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The effect of processing variables on the biscuit-making potential of cocoyam-brewer's spent grain flour blends

ABDULHAMEED ADEWALE ODESEYE[1], SAMUEL OLUSEGUN AWONORIN[2], RUKAYAT OLUWADAMILOLA ABDUSSALAAM[3*], LATEEF OLADIMEJI SANNI[2], TAJUDEEN MURAINA ADENIYI OLAYANJU[4]

[1]*Agricultural and Rural Management Training Institute, Ilorin, P.M.B. 1343, Ilorin, Nigeria*
[2]*Federal University of Agriculture, Department of Food Science and Technology, P.M.B. 2240, Abeokuta, Nigeria*
[3]*Federal University Wukari, Department of Hospitality and Tourism Management, P.M.B. 1020, Wukari, Nigeria*
[4]*Federal University of Agriculture, Department of Agricultural Engineering, P.M.B. 2240, Abeokuta, Nigeria*

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ABSTRACT

In developing nations, the use of composite flours in baked products through value addition is increasing. This study investigated the effect of processing variables on the biscuit-making potential of cocoyam-brewer spent grain flour (CYF-BSG) blends. Blends were prepared in ratios (100:0, 90:10, 80:20, and 70:30). Response Surface Methodology consisting of three independent variables at three levels: CYF-BSG (90:10, 80:20, and 70:30) flour blends, mixing time (5, 10 and 15 minutes), and baking time (30, 40, and 50 minutes) were employed to optimize the effects on the biscuits' proximate and physical properties. The results showed that moisture, protein, crude fibre, carbohydrates, and ash were significantly ($p<0.05$) affected by brewer spent grain (BSG) substitution. The protein was significantly ($p<0.05$) affected by baking time and the interactive effect of mixing and baking time, while the texture was significantly ($p<0.05$) affected by baking time and the interactive effect of the BSG substitution and mixing time. The spread ratio was significantly ($p<0.05$) linearly affected by the BSG substitution and the interactive effect of mixing and baking time. The optimum conditions for producing the biscuits based on 65.29% desirability were 25.24% BSG substitution, 13.54 minutes mixing time, and 33.14 minutes baking time at 160 °C baking temperature. This study showed that CYF-BSG flour blends have great potential for biscuit-making.

Introduction

The use of composite flour for baked products is increasing daily in developing countries. This has led many researchers into developing arrays of products from flour blends made from different crops such as cereals, legumes, roots, and tubers, as well as their residual waste called 'SPENT'. These combinations are carried out for different reasons, such as supplementation to fight malnutrition, economy to reduce the cost of production (or importation) of wheat or increase the utilization of local crops (Ayo and Gaffa, 2002). Such blends of flours are called composite flours. Generally, the aim of producing composite flours is to get products with better nutritional or sensory qualities than the individual flours. More so, any composite flour produced must be readily available, culturally acceptable, and provide improved nutrition (Akobundu et al., 1998).

One of such local crops utilized less in Nigeria is cocoyam, which is traditionally a subsistence crop for many people in the tropics, often referred to as poor man, rural dwellers, or less privileged food (IITA, 1992). It is a tuber crop that can be boiled, baked, or mashed and used as staple food or snack (Enwere, 1998; Aboubakar et al., 2010; Ndabikunze et al.,

*Corresponding author E-mail: sannirukayat@gmail.com

2011). Cocoyam flour is reported to have found utilization in making biscuits and as a composite in bread making (Idowu et al., 1996).

Brewer's spent grain (BSG) is the most abundant agro-industrial by-product of beer production, among others such as spent hops and surplus yeast (Mussatto, 2008). It is a by-product obtained from the mashing operation of malted sorghum - a fundamental operation in the brewing process. Mashing is basically done to solubilize the malted cereal, to ensure the adequate extraction of wort (Fillaudeau et al., 2006). Tang et al. (2009) reported that the amount of BSG generated is about 85% of the total by-products recovered during the process. Being a heterogeneous mixture of grain remnants from which the soluble and mash digestible components of malt have been extracted, it is particularly rich in protein (20-25 %) and fibres (65-70 %) (Salihu and Muntari, 2011). This has promoted its use for food supplementation, mostly in developing and under-developed nations, where there is a high prevalence of the double burden of malnutrition characterized by the coexistence of protein energy malnutrition (PEM), obesity, diabetes, cancer, cardiovascular disease, and constipation (Kamaltij et al., 2010; Farcas et al., 2014). The most common use of BSG is in animal feeds, but researches have actually proved that it is possible to make value-added products from it, both for food and non-food potentials (Santos et al., 2003; Sobukola et al., 2012 and Malomo et al., 2013). Accordingly, the reported non-food uses of BSG include energy production, brick components, charcoal, paper manufacture, biotechnological processes, use as adsorbent/additives and also as a substrate for microorganism (mushroom species) cultivation (Santos et al., 2003; Salihu and Muntari, 2011; Malomo et al., 2013).

