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# Optimization of proximate composition and functional properties of composite flours consisting wheat, cocoyam *(Colocasia esculenta)* and bambara groundnut *(Vigna subterranea)*

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**Abstract**

Optimization of the production of composite flour from wheat, cocoyam and bambara groundnut flours using optimal mixture design of response surface methodology was carried out. The responses were the proximate and functional properties. From the result, the optimized composite flour defined as the blend with overall best proximate composition and functional properties consisted 60% wheat flour, 30% cocoyam flour and 10% bambara groundnut flour. This optimized blend had 387.91Kcal/100g energy value, 0.759 g/ml bulk density, 2.4 g/g water absorption capacity, 01.842 g/g oil absorption capacity, 1.26 swelling index, 10% least gelation and 40% emulsion capacity. Statistical analysis showed that the models as well as the linear, quadratic and cubic model terms were significant (P≤ 0.05) for bulk density, water absorption, oil absorption capacity, crude fibre, moisture content, carbohydrate and fat content while only linear and cubic model terms were significant (P≤ 0.05) for protein and ash contents respectively. In conclusion, composite flour from bambara groundnut, cocoyam and wheat flour have acceptable proximate and functional properties which suggests the suitability of the composite flour in terms of nutritional and functional qualities necessary for the production of enriched gluten-free food products.



## Introduction

In Nigeria, ready-to-eat baked products (snacks) consumption is on the rise depending solely on imported wheat (Akpapunam *et al.*, 1999). Researches centred on production of composite flour with wheat flour supplemented with locally sourced food materials like cereals, tubers and legumes are on the increase (Ayo and Gaffa, 2002; Olaoye *et al*., 2006; Awolu *et al*., 2015). Composite flours without wheat, consisting combinations of appropriate cereals, tubers and legumes have also been developed (Awolu *et al*., 2015; Omoba *et al*., 2013). Development of composite flours were meant to reduce dependency on importation of wheat and also to develop gluten-free food products suitable gluten-intolerant people. In this regard, ready-to-eat for extruded snack consisting rice, cassava and kersting's groundnut flour was developed (Awolu *et al*., 2015) while Omoba *et al.* (2013) evaluated brewers' spent grain-plantain composite flour and cookies. The results of the researches showed that substitution of wheat partially or fully with some other locally available crops produced composite flour with acceptable physicochemical and rheological properties.

Cocoyam is one of the most valuable root crops in Nigeria, and the second most valuable in West Africa. Although it is less important than other tropical roots such as yam, cassava and sweet potato, it is still a major staple in some parts of the tropics and sub-tropics (Ojinaka *et al.*, 2009). Cocoyam is rich in digestive starch, good quality protein, vitamin C, thiamine, riboflavin, niacin and high scores of protein and essential amino acids (Onayemi and Nwigwe, 1987; Lewu *et al*., 2009).

Bambara groundnut is of prime importance in human and animal nutrition due to its high protein content (20% – 50%). It is an important source of cheap protein in many African countries where animal protein is expensive (Brough *et al*., 1993). Bambara is a good source of fibre, calcium, iron and potassium; unusually high in methionine. The seed of bambara groundnut have been found to be useful for baby food, human consumption, industrial products and for animal feed (Akani *et al*., 2000).

Major characteristics of food materials to be used in composite flour blends are; they should be readily available, culturally acceptable and provide necessary nutritional requirements (Akobundu *et al*., 1998). Idowu *et al.* (1996) studied the use of cocoyam flour as composite with wheat flour in biscuit production. Also, biscuits with high sensory ratings have been produced from blends of wheat and fonio (McWatters *et al*., 2003); cocoyam and pigeon

