Quality Evaluation of Cookies Produced from Yellow Root Cassava and Bambara Groundnut Flour Blends

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ABSTRACT

Food-to-food fortification is a worthwhile approach for elevating the standard of nutrition of populations. This study evaluated the quality characteristics of cookies produced from blends (%) of yellow root cassava known as provitamin A cassava (PVAC) and Bambara groundnut (BG) flours (100:0, 80:20, 60:40, 40:60, 20:80 and 0:100). The formulated cookies were evaluated for physical properties, colour parameters, anti-nutritional factors, proximate, mineral, beta-carotene, sensory properties and in vitro protein digestibility using standard methods.

Moisture content of the enriched cookies (5.75-6.74%) was within permitted moisture level for cookies that will not encourage the growth of microorganisms. Increased substitution with BG flour resulted to increase in protein (3.46-16.33%), ash (2.64-4.26%), fat content (21.66-24.63%), and energy value (458.88-480.69 kcal/100g) respectively. Cookies with high beta-carotene content (47.06-91.39µg/100g) were produced as a result of incorporating PVAC flour to the composite flours. The mineral content of the cookies was shown to have decreased with increasing Bambara substitution for calcium and sodium whereas an increase with increasing Bambara substitution was recorded for magnesium, phosphorus, potassium, iron and zinc respectively. Physical properties of the cookies ranged from 8.31-9.02g weight, 4.08-4.53cm diameter, 0.54-0.68cm thickness, 6.04 - 8.46 spread ratio and 4.13-5.66kg breaking strength.

Anti-nutritional factors in the cookie samples were within acceptable limits. Sensory analysis revealed that PVAC60:BG40 was the limit for moderate acceptance based on organoleptic characteristics. In-vitro protein digestibility revealed that the enriched cookies are highly digestible (76.05-81.06%) and improved with increased Bambara flour substitution. This investigation showed that the production of cookies from PVAC and BG flours gave rise to products with improved nutrient composition, digestibility, sensory properties and permissible/safe antinutrient limit which can be optimized for value addition. It is inferred that the nutrient-rich cookies made in this study would help treat vitamin A deficiency, protein energy malnutrition, and other conditions linked to poor/under nutrition.

Keywords: Yellow root cassava; Bambara groundnut; Enriched cookies; Composite flour; Food-to-food fortification

INTRODUCTION

The restricted leisure time and longer work hours of the global lifestyle have boosted the need for ready-to-eat foods (1). In addition to being nutritionally superior and healthy, consumers desire snacks that taste, smell, and look appealing (2,3). The demand for ready-to-eat, convenient foods like biscuits, bread, cakes, chin-chin, cookies, and other pastry products has expanded as a result of the popularity of bakery goods (4).

Cookies are small flat, sweet baked foods that are often made using flour, eggs, sugar, and either butter, cooking oil, or fat (5). They are inexpensive, wholesome, ready-to-eat baked snacks that come in a variety of sizes and shapes (6). Cookies have gained popularity due to their inexpensive cost of production, convenience, long shelf life brought on by their low moisture content, and capacity to transport both essential and non-essential nutrients (7). Because they are widely accessible in nearby stores as ready-to-eat, affordable, practical, and delectable food goods, and also because of their creamy taste and low water activity which characterizes their extended shelf life, cookies are one of the most common baked items consumed by all age groups in numerous nations including Nigeria (8,9). Most bakery products are produced using wheat as their main component because it is a cereal well-known for its gluten content (10). However, a number of factors, including the negative economic impact of wheat importation on low- or non-wheat producing countries and the link between gluten sensitivity and wheat protein, have made it necessary to replace wheat with nutrient-dense locally grown crops like legumes, roots, and tubers (7).

Root and tuber crops such as cassava and yam are second to importance to cereals as a source of carbohydrates worldwide (11). Cassava is the second-most significant tropical root crop in West Africa (12,13). However, the flesh of cassava tubers is typically cream or white, and they do not have detectable levels of carotenoids (4).