One of the beneficial products made of composite flour in developing nations are biscuits. They are often identified as ready-to-eat, convenient, and cheap baked products (Hussain et al., 2006; Oluwamukomi et al., 2011) accepted by the entire population. They are nutritive snacks produced from unpalatable dough (Olaoye et al., 2007) and contain purposeful digestive and dietary principles (Kulkarni, 1997). Basically, soft wheat flour is the major ingredient in biscuit making, but studies over two decades have proved the possibility of whole or partial substitution with flours from crops of less attention in developing countries. This is to reduce the total reliance on wheat importation to the fulfil domestic demand, and perhaps encourage diversification or unleash the potentials of the root crop. This study aims to investigate the potentials of CYF-BSG flour blends in biscuit making and to determine how processing variables influence the quality attributes of the biscuits. Hitherto, the results from this study may encourage the use of flours from underutilised crops and add value to BSG, thereby turning waste to wealth that can be used in combating malnutrition.

Materials and methods

Cocoyam corms (*Colocasia esculenta*,) and other ingredients used, except for BSG, were purchased from a local market in Abeokuta, Ogun State, while a fresh sample of brewer's spent grains (BSG) was obtained from Nigeria Breweries Plc, Sango, Ogun State.

Sample preparation

Production of cocoyam flour

Cocoyam flour was prepared using the method of Ezeocha, Omodamiro, Oti, and Chukwu (2011). The corms were cleaned, peeled, and sliced using a manual slicer with a stainless blade, into 2 – 2.5 mm thick slices and washed. The slices were then blanched for 5 minutes and then dried in the oven (SANYO Gallenkamp OMT 075) at 70 °C for 9 hours. The dried samples were milled, sieved (250 μm), and stored in air-tight containers for subsequent analysis.

Production of brewer's spent grain

The brewer's spent grain obtained was processed into flour using the method described by Ajanaku et al. (2011). The fresh BSG was dried in the oven (SANYO Gallenkamp OMT 075) at 60 °C for 7 hrs, milled, sieved (250 μm), and packed for further analysis.

Experimental design

Response surface methodology was used to investigate the effects of baking variables: flour blends (X_1), mixing time (X_2), and baking time (X_3), at the constant temperature of 160 °C on the response variables (proximate composition and physical properties) of the biscuit samples. The Box-Behnken design was used to analyse and optimize the process variables with seventeen experimental runs comprising central points of five replicates, which were randomly performed to minimize the effect of unexpected variability in the observed responses due to extraneous factors. A model of a second order polynomial was generated for the dependent variables to fit the experimental data and to quantify the influence of the variables as in the parent model in the following way:

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

Table 1. Coded and un-coded levels for the response surface design

Variables	Levels		
	-1		+1
CYF-BSG Blends (%) X_1	10	20	30
Mixing Time (mins) X_2	5	10	15
Baking Time (mins) X_3	30	40	50

Optimization

The optimum levels of the independent variables studied in this research were determined with respect to the responses (proximate composition and physical properties) using Design Expert version 6.0.8 (2002) (Stat-Ease, Inc., Minneapolis, MN). Based on goal desirability ≤100, all the processing conditions were kept within range to obtain biscuits with minimum colour, texture, and spread ratio, and the maximum breaking strength index, minimum moisture and crude fat, maximum protein, crude fibre, and the appreciable level of carbohydrate and ash content.

Preparation of Biscuit Samples

The biscuits were prepared using the method described by Okaka (1997).

Proximate composition

The proximate composition (moisture, ash, crude fat, crude protein, and crude fibre) of the samples was analysed in duplicates according to AACC (2000). Carbohydrates were determined by difference.

Determination of physical properties

The physical characteristics (width, thickness, and spread factor) were determined according to the AACC (2000) Method No. 10-53.