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Table 1. Composite flour obtained from the optimal mixture model of RSM

| Run | Wheat flour (g/100g) | Cocoyam flour (g/100g) | Bambara flour (g/100g) |
|---|---|---|---|
| 1 | 50 | 40 | 10 |
| 2 | 85 | 10 | 5 |
| 3 | 52.5 | 40 | 7.5 |
| 4 | 76.25 | 17.5 | 6.25 |
| 5 | 55 | 40 | 5 |
| 6 | 50 | 40 | 10 |
| 7 | 60 | 30 | 10 |
| 8 | 85 | 10 | 5 |
| 9 | 65 | 30 | 5 |
| 10 | 52.5 | 40 | 7.5 |
| 11 | 70 | 20 | 10 |
| 12 | 80 | 10 | 10 |
| 13 | 61.25 | 32.5 | 6.25 |
| 14 | 80 | 10 | 10 |
| 15 | 65 | 25 | 10 |
| 16 | 55 | 40 | 5 |

pea (Okpala and Chinyelu, 2011). This study will optimize the production of composite flours from wheat, cocoyam and bambara groundnut flours. The proximate and functional properties of the composite flour will be evaluated in order to access its nutritional and functional quality.

## Materials and Methods

*Materials*

Whole wheat flour, cocoyam tubers and bambara groundnut were purchased from local market in Akure, Ondo state, Nigeria.

*Experimental design*

Optimal mixture design of Response Surface Methodology (RSM) was used for the experimental design. This generated which generated 16 experimental runs (Table 1). The independent variables were cocoyam, bambara groundnut and wheat flours while the responses were functional properties (bulk density, water absorption capacity, oil absorption capacity, swelling index, swelling capacity, least gelation, emulsion capacity) and the proximate composition (moisture, protein, fat, carbohydrates, ash and fibre contents).

*Production of cocoyam flour*

The method of Rita and Sophia (2010) was used. Cocoyam tubers (700 g) were washed in sulphated water five times until all debris was removed. The tubers were manually peeled; each tuber was cut into 5 vertical dices in order to increase the surface area for quick and complete drying. The diced cocoyam were oven-dried at 65$^o$C, and later milled using hammer mill, cooled, sieved and stored at room temperature for further processing

*Production of bambara groundnut flour*

Bambara groundnut (250 g) was soaked in clean water for 24 h, dehulled and the chaffs removed from the seed. The dehulled seeds were then oven-dried at 65$^o$C and dry-milled to fine powder. The flour was later stored under a cool, dry air.

*Preparation of composite flour*

Composite flour comprising wheat, cocoyam and bambara groundnut flours were prepared based on the combination obtained from the experimental design as shown in Table 1.

*Proximate analysis of the composite Flour*

This was carried out using Association of Official Analytical Chemists (AOAC, 1995) methods in order to determine the percentages of moisture contents, protein, crude fibre, fat and carbohydrate in the composite flour.

*Bulk density (BD)*

Bulk density was estimated by method described by Maninder *et al*., (2007). The flour samples were gently filled into 10 ml graduated cylinders. The bottom of each cylinder was tapped gently on a laboratory bench several times until diminution of the sample level ceases after filling to the 10 ml mark. Bulk density was then calculated as weight per unit volume of sample (g/ml) as given in Eq. (1)

$$Bulk\ density = \frac{weight\,of\ sample}{volume\,of\ sample} \quad (1)$$

*Water absorption capacity (WAC)*

Water absorption capacity was determined using the procedure of Sathe *et al*., (1982a). One gram of the sample was mixed with 10 ml distilled water for 5 min on a magnetic stirrer. The mixture was centrifuged at 3500 rpm for 30 min and the volume of the supernatant noted. WAC was calculated using Eq. (2)

$$WAC = \frac{volume\ of\ distilled\ water \times 100}{weight\ of\ sample\ used} \quad (2)$$

*Oil absorption capacity (OAC)*

One gram of sample was weighed, 10 ml of vegetable oil of a known density (0.99 mg/ml) was added to the sample and the mixture stirred on a magnetic stirrer at 1000 rpm for 5 min. The mixture was centrifuged at 3500 rpm for 30 min and the supernatant removed and measured with 10 ml measuring cylinder (Sathe and Salunkhe, 1982). The OAC was calculated using Eq. (3)

$$OAC = \frac{volume\ of\ oil\ absorbed \times density \times 100}{weight\ of\ sample\ used} \quad (3)$$