Vitamin A continues to be an essential part of human nutrition, as it helps with eyesight, cell differentiation, the synthesis of glycoprotein, reproduction, and general growth and development. Vitamin A Deficiency (VAD) and the seriousness of the effects, prevention, and treatment have turned into a worldwide concern (4), since a population's health and development are seriously endangered by a shortage of these micronutrients, especially in developing nations (14). As a result, the creation and spread of varieties of yellow root cassava, also known as Pro-vitamin A cassava, would support ongoing VAD prevention efforts by providing vitamin A through a common food that people consume every day. Assessing different food forms made from these newly developed crops for potential value addition to boost better and widespread usage of the crop becomes a need since the pro-vitamin A (beta-carotene) content, would enhance the consumers' nutritional standing (4). Also, this will improve the availability of different vitamin A-based diets across the nation. Cookie being food with good fat content is a welcome option to consider utilization of provitamin A cassava with the aim of enhancing bioavailability as presumed by Hailu, (15) as one of the determinant factors that can affect the bioavailability and bioconversion of provitamin A carotenoids.

For more than 2 billion people worldwide, cassava root is a staple crop that provides the majority of their starch and energy needs (16,9) but is low in many other vital micronutrients, including proteins. The low protein content of cassava flour (CF) is one of the problems limiting its use in food production (17). In developing nations, malnutrition has long been characterized by low protein intake (18). Malnutrition and food insecurity increase a person's or a population's risk of contracting diseases. According to data, 22.8% of Nigeria's under-5 population suffers from severe stunting (19). Children who are undernourished cannot afford to learn effectively due to cognitive issues, vitamin shortages, stunting, and other long-term effects of previous under-nutrition (20). Food technologists are adjusting their focus to develop nutrient-rich products in response to rising demand for healthier diets. The simplest and most common way to make ready-to-eat food more nutrient dense is to fortify it with protein, vitamins, minerals, and other nutrients (21).

Food-to-food fortification (FtFF) is a cutting-edge method for regulating micronutrients using a food-based strategy. To increase the nutritional qualities of foods that are lacking in certain nutrients, the strategy involves adding foods that are high in micro- or macronutrients (22, 23). According to Honi (3), this idea of increasing the consumption of foods high in essential micronutrients is more or less a sustainable strategy to reduce under-nutrition. Fortification with flour rich in proteins and a measurable amount of vitamins and minerals is therefore necessary to improve the nutritional content of foods designed from cassava flour (17).

Bambara groundnut (*Vigna subterranea (L.) Verdc.*) is an underutilized African legume despite being Africa's third most significant legume after the common peanut/groundnut (*Arachis hypogaea*) and cowpea (*Vigna unguiculata*) (24). Undernourishment can be reduced by using Bambara groundnut, which is a source of protein, carbohydrates, lipids, and minerals like iron. It is easily accessible, yet underutilized and poorly advertised in both domestic and foreign markets (25).

One of the primary factors lowering the nutritional content of legumes is the low digestion of the protein they contain (26). Although pretreatments like boiling, germination, and soaking have been shown to enhance the protein digestibility of Bambara groundnut (27,26). Nwadi *et al*., (28) in a current review suggested investigation of the digestibility of products enriched with Bambara groundnut using in vivo and/or in vitro processes.

Composite flours, which are partly replaced with other natural nutritional elements (such as vitamins, minerals, proteins, dietary fiber, and antioxidants), have drawn the interest of manufacturers and consumers in recent years as a result of customers' desire for healthier food items (29). The term "composite flour" describes a blend of wheat flour and non-wheat flours from cereals, legumes, roots, and tubers, or it can also refer to a mixture of non-wheat flours (30). One of the many benefits of composite flour is its crucial role in compensating for vitamin deficiencies. It encourages the growth of high-yielding native plant species and improves domestic agriculture as a whole. It also keeps the hard currency safe (4). There is currently scarcity of information on the utilization of composite flour made from yellow root cassava and Bambara groundnut flour in cookie making.

