioprocess BSG exhibited enhanced antioxidant activity, characterized by high radical scavenging activity, long-term inhibition of linoleic acid oxidation, and protective effect toward oxidative stress on human keratinocytes [64].

3.5. Effect of Process Parameters on the Physicochemical, Nutritional, and Functional Properties of Adakwa Enriched with TBSG

Using the central composite experimental design, results obtained for the effect of process parameters on the Fibre content and the FRAP of the TBSG enriched Adakwa is as presented in **Table 7**.

3.5.1. Effect of % TBSG, Temperature, and Time on the Fiber Content of Adakwa

From the ANOVA analysis and Pareto chart of, of fiber on **Figure 3**, it can be seen that % BSG, temperature, and time all had a significant ($P < 0.05$) effect on the fiber content of adakwa. Amongst the interactions between % TBSG, temperature, and time, those with a positive significance ($P < 0.05$) were the quadratic effect of % TBSG and time along with the interactive effect of % BSG-time. Also, the quadratic effect of temperature had a positive significance at $P > 0.05$. The rest of the factors and interactive effects showed a negative significant ($P < 0.05$) effect on the fiber content of adakwa apart from the interactive effect of temperature time.

The model equation obtained from the regression coefficient for fiber content was:

Table 7. Effects of process parameters on Fibre content and FRAP of TBSG enriched Adakwa.

	Experimental Factors			Responses	
	X_1	X_2	X_3	Y_1	Y_2
RUNS	% of TBSG to ground nut and corn flour (%),	Temperature (˚C)	Time (mins)	Fiber (g/ml)	FRAP (%)
1	25	109.77	25	9.5	5.65
2	25	160.23	25	7.31	5.35
3	40	120	20	9.45	6.59
4	40	150	30	8.46	6.45
5	25	135	33.41	8.28	5.2
6	25	135	25	7.26	5.24
7	25	135	25	8.12	5.17
8	25	135	16.59	10.8	5.21
9	50.23	135	25	9.795	6.61
10	10	150	30	8.67	5.37
11	0	135	25	10.74	2.1
12	10	120	30	8.52	5.57
13	40	150	20	7.88	6.13
14	40	120	30	10.78	6.21
15	10	120	20	10.98	5.32
16	10	150	20	11.575	5.23

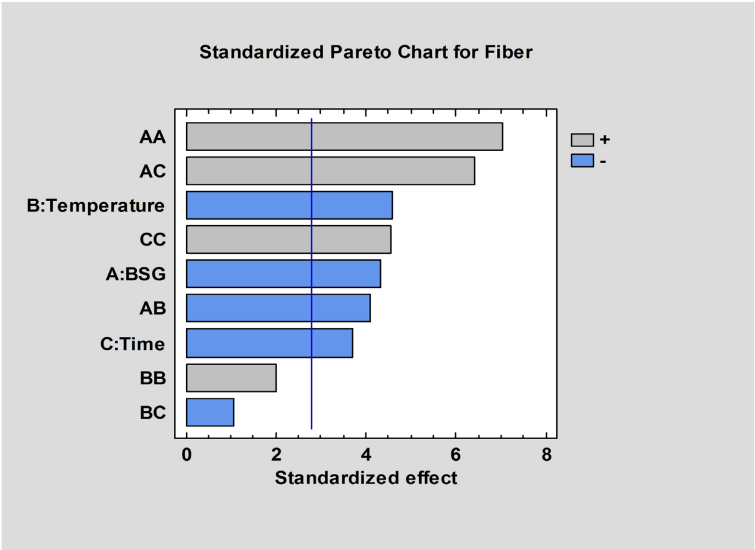

Figure 3. Pareto chart representing the effect of % TBSG, temperature, and time on the fiber content of adakwa.

$$\text{fiber} = 47.8625 - 0.182881X_1 - 0.230868X_2 - 1.46864X_3 + 0.00408615X_1^2 - 000257778X_1X_2 + 0.0121333X_1X_3 + 0.00115557X_2^2 - 0.002X_2X_3 + 0.0264513X_3^2$$

According to [67], the model is considered valid as the R-squared value for fiber content is 97.85% > 70% and adjusted R-squared = 93.03% with Standard Error of Est. = 0.4 < 10% (The optimized conditions to attain a maximum fiber content of 17.68 mg/100 g was found to be; % TBSG: 10%; temperature: 147.21; Time: 16.59 mins.

The effect of % TBSG and temperature on the fiber content of adakwa at a constant time is depicted in **Figure 4(a)** below. The fiber content tends to increase with an increase in temperature and decrease in % TBSG. This could be so because at high temperatures there is a breakdown of the glycosidic bonds of polysaccharides which can lead to the release of oligosaccharides and thus increase the quantity of soluble dietary fiber [68].

When the % TBSG is kept constant, the effect of temperature and time on the fiber content can be studied as shown in **Figure 4(b)**. In this case the fiber content was seen to increase with an increase in temperature and a decrease in time. This could be a result of the formation of resistance starch Maillard reaction products which are resistant to degradation/digestion [69].