*Gelation properties*

Gelation properties of composite flour were evaluated using the method of Sathe *et al*, (1982b). Test tubes containing suspensions of 2%, 4%, 6%, 8%, 10%, 12%, 14%,16%, 18% and 20% (w/v) of the composite flour in distilled water were heated for 1 h in boiling water, followed by rapid cooling under cold running water. The tubes were cooled further at 40$^o$C for 2 h. The least gelation concentration (LGC) was taken as period the sample inside the inverted tube did not fall.

*Swelling index*

This was determined as the ratio of the swollen volume to the ordinary volume of a unit weight of the flour. The method of Abbey and Ibeh (1988) was used. One gram of the sample was weighed into a clean dry measuring cylinder. The volume occupied by the sample was recorded before 5 ml of distilled water was added to the sample. This was left to stand undisturbed for an hour, after which the volume was observed and recorded again. The index of swelling ability of the sample was calculated using Eq. (4).

$$Swelling\ index = \frac{weight\ occupied\ by\ sample\ after\ swelling}{volume\ occupied\ by\ sample\ before\ swelling} \quad (4)$$

*Statistical analysis*

The data obtained were analyzed using the Design-Expert software (Trial version 8.0.3.1, Stat-Ease Inc., Minneapolis, USA). In order to correlate the response variable to the independent variables, multiple regressions was used to fit the coefficient of the polynomial model of the response. The quality of the fit of the model was evaluated using analysis of variance (ANOVA).

## Results and Discussion

*Proximate composition of composite flour (wheat, cocoyam and bambara groundnut flour)*

The result of the proximate composition of composite flour is presented in Table 2. The moisture content of composite flour ranged from 10.555 to 12.515 g/100g. The crude protein ranged from 10.680 to 13.920 g/100g. Complementing the composite flour with bambara groundnut flour improved the protein value of the composite flour. This was also observed by Amandikwa (2012).The crude fat ranged from 4.435 to 8.795 g/100g, the ash content ranged from 0.795 to 2.400 g/100g, the crude fibre ranged from 0.345 to 0.860 g/100g while the carbohydrates ranged from 64.630 to 71.315 g/100g. The energy value ranged from 367.89 Kcal/100g to 387.91 Kcal/100g. The result showed that the proximate composition of the composite flour is better than the value obtained for either 100% wheat flour or cocoyam flour.

The contribution of bambara groundnut to protein (CHON) was very high. This justified the addition of bambara groundnut to the composite flour which was intended to improve the protein content. The result of the ANOVA showed that the model (quadratic) and model terms (linear mixture, AB, $A^2BC$, $AB^2C$, $ABC^2$) were all significant (p≤0.05). The final equation is shown Eq. (5)

$$Protein = +13.69A + 12.10B + 89.20C - 6.47AB - 94.81AC - 101.37BC + 348.75A^2BC + 643.63AB^2C - 2353.80ABC^2 \quad (5)$$

Wheat and cassava flours contributed more than bambara groundnut flour to the fibre content. As the amount of wheat and cassava decreases, the fibre content also decreased. The ANOVA showed that the model, linear mixture and the entire model terms except AB were significant (p≤0.05). The final equation is given in Eq. (6)

$$Fibre = +0.73A + 0.59B + 5711.24C + 0.12AB - 9067.72AC - 9225.75BC + 6954.73ABC + 3.16AB(A-B) + 3364.91AC(A-C) + 3587.67BC(B-C) \quad (6)$$

*Functional properties of composite flour (wheat, cocoyam and bambara groundnut flour)*

The 3D plot showing the effect of wheat flour, cocoyam flour and bambara flour on bulk density (BD) is shown in Figure 1. Wheat and cocoyam flours increased the bulk density of the composite