Colour analysis

Using a high-resolution digital camera (Canon Power Shot A2200 HD, 14.1 Mega Pixel, 4× digital zoom digital camera), the colour difference (ΔE*) was measured using a simple digital imaging method (Yam and Papadakis, 2004) as below:

$$\Delta E^* = [\ (L_0^* - L^*)^2 + (a_0^* - a^*)^2 + (b_0^* - b^*)^2\ ]^{1/2}$$

where: $L^* = \frac{L}{255} \times 100$; $a^* = a \times \frac{240}{250} - 120$; $b^* = b \times \frac{240}{255} - 120$

Statistical analysis

The statistical analysis was performed using the analysis of variance (ANOVA) for all data. The program Design Expert version 6.0.8 (2002) (Stat-Ease, Inc., Minneapolis, MN) for Windows was used for this purpose.

Results and discussion

The proximate composition of cocoyam flour is shown in Table 2. The protein content (3.54%) was low compared to the reports of previous studies on cocoyam flour; 8.08-8.74 % (Onwuamanam et al., 2010), 4.93-5.17 % (Ogunlakin et al., 2012), 7.4-8.9 % (Amandikwa, 2012). Crude fibre was within the range of 1.5-2.4 % reported by Amadikwe (2012), greater than 0.20-0.99 % reported by Onwuamanam et al. (2010), and lower than 2.70-2.97 % by Ogunlakin et al. (2012). An appreciable amount (80%) was observed for carbohydrate content, and it is comparable to reports of similar studies. The deviations according to previous reports may be attributed to various factors such as age, variety, and climate, and the cultivation period of the cocoyam tubers. Ihekoronye and Ngoddy (1985) also established that maturity at harvest, storage length, and elapsed time between harvesting and processing are great factors that could contribute to the observed variations. The other factor responsible for the variations was the pre-treatment used, such as fermentation, chemical treatment (sodium metal bisulphite, NaS_2O_5; lime juice etc.), and blanching. Consequently, the proximate composition result of the brewer's spent grain (BSG) shown in Table 2 indicated a great potential for protein and fibre supplementation. The observed value of 23.27% of protein is comparable with 23.7% for cowpea, 24.7% for ground nut, but lower than 26.3% for pigeon pea and 38.7% for soybean (Omohimi et al., 2013). A comparison with previous reports showed that the observed 18.97% for fibre is greater than 17.60% reported by Briggs, Hough, Stevens, and Young (1996) and 9.19% reported by Sobukola et al. (2012). This translates that both protein and carbohydrates were not fully solubilized during the mashing operation, whereby, the fibrous residues remain an added value to the quality and quantity of the fibre content of brewer's spent grain. Thus, these attributes can still be exploited for nutrition, not only in animal food, but in human food composition as well.

Table 2. Proximate composition of cocoyam and brewer's spent grain flours

SAMPLE	CHO (%)	PROTEIN (%)	FIBRE (%)	FAT (%)	ASH (%)	MOISTURE (%)
CYF	80.08±0.007	3.54±0.028	1.72±0.014	0.73±0.007	3.21±0.050	10.72±0.035
BSG	42.32±0.007	23.27±0.007	18.97±0.014	3.22±0.014	2.40±0.014	9.83±0.014

CYF = cocoyam flour   BSG = brewer's spent grain   CHO = carbohydrates

Table 3. Response surface result for the proximate composition of the biscuit samples

X_1	X_2	X_3	Y_1	Y_2	Y_3	Y_4	Y_5	Y_6
30	40	15	3.01	5.10	23.34	7.84	59.24	1.47
20	40	10	4.29	9.10	19.93	12.50	51.69	2.49
20	50	15	3.65	8.18	21.43	9.00	55.29	2.46
10	40	5	3.24	6.86	22.57	6.80	59.04	1.49
20	30	15	3.78	8.17	19.43	12.62	54.02	1.98
10	40	15	3.70	7.08	22.70	11.00	53.55	1.97
30	40	5	2.94	6.25	23.34	8.57	57.90	1.00
20	40	10	3.16	5.68	22.38	5.00	62.29	1.49
20	50	5	6.67	9.07	20.45	9.80	51.07	2.94
30	50	10	4.73	9.35	21.43	12.87	48.65	2.97
20	30	5	2.94	6.85	21.25	4.76	62.24	1.96
20	40	10	3.72	8.02	18.86	8.82	59.09	1.49
10	50	10	3.78	8.17	19.43	12.62	54.02	1.98
20	40	10	2.78	8.31	21.95	12.00	52.99	1.97
30	30	10	3.47	7.47	22.73	8.74	55.61	1.98
20	40	10	3.49	9.32	21.83	12.87	50.02	2.48
10	30	10	4.41	8.40	21.07	5.88	58.77	1.48

X_1-X_3 are processing variables which represent flour blends (CYF-BSG), baking time, and mixing time, respectively; Y_1-Y_6 are moisture, protein, crude fat, crude fibre, carbohydrates, and ash, respectively.