Worthy of note is that the main objective of Food-to-food fortification is to deliver nutrient-rich foods to meet daily nutritional needs without sacrificing sensory appeal (31,23). The purpose of this study is therefore to produce an acceptable and nutrient-dense cookie using Provitamin A cassava and Bambara groundnut. The effect of replacement levels on cookie nutritional, physicochemical and sensory characteristics as well as the digestibility of the protein will then be determined with a view to increasing the accessibility of vitamin A-based diets in the country in addition to the increased use of both Bambara groundnut and Provitamin A cassava (PVAC).

MATERIALS AND METHODS

Source of Raw Materials

Yellow root cassava [IBA48100 (Security)] was sourced from National Root Crops Research Institute (NRCRI), Umudike, Umuahia, Abia State. Dried Bambara groundnut seeds (cream coloured variety), and other ingredients required for cookie production were purchased from Bodija, a local market in Ibadan, Oyo State, Nigeria. Analytical-grade supplies were utilized for all other equipment and chemicals.

Processing of Flours

Yellow root cassava was processed into flour using a slight improvement on the procedure outlined by Okoye and Ezeugwu, (4). After thoroughly cleaning the whole cassava roots to get rid of any stubborn dirt, they were manually peeled using kitchen knives made of stainless steel. Clean water was used to rewash the peeled roots and rinsed, a commercial hammer mill was used to grate yellow root cassava into a mash and bagged to remove water. The cake that resulted from the dewatering process was broken up into small pieces and sieved. The sifted semi dried mash was oven-dried (hot air electric drying oven) at 50 ^{0}C for 4 hrs. Following the drying process, the samples were ground and screened using a 250 mm mesh sieve to produce smooth yellow-root cassava flour with consistent particle size. After that, the flour was sealed in a black polypropylene bag and stored at room temperature until it was needed again. Figure 2.1 depicts the unit operations used to turn yellow root cassava into flour.

A small variation was made to the procedure outlined by Arise *et al*., (24) to produce Bambara groundnut flour. Bambara groundnuts were sorted to get rid of unwanted items like dirt and stones and to distinguish between seeds that were infected with insects and those that were desired. In addition, broken, wrinkled, and immature seeds were separated out and left in a bucket with a lid to soak in water for four days at room temperature. After soaking, the seeds were then dehulled (the soaking eased removal of the outer coat), and allowed to dry in a cabinet oven at 50°C for 2 days. Following their dehulling, the grains were ground in a Warring laboratory mill blender (HGBTWTS3, Torrington, CT, USA) and sieved through a 250 mm screen mesh to produce fine flour. The flour was subsequently kept in air-tight ziplock bags prior to use; Figure 2.2.

Formulation of Composite flour

In order to produce the experimental composite flour, a substitution procedure was used to formulate six proportions of different ratios as represented in Table 2.1. The flours were thoroughly mixed using Eurosonic electric blender for 1min to obtain homogenous flour blends which were tagged and stored in airtight containers at room temperature (30 ± 2°C) prior to its requirement.

Cookie Preparation

Small adjustment of the procedure outlined by Arise *et al*., (7) was adopted for cookie preparation. In particular, 100.0 grams of flour, 40.0 grams of hydrogenated vegetable fat, 25.0 grams of granulated cane sugar, 31.0 grams of fresh whole eggs, 7.8 grams of full-fat powdered milk, 0.3 grams of nutmeg, 5.0 milliliters of liquid vanilla flavor, 1.0 grams of salt, and 1.0 grams of baking powder were utilized. For 5 minutes, fat and sugar were creamed at medium speed using a hand mixer. After mixing for 30 minutes, eggs and vanilla flavor were added. After being weighed out individually, the dried ingredients—milk, nutmeg, flour, baking powder, and salt—were properly mixed and added to the cream mixture. This was followed by another 10-minute mixing period to produce a dough. The dough was rolled out to a consistent 0.25 cm thickness and then divided into 4.5 cm diameter circles. The formed dough was baked for 20 minutes at 185°C. Following a period of cooling at ambient temperature, the cookies were packaged in a clear polyethylene bag and refrigerated at 4°C until needed.