Table 2. Proximate composition (g/100g) and energy value of composite flour comprising wheat, cocoyam and bambara groundnut

| S/N | A | B | C | MC | CHO | Protein | Fat | Ash | Fibre | Energy |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 50 | 40 | 10 | 10.745 | 71.315 | 10.68 | 4.435 | 2.325 | 0.5 | 367.89 |
| 2 | 85 | 10 | 5 | 11.43 | 65.475 | 13.67 | 6.92 | 1.78 | 0.725 | 378.86 |
| 3 | 52.5 | 40 | 7.5 | 10.555 | 70.84 | 12.405 | 5.155 | 0.795 | 0.25 | 379.38 |
| 4 | 76.25 | 17.5 | 6.25 | 11.63 | 64.785 | 13.64 | 7.595 | 1.705 | 0.645 | 382.06 |
| 5 | 55 | 40 | 5 | 10.99 | 67.545 | 11.57 | 7.15 | 2.4 | 0.345 | 380.81 |
| 6 | 50 | 40 | 10 | 10.745 | 71.315 | 10.68 | 4.435 | 2.325 | 0.5 | 367.89 |
| 7 | 60 | 30 | 10 | 10.605 | 64.63 | 13.92 | 8.19 | 2.185 | 0.47 | 387.91 |
| 8 | 85 | 10 | 5 | 11.43 | 65.475 | 13.67 | 6.92 | 1.78 | 0.725 | 378.86 |
| 9 | 65 | 30 | 5 | 11.585 | 65.75 | 11.16 | 8.795 | 2.145 | 0.565 | 386.79 |
| 10 | 52.5 | 40 | 7.5 | 10.555 | 70.84 | 12.405 | 5.155 | 0.795 | 0.25 | 379.38 |
| 11 | 70 | 20 | 10 | 12 | 67.135 | 12.565 | 5.62 | 1.92 | 0.76 | 369.38 |
| 12 | 80 | 10 | 10 | 12.515 | 64.955 | 12.845 | 7.24 | 1.96 | 0.485 | 376.36 |
| 13 | 61.25 | 32.5 | 6.25 | 11.57 | 65.685 | 13.78 | 6.685 | 1.42 | 0.86 | 378.03 |
| 14 | 80 | 10 | 10 | 12.515 | 64.955 | 12.845 | 7.24 | 1.96 | 0.485 | 376.36 |
| 15 | 65 | 25 | 10 | 11.58 | 65.955 | 12.16 | 7.81 | 2.01 | 0.485 | 382.75 |
| 16 | 55 | 40 | 5 | 10.99 | 67.545 | 11.57 | 7.15 | 2.4 | 0.345 | 380.81 |

*A (Wheat flour); B (Cocoyam flour); C (Bambara groundnut flour); MC (Moisture content)

flour. Bulk density is a function of particle size as particle size is inversely proportional to bulk density (Onimawo and Akubor, 2012). It has been reported that bulk density is influenced by the structure of the starch polymers and loose structure of the starch polymers could result in low bulk density (Malomo *et al*., 2012). Bambara, being proteinous in nature does not significantly contribute to bulk density. Higher bulk density is desirable for greater ease of dispersibility and reduction of paste thickness (Amandikwa, 2012) while low bulk density of flour is a good physical attribute when determining transportation and storability. The analysis of variance (ANOVA) indicated that the model and model terms (linear mixture, AB, AC, BBC, ABC, AC(A-C) and BC(B-C) were all significant (p≤0.05). The final equation expressing the relationship of the term coefficients with the bulk density is shown in Eq. (7).

$$BD = +0.78A + 0.65B + 1439.18C + 0.098AB - 2277.55AC - 2328.21BC + 1750.97ABC + 0.40AB(A-B) + 839.94AC(A-C) + 910.88BC(B-C) \quad (7)$$