Table 4. Coefficients of regression with respect to process variables for the proximate composition of the biscuits

Coeff.	Y_1	Y_2	Y_3	Y_4	Y_5	Y_6
X_1	0.86*	1.40*	-0.74	2.86*	-5.01*	0.62*
X_2	0.018	0.21	-0.19	-0.49	0.33	0.12
X_3	-0.31	0.21	-0.27	0.92	-0.55	0.0005
X_1X_1	0.38	0.22	0.29	-0.70	-0.43	0.24
X_2X_2	-0.72*	-0.47	1.63*	0.67	-1.10	-0.015
X_3X_3	0.094	-0.73*	1.00	-0.57	0.22	-0.015
X_1X_2	-0.31	-0.16	0.62	0.95	-0.74	-0.36
X_1X_3	-0.58	0.30	-0.08	1.13	-0.66	-0.11
$X_2 X_3$	0.11	-0.90*	0.34	-0.48	1.05	-0.13
β_0	3.87	8.19	20.04	9.79	56.23	1.88
MODEL SUMMARY STATISTICS						
R^2	0.8107	0.9186	0.7781	0.6959	0.8002	0.8388
F-Value	7.85*	37.93	0.47	0.24	1.54	0.22
SD	0.61	0.55	0.99	2.36	2.79	0.33

*indicates significant values (p<0.05); β_0 is intercept; X_1-X_2X_3 are regression coefficients; Y_1-Y_6 are moisture, protein, crude fat, crude fibre, carbohydrates, and ash, respectively. SD = Standard Deviation; R^2 = Prediction Ability; F-value = Lack of fit (the model requires a non-significant F-Value)

Proximate composition of the biscuit samples

Tables 3 and 4 show the results of the proximate composition of the biscuit samples and the corresponding regression coefficients, respectively. Figs. 3-8 are the contour plots for each of the proximate responses. The negative sign shows the direction in which the response is increasing or decreasing. A linear behaviour was observed from the contour plot (Fig. 1), with an increase in moisture content of the biscuit as the substitution of brewer's spent grain increased. The

moisture loss during baking increased with baking time, while a quadratic effect was shown with the mixing time. The statistical analysis of the proximate composition (Table 4) revealed that the independent variables had a significant effect (*p*<0. 05) on the moisture content of the biscuits. Thus, a reduction in moisture to 2.78 - 6.67 % (biscuit) as the baking time increased at the constant baking temperature of 160 °C was as expected. The moisture content is within the range (<12%) that can inhibit microbial or enzymatic activity, which can enhance spoilage and impair shelf stability (Omohinmi et al., 2013). The model developed for predicting the biscuit moisture content could explain the 81.07% goodness of the model with a significant lack of fit of 7.85.

The contour plot for protein content, Fig. 2, showed a direct proportionality with a remarkable increase in protein content as the level of BSG, mixing, and baking time increased. Statistical analysis (Table 4) showed that the crude protein content of the biscuits was significantly affected (p<0.05) by the BSG substitution, the quadratic effect of baking time, as well as the interactive effect of mixing and baking time. The increment could be attributed majorly to brewer's spent grain's high protein content, which is similar to the claim by Sobukola et al. (2012). Consequently, the effect of mechanical shearing during mixing could also be a factor in making more protein available, due to the exposure and the breakdown of bound protein in the dough matrix in response to the shearing effect. The role of baking temperature is another crucial factor in the protein increment. The regression model for protein explained the 91.86% goodness of the model with a non-significant lack of fit of 37.93.

The response contour plot (Fig. 3) showed a quadratic effect of mixing time on the crude fat content of the samples. Initially, it showed a decrease in the crude fat as mixing time increased, which later increased. The observed increase could be attributed to the degree of exposure of both the damaged starch granules and the denatured protein (due to the shearing effect during mixing) to oil absorption during mixing, the entrapment of which was eased by the melting action of the generated heat. This was explained by Contamine et al. (1995) with three hypotheses. First, that the fat was physically trapped by the newly formed network in the dough during mixing. Second is the possibility of a strong interaction between the fat and other flour constituents such as protein. Lastly, the formed fat emulsion may appear as small drops in a more or less continuous state composing of water, protein, and starch. Similarly, samples with a high level of brewer's spent grain substitution were observed to record the highest crude fat content. This could be attributed to the affinity of starch granules of the cocoyam flour which is low in fat content. Also, the crude fat content was only significantly affected (p<0.05) by mixing time, as shown in Table 4. The regression model for crude fat indicated goodness, R^2 value of 77.81%, with a non-significant lack of fit of 0.47.