Six samples of cookie for each formulation were obtained and were coded accordingly based on the flour blend for which they were produced as Ac, Bc, Cc, Dc, Ec, and Fc. The process was replicated at least in triplicate to obtain enough samples to analyze the different parameters in this study.

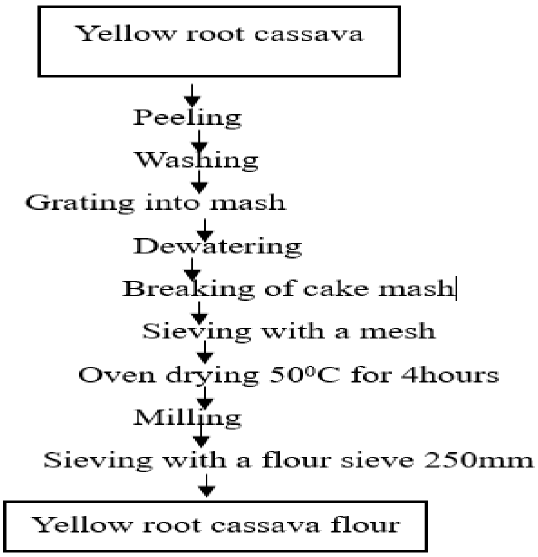

Figure 2.1: Production of flour from yellow root cassava (4)

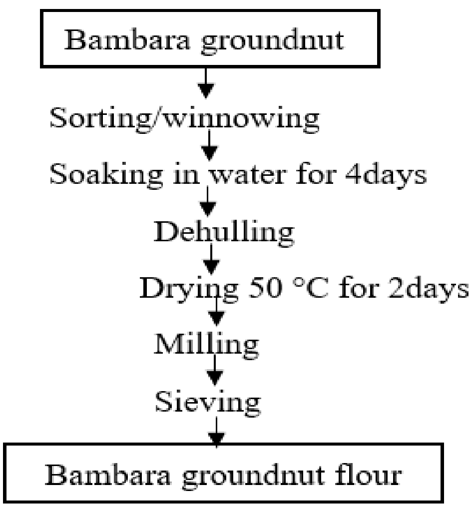

Figure 2.2: Production of flour from Bambara groundnut (24)

Table 2.1: Formulation of Pro-vitamin A Cassava (PVAC) and Bambara groundnut (BG) composite flours for cookie production

Formulation	Sample code	% of flour in the formulation	
		PVAC	BG
PVAC_BG (0%)	Ac	100	0
PVAC_ BG (20%)	Bc	80	20
PVAC_ BG (40%)	Cc	60	40
PVAC_ BG (60%)	Dc	40	60
PVAC_ BG (80%)	Ec	20	80
PVAC_BG (100)	Fc	0	100

PVAC=Provitamin Cassava; BG = Bambara Groundnut

Physical Properties of Cookies

The physical properties of the cookies; weight, diameter, thickness, spread ratio and breaking strength were obtained using the techniques outlined by Arise *et al.*, (7) and Offia-Olua and Akubuo, (32). Colour was examined using Ajibola (20) method.

Proximate Composition of Cookie samples

Moisture, crude protein, fat, ash, and crude fibre of cookie samples were assessed using the standard techniques described in the AOAC (33). Utilizing data on moisture, crude protein, lipid, crude fiber, and ash content, the carbohydrate content was calculated as the weight difference; on the other hand, the energy value (kcal/100 g) was assessed using the Atwater conversion factor (9 × % lipids + 4 × % proteins + 4 × % carbohydrates) (34).