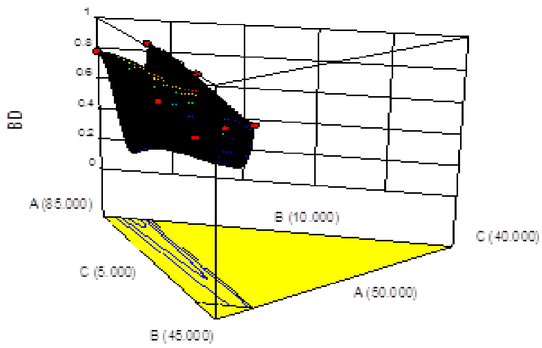
The effect of the composite flours on the water absorption capacities is shown in Figure 2. As bambara groundnut content increases, WAC decreases. This conforms to the work of Malomo *et al.* (2012) where the WAC decreases with increasing protein content. The effect of wheat and cassava flours showed that WAC increases with increased wheat and cassava flours, and vice versa. Water absorption characteristic represents the ability of the product to associate with water under conditions when water is limiting such as dough and pastes. Water absorption capacity is important in the development of ready to eat foods. It has been observed that a high absorption capacity assure product cohesiveness (Houson and Ayenor, 2002). Niba *et al*. (2001) also reported that water absorption capacity is important in bulking and consistency of products as well as baking applications.

The ANOVA result showed that the model and model terms (linear, quadratic and cubic) were all significant (p≤0.05) except AB. The final equation is shown in Eq. (8).

$$WAC = +2.00A + 1.19B - 14734.17C + 0.54AB + 23359.89AC + 23856.42BC - 17971.59ABC - 9.47AB(A-B) - 8644.91AC(A-C) - 9321.26BC(B-C) \quad (8)$$

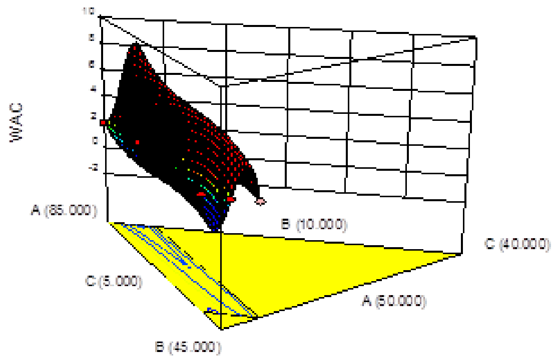
The 3D plot showing the effect of the composite flours on the oil absorption capacities (Figure 3) showed that wheat had highest effect on the OAC. The OAC decreases as the wheat content decreases. The effect of cocoyam on the OAC is next to that of wheat. The contribution of bambara groundnut flour on OAC was the least. Oil absorption capacity is attributed mainly to the physical entrapment of oils. It is an indication of the rate at which protein binds to fat in food formulations (Onimawo and Akubor, 2012). Oil absorption capacity is useful in formulation of foods such as sausages and bakery products. Fat acts a flavour retainer and increases the mouth feel of foods. Fat increases the leavening power of the baking powder in the batter and improves the texture of the baked product.

The ANOVA result showed that the model and model terms (linear mixture, AC and BC) were significant (p≤0.05) except AB. The final equation is



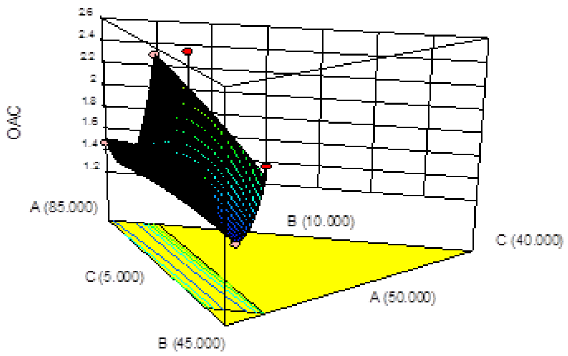

*A (Wheat flour); B (Cocoyam flour); C (Bambara groundnut flour); BD (Bulk density)