The response surface plot (Fig. 4) showed a linear and direct proportionality with the increase in crude fibre as the brewer's spent grain level increased. As shown in the statistical analysis result, only the brewer's spent grain has a significant effect (p<0.05) on the crude fibre of the biscuits. The increase in the fibre content of the biscuits could be attributed to a high composition of cellulose, hemicelluloses, and lignin content of the brewer's spent grain. Also, the alteration in the fibre structures with a possible transition in form from insoluble to soluble dietary fibre, the development of enzyme-resistant indigestible glucans formed by trans-glycosidation, and the formation of resistant starch (Omohimi et al., 2013) might also be factors for the fibre increment. The developed regression model showed a goodness of 69.59%, an indication of variability accounted for, and a non-significant lack of fit of 0.24.
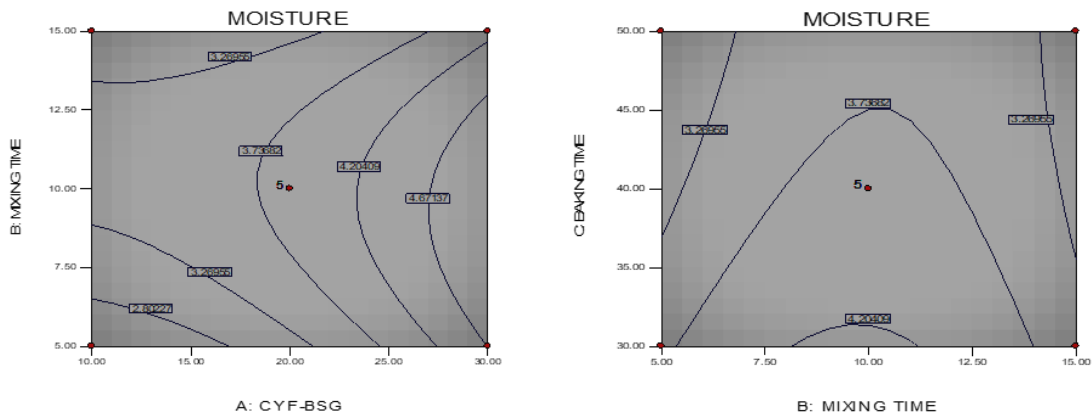
Fig. 1. Response surface and contour plots of moisture content as affected by flour blends, mixing time, and baking time
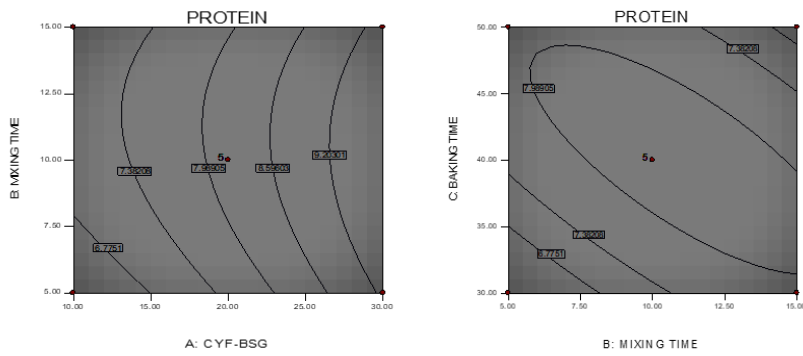

Fig. 2. Response surface and contour plots of crude protein as affected by flour blends, baking time, and mixing time
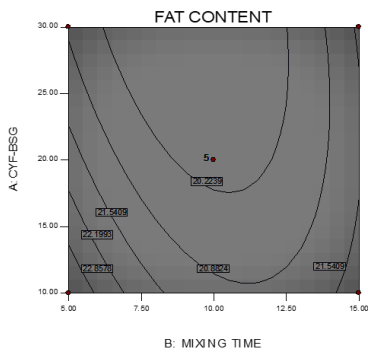