When the effect of % TBSG and time was studied at a constant temperature on the fiber content (**Figure 4(c)**), it tends to increase with an increase in both % TBSG and time. This could be attributed to the fact that the TBSG is rich in fiber thus adding the quantity of TBSG into adakwa tends to elevate the fiber content. This was similar to the works of [58] who reported an increase in the fiber content of cookies incorporated with TBSG. Health benefits are often attributed to dietary fiber, but it is often difficult to attribute the effects solely to increased dietary fiber consumption. Increasing consumption of high-fiber foods increases dietary fiber intake which exerts positive physiological effects on the body [70].

3.5.2. Effect of % TBSG, Temperature, and Time on the % FRAP of Adakwa

From the ANOVA analysis and Pareto chart (**Figure 5**), % TBSG had a significant (P < 0.05) effect on the % FRAP of adakwa.

Amongst % TBSG, temperature, and the time those with a positive significance (P < 0.05) were % BSG and the quadratic effect of temperature and time along with the interactive effect of % TBSG-time. The rest of the factors and interactive effects showed a negative significant (P < 0.05) effect on the % FRAP of adakwa.

The model equation obtained from the regression coefficient for % FRAP was;

$$\%\ \text{FRAP} = 30.715 + 0.117178X_1 - 0.328436X_2 - 0.409966X_3 + 0.000517676X_1^2 - 0.000372222X_1X_2 + 0.000616667X_1X_3 + 0.00126579X_2^2 - 0.000383333X_2X_3 + 0.00877581X_3^2$$

The model is considered valid as R-squared value for fiber content is 70.0354% > 70% and Absolute Error = 0.4351 < 10% [67].