Figure 1. 3D plot showing the effect of composite flours on bulk density




*A (Wheat flour); B (Cocoyam flour); C (Bambara groundnut flour); WAC (Water absorption capacity)

Figure 2. 3D plot showing the effect of composite flours on water absorption capacities




*A (Wheat flour); B (Cocoyam flour); C (Bambara groundnut flour); OAC (Oil absorption capacity)

Figure 3. 3D plot showing the effect of the composite flours on oil absorption capacities

shown in Eq. (9)

$$OAC = +1.51A + 1.93B + 101.06C + 0.19AB - 109.59AC - 116.31BC \quad (9)$$

The emulsion characteristic (EC) of proteins contributes much to their functionality in foods. Soluble proteins are surface active and promote formation of oil-in-water emulsion (Onimawo and Akubor, 2012). The result showed that EC was high when wheat and cocoyam levels were high but low bambara groundnut contents and vice versa. The result of the ANOVA showed that the model and model terms (linear mixture and AB) were significant ($p \leq 0.05$). The $R^2$ and Adj. $R^2$ values were 0.8412 and 0.7610 respectively. The final equation is given in Eq. (10).

$$EC = +4.00A + 0.94B + 18674.44C - 2.55AB - 30059.74AC - 30337.74BC + 23630.2ABC - 10.72AB(A-B) + 11577.51AC(A-C) + 11996.76(B-C) \quad (10)$$

The least gelation concentration (LCG) varies for different flours. Sathe *et al*. (1982) associated the variations in the gelling properties of different flours to the different ratios of protein, carbohydrate and lipids that make up the flours. Interaction among these components played a significant role in functional properties as it affects gelation. High values of least gelation were obtained when the variables were either high or low. At intermediate (mean) values, the least gelation was low. The result of the ANOVA showed that the model (quadratic) and model terms (linear mixture, AB, AC, and BC) were significant ($p \leq 0.05$). The $R^2$ and Adj. $R^2$ values were 0.9699 and 0.9355 respectively. The final equation is given in Eq. (11).

$$LCG = +42.67A + 50.26B + 256.90C - 39.38AC - 167.29BC \quad (11)$$

Swelling index (SI) and swelling capacity (SC) are functions of loose particles. Generally cocoyam samples displays good swelling index when compared to other root crops like cassava (Ojinaka *et al*., 2009). The starch grain of cocoyam is about one tenth of potato starch grain.

Bambara groundnut flour contributes most to solubility index more than wheat and cassava flours. As bambara groundnut increases, the solubility index decreases and vice versa. The ANOVA result for solubility index showed that model and model terms ($A^2BC$, $AB^2C$, $ABC^2$) were significant ($p \leq 0.05$).

Maximum values of swelling capacity were obtained at the maximum and minimum values of the composite flours. At mean (intermediate) values the swelling capacity was minimum. The ANOVA showed that the model and model terms (AC, BC, AC(A-C), BC(B-C)) were significant ($p \leq 0.05$). The $R^2$ and Adj. $R^2$ values of swelling capacity were 0.9400 and 0.8500 respectively. The final equations for solubility index (SI) and solubility complex (SC) are shown in equations 12 and 13 respectively.

$$SI = +1.26A + 1.17B + 3.74C - 0.47AB - 3.63AC - 2.70BC + 48.83A^2BC + 58.96AB^2C - 291.92ABC^2 \quad (12)$$

$$SC = +12.06A + 8.27B + 433.67C + 8.99AB - 492.08AC - 449.32BC - 249.19A^2BC - 391{,}18AB^2C + 403.60ABC^2 \quad (13)$$

## Conclusion

The composite flour consisting wheat, cocoyam and bambara groundnut flours possessed good protein and fibre contents. Wheat had positive effect on the protein while cocoyam had positive effect on the ash content. The presence of bambara groundnut enhanced the water absorption capacity. Higher bambara groundnut flour also reduced the bulk density of the composite flour, In general the composite flour showed good proximate and functional properties.

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