Fig. 3. Response surface and contour plots of crude fat as affected by flour blends and mixing time
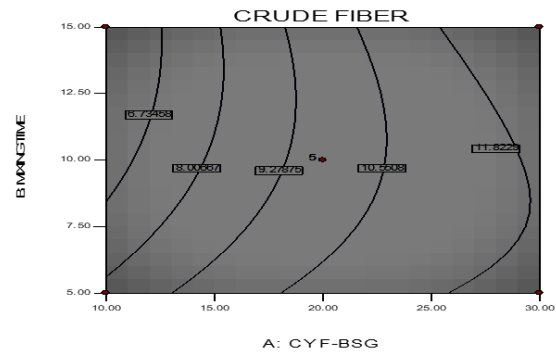

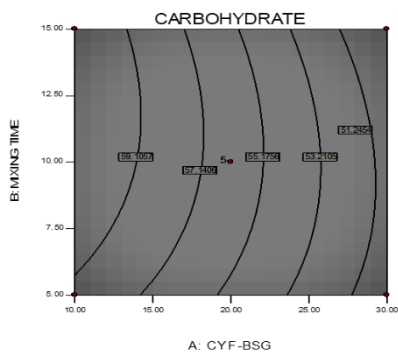**Fig. 4.** Response surface and contour plots of crude fibre as affected by flour blends and mixing time

Fig. 5. Response surface and contour plots of carbohydrates as affected by flour blends and mixing time
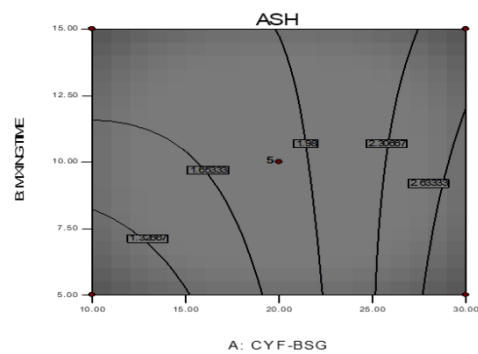

Fig. 6. Response surface and contour plots of ash as affected by flour blends and mixing time

The response surface plot (Fig. 5) revealed an inverse proportionality with the carbohydrate content decreasing as brewer's spent grain substitution increased. A similar trend was reported by Sobukola et al. (2012), who studied the effect of brewer's spent grain addition on the properties of extruded yam starch-based pasta. The displacement by non-starchy brewer's spent grain of some of the starch portion of the cocoyam flour in the blends may have resulted by the observed trend. The cocoyam flour supplied the major carbohydrate, confirming it as a good source of carbohydrates and an energy yielding staple. The proximate composition of brewer's spent grain (Table 2) even indicated that it is low in starch content, as the majority of the starches have been solubilized and digested during the mashing operation. Wang et al., (1993) also reported that this could also be a result of incomplete starch gelatinization due to heat during baking, the fragmentation of which favours dextrination and may also influence carbohydrate availability. However, the few available carbohydrates can be traced to the effect of mechanical shearing during mixing, which brings about the breaking of the bonds binding some carbohydrate materials within the matrix, making hitherto unavailable carbohydrates available (Omohimi et al., 2013). The statistical analysis showed that only BSG had a significant effect ($p<0.05$) on the carbohydrate content of the samples. The developed model gave a goodness of 80.02% and a non-significant lack of fit of 1.54.

From the response contour plot (Fig. 6), a linear and direct proportionality between the ash content and the brewer's spent grain was observed. Ash content increased as the BSG substitution increased, a similar observation was made by Ainsworth et al. (2007) and Sobukola et al. (2012). This reflects the presence of a large amount of inorganic elements in the brewer's spent grain. The statistical analysis showed that the ash content of the biscuit samples was significantly affected ($p<0.05$) by the BSG substitution in the flour blends, as shown in the regression result. The regression model described the ash content with 83.88% goodness, R^2 and, a non-significant lack of fit of 0.22.

Physical Properties

Colour is an essential indicator of quality in food processing that reflects both the degree of chemical reactions and the degradation. The regression coefficient (Table 6) showed, unexpectedly, that none of the samples were significantly ($p<0.05$) affected by any model term.

Table 5. Response surface results for the physical properties of the biscuits

X_1	X_2	X_3	Y_7	Y_8	Y_9
30	40	15	27.42	23.67	5.49
20	40	10	26.15	28.70	5.38
20	50	15	17.49	21.53	5.43
10	40	5	26.13	20.90	5.04
20	30	15	17.48	25.83	5.12
10	40	15	15.55	24.10	4.84
30	40	5	17.13	21.90	4.95
20	40	10	39.69	20.70	5.30
20	50	5	7.57	19.80	5.70
30	50	10	8.35	34.43	5.42
20	30	5	28.70	30.57	5.24
20	40	10	17.37	22.54	5.06
10	50	10	17.48	25.83	5.12
20	40	10	29.76	30.77	5.49
30	30	10	5.32	16.43	5.99
20	40	10	17.78	24.17	5.65
10	30	10	17.81	20.27	4.88

X_1- X_3 are processing variables which represent flour blends (CYF-BSG), baking time, and mixing time, respectively; $Y_7 - Y_9$ are product responses for the runs which are colour, texture, spread ratio.