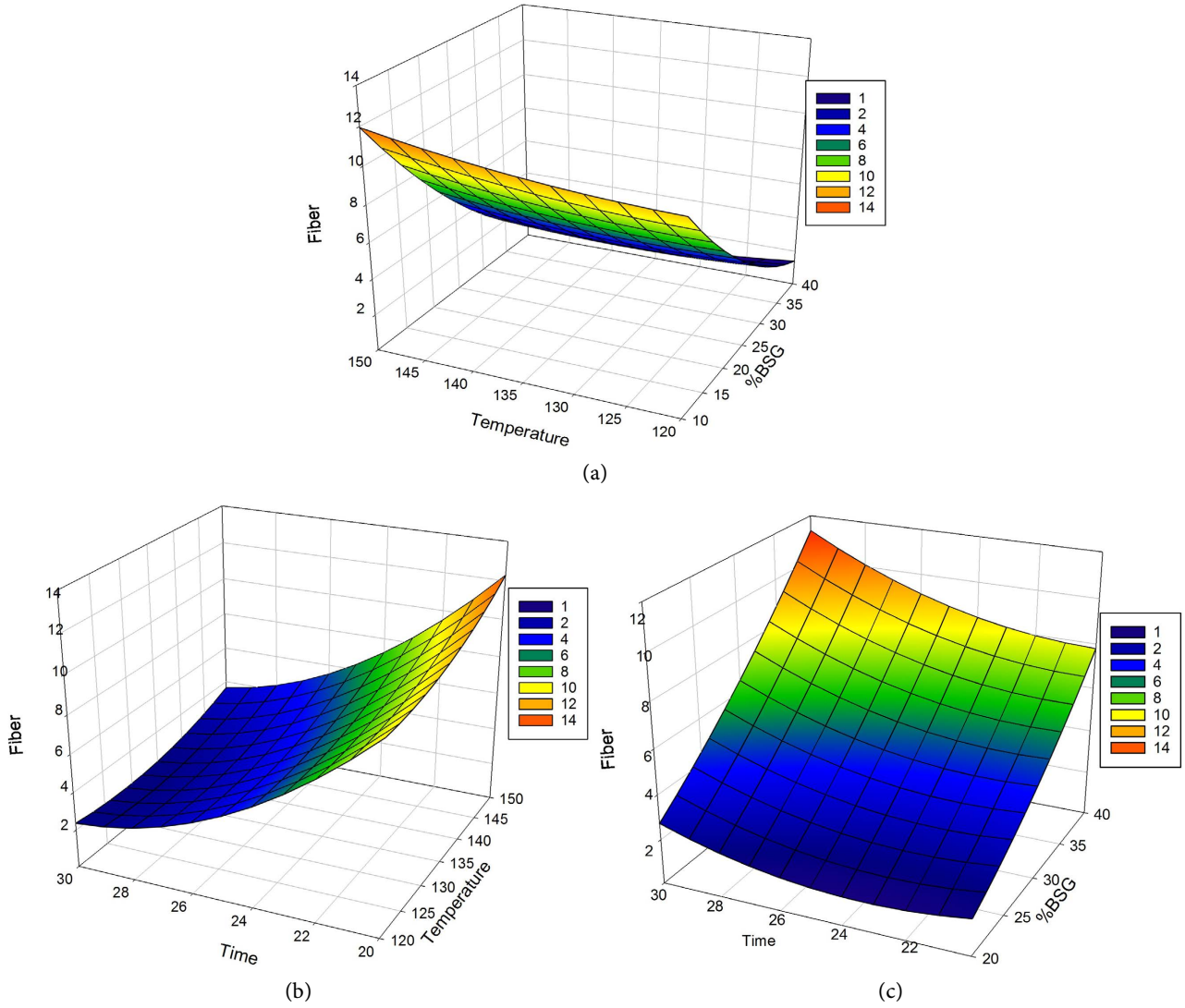

Figure 4. Response surface for the fiber content of adakwa as a function of (a) %BSG and Temperature; (b) Temperature and Time; (c) % TBSG and Time.

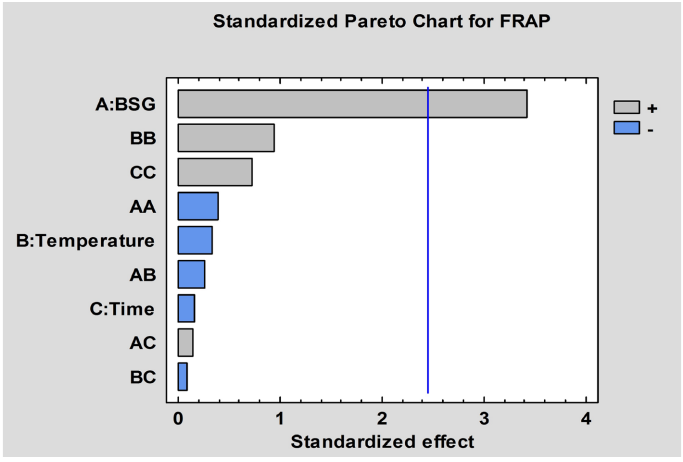

Figure 5. Pareto chart representing the effect of % TBSG, temperature, and time on the FRAP content of adakwa.

Table 8. Sensory evaluation results for adakwa.

Sample (N = 30)	Colour	Taste	Aroma	Mouthfeel	Texture	Overall acceptability
0% TBSG	6.72 ± 0.78^{a}	6.7 ± 1.01^{a}	6.5 ± 1.11^{a}	7.7 ± 0.65^{b}	8.1 ± 0.77^{b}	6.7 ± 0.45^{a}
47% TBSG	5.45 ± 0.76^{a}	7.9 ± 0.79^{b}	8.0 ± 1.0^{b}	7.10 ± 0.16^{b}	8.5 ± 1.6^{b}	7.6 ± 0.98^{b}

Values are mean ± standard deviation. Values with the same superscript letters along the column are not significantly different while those with different superscript letters along each column are significantly different from each other ($P > 0.05$).

The optimized conditions to attain a maximum fiber content of 8.145% were found to be; % TBSG: 50.23%; temperature: 110.07; Time: 33.41 mins.

The FRAP tends to decrease with an increase in temperature. This is in correlation with the works of [71] who reported an increase in the FRAP with an increase in temperature up to a maximum temperature of 42.5 above which there is a decrease in FRAP value. The optimized conditions to attain a maximum fiber content and FRAP was found to be; % TBSG: 47.06%; temperature: 123.17˚C; Time: 30.34 mins.

3.6. Sensory Evaluation

Sensory evaluation was done on adakwa which was prepared using Traditional Brewer Spent Grain (TBSG). Table 8 shows the mean sensory scores for adakwa prepared using TBSG. Mean scores for color, taste, mouthfeel, aroma, texture, and overall acceptability reveal that no significant difference (P-value > 0.05) was observed between attributes of adakwa prepared from TBSG. Sample 47% TBSG had the best overall acceptability after sensory evaluation with sensory scores of; 5.45 ± 0.76, 7.9 ± 0.79, 8.0 ± 1.0, 7.10 ± 0.16, 8.5 ± 1.6, 7.6 ± 0.98 for color, taste, aroma, mouthfeel, texture and overall acceptability respectively. From the sensory evaluation still, most of the panelists chose their overall acceptability based on the texture of the adakwa, and also the overall acceptability reading was closest to like very much.

4. Conclusion and Perspectives

The results of this research showed that adakwa produced using TBSG aids in improving its physicochemical and nutritional properties. The optimized conditions to attain a maximum fiber content and FRAP were found to be: % TBSG: 47.06%; temperature: 123.17˚C; Time: 30.34 mins. Adakwa produced with incorporation of 47.0% TBSG at 123˚C for 30 mins had the highest sensory score of: 5.45 ± 0.76, 7.9 ± 0.79, 8.0 ± 1.0, 7.10 ± 0.16, 8.5 ± 1.6 and 7.6 ± 0.98 for color, taste, aroma, mouthfeel, texture and overall acceptability respectively. Thus, TBSG can be used to improve the physicochemical and nutritional properties of adakwa thereby increasing mostly the crude fiber content in humans.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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