Table 6. Coefficients of regression with respect to the process variables for the physical properties of the biscuits

Factors	Y7	Y8	Y9
X1	-6.47	1.63	0.20*
X_2	-1.91	-1.94	0.046
X_3	5.59	2.93*	-0.15
X_1X_1	2.92	1.67	0.048

Table 6. Continued...

X_2X_2	-2.45	2.89	0.15
X_3X_3	4.44	-2.35	0.19
X_1X_2	-0.54	-4.73*	-0.015
X_1X_3	1.26	2.28	-0.15
$X_2 X_3$	1.97	0.14	-0.29*
B_0	17.53	23.20	5.12

MODEL SUMMARY STATISTICS

R^2	0.6202	0.8592	0.7683
F-Value	5762.43*	1.23	1.76
SD	8.26	2.65	0.23

*indicates significant values ($p<0.05$); β_0 is intercept; X_1-X_3 are regression coefficients; Y_7-Y_9 are colour, texture, spread ratio. SD = Standard deviation, R^2= Prediction ability; F-value = Lack of fit (the model requires a non-significant F-Value)

But a close observation of the response surface plots (Fig. 7) reflected an inverse relationship of the colour with the brewer's spent grain level; colour was found decreasing as the BSG substitution increased, i.e. the lightness of the biscuit decreases as the brewer's spent grain substitution increases, a similar trend was observed by Ajanaku et al. (2011). More so, Ghiassi et al., (2011) established that the higher the ΔE^* value, the lower the colour quality for the sample. Thus, the sample with high colour intensity (high value) could be accrued to the occurrence of the Maillard reaction (Non-enzymatic browning), which was a result of the reaction between amino acids (protein) and reducing sugar at the 160 °C baking temperature; caramelization of sugar, and the dextrination of starch. Another factor for the increasing colour intensity (decreasing lightness) is the burning effect on the sample surface as the baking time increases. The regression model described the model with 62.02% goodness and a significant lack of fit of 5762.43.

According to the response surface plots, (Fig. 8), the texture increased with increased brewer's spent grain substitution, while mixing time showed a slight decreasing effect. This implied that the brewer's spent grain substitution imparted a more significant hardening effect on the biscuits, thereby requiring higher force to break. Consequently, the possibility of high aeration during mixing, which was retained in the matrix, as noted by Jissy and Leelavathi (2006), might also be responsible for the sparing decreasing effect of mixing time on the texture of the biscuits. The authors added that Hornstein et al. (1943) claimed that the consistency of the worked dough has a high significant effect on the texture of the cookies.
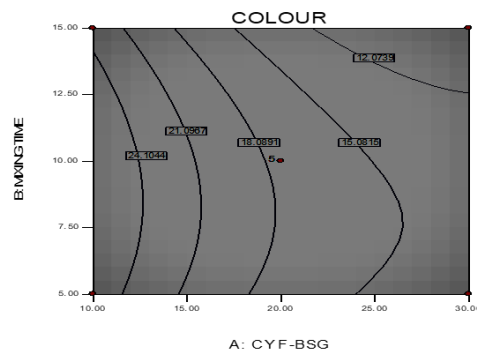

Fig. 7. Response surface and contour plots for colour as affected by flour blends and mixing time
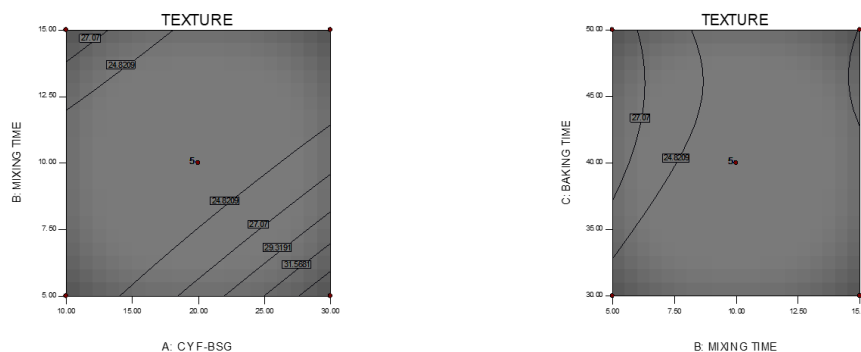

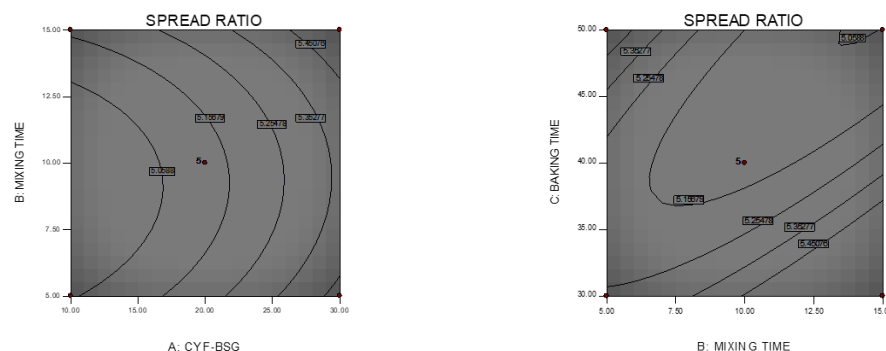**Fig. 8.** Response surface and contour plots of texture as affected by flour blends and mixing time

Fig. 9. Response surface and contour plots of the spread ratio as affected
by flour blends and mixing time

The plot also revealed an increasing trend in the texture with the increase in baking time. This could be characterized by the development of the protein matrix and starch gelatinization with available moisture in the matrix and/or plasticization of protein and starch which causes the formation of crust on the biscuit surface as moisture is lost. It is also worth noting that the biscuit texture may vary within the same mass body due to uneven moisture spread, especially in a conventional oven. The statistical results showed that baking time, the interactive effect of flour blends, and mixing time had a significant effect ($p < 0.05$) on the texture of the samples. The regression coefficient model for the breaking force gave a goodness of 85.82% and a non-significant lack of fit of 1.23.

The regression coefficient (Table 6) showed that the spread ratio was significantly affected ($p < 0.05$) by flour blends, mixing, and baking time. The response surface plot (Fig. 9) showed a decrease in the spread ratio with the increase in brewer's spent grain substitution. This showed that as substitution increased, the spread ratio decreased, a behaviour that is attributable to the degree of viscosity of the dough. This revealed that the dough viscosity increased with the further addition of brewer's spent grain, which therefore induced the inverse response in the spread ratio. Abu-Salem and Abou-Arab (2011) also reported a similar trend, proving that composite flours form aggregates which increase the number of hydrophilic ends found within the starches and proteins, thereby increasing the competition for limited free water in cookie dough. Starch granules and polymer molecules were strongly bonded together and swelling was limited. As such, gradual moisture removal as baking proceeds might make the water in the mass inadequate to dissolve sugar during baking, and the polymers cooling rapidly form large molecular aggregates as gel (Awan et al., 1991; Abu-Salem and Abou-Arab, 2011). Interactive effects of baking time reflected a sparing increase in the spread ratio, while a sharp

increase in the spread ratio was observed with the increase in mixing time. This is accruable to mechanical effects of mixing on protein network development, which is majorly responsible for the viscoelastic behaviour of the dough. Despite that, the dough obtained was gluten free, but the mixing was able to provide a sufficiently extensible and easy-to-cheat dough. Such non-elastic dough prevented the dough from retracting after cutting. Contamine et al. (1995) added that the absence of retraction is considered a good quality for biscuits, as it determines the potential of the biscuits for packaging. Also, during baking, spreading was minimal and limited, a major reason for the non-sharp effect of baking time on the spread ratio. The regression model indicated a goodness of 76.83% with a non-significant of 1.76.

Optimization

In terms of all the studied quality attributes, the numerical optimum conditions based on the desirability function (65.29) are: BSG substitution of 25.24, mixing time of 13.54 minutes, and baking time of 33.14 minutes, at 160 °C baking temperature.

Conclusion

The proximate composition and physical properties of the product were observed to be affected by each of the independent variables that were studied, except for the colour, which showed no effect on any of the variables. However, in terms of all the studied quality attributes, the numerical optimum conditions based on the desirability concept (65.29) are: BSG substitution of 25.24, mixing time of 13.54 minutes, and baking time of 33.14 minutes, at 160 °C baking temperature.

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