Mineral Analysis of Cookie Samples

Mineral analysis of the cookie samples was assessed following the standard methods described in the AOAC (33).

Determination of Beta Carotene Content of Cookies

Pro-vitamin A content in the cookies was assessed with the use of Atomic Absorption Spectrophotometry as described by Honi, (3) and Fortunatus *et al*., (35).

Sensory Evaluation of Cookie Samples

The sensory qualities of the Provitamin A-Bambara cookies were assessed using the techniques outlined by Arise *et al*., (7) and Iwe (36). The appearance, taste, aroma, crispness/texture and overall acceptability of the prepared cookie samples (6 samples) were assessed by a 20-member panel of semi-trained judges (average age of 25 made up of 10 female and 10 male) randomly selected from students of Department of Food Technology, University of Ibadan, who are typical consumers of cookie and are acquainted with the qualities that make a cookie. Sensory attributes of the cookies were scored on a 9-point Hedonic scale. On this scale, 9 represents like extremely; 8-like very much; 7-like moderately; 6-like slightly; 5-niether like nor dislike; 4-dislike slightly; 3-dislike moderately; 2-dislike very much; and 1-dislike extremely.

The evaluation started 2hours after production. Samples were placed on white plates and recognized using random three-digit numbers to prevent bias (Ac=305, Bc=311, Cc=817, Dc=502, Ec=104, Fc=174). Before and after evaluating each product, the panellists were told to sip water in order to prevent a carry-over effect.

Evaluation of the In-vitro Protein Digestibility of Cookie Samples

Using the three-enzyme pH-drop method as outlined by Falade and Akeem, (37), the in vitro protein digestibility of the cookies was assessed. Each sample weighing 6.20 mg, was dissolved in 4 milliliters of distilled water. The pH was brought in 8.0 using 0.1 N NaOH, all the while being stirred at 37–°C in a water bath. A multi-enzyme solution, maintained in an ice bath and adjusted to pH 8.0 as previously mentioned, contained 1.60 mg of trypsin, 12.40 mg of chymotrypsin, and 5.20 mg of peptidase per 4 milliliters of distilled water. The sample solution was mixed continuously at 37°C with a 400 µl aliquot of the multi-enzyme solution added. 10 minutes after adding the enzyme solution, the pH of the mixture was measured. After which the in vitro protein digestibility was calculated using the equation below;

$$\textit{In vitro protein digestibility (\%)} = 210.464 - 18.103X$$

X = pH of the sample suspension after 10 min digestion with multi-enzyme solution.

Statistical Analysis

All experimental data were reported as mean ± SD (standard deviation) of duplicate determinations. The data obtained were subjected to one-way analysis of variance (ANOVA) whereas Duncan's multiple range test (DMRT) was conducted to separate the means at P<0.05 (95 % confidence interval). These were achieved using the Statistical Package for Service Solution (SPSS) version 25.0. Data were presented in tabular and graphical forms.

RESULTS AND DISCUSSION

Physical Properties of the Cookie Samples

The physical properties of cookies are important indicators of their quality (7). Table 3.1 displays the physical characteristics of cookies (Fig.3.1) made from flour blends of Provitamin A cassava flour and Bambara groundnut flour.

The weight of the cookies varied from 8.31 to 9.02 g; cookie sample Fc was the heaviest (9.02g) and bulkiest among the samples, while cookie sample Ac had the least weight (8.31g). The weight of composite cookies differed significantly (p<0.05). The inclusion of Bambara flour in provitamin A cassava flour resulted in a significant (p < 0.05) increase in the weight of the cookies. The increase in the weight of composite cookies could be attributed to the higher bulk density of Bambara flour than cassava. This is likely because the mass, size, and shape of individual particles are key factors influencing bulk density (7). The increased bulk density of cassava-Bambara flour blends could also explain the greater weight of the composite cookies. Apotiola and Fashakin, (38) and Chinma *et al*., (39) also attributed increase in weight of composite cookies to the high bulk density of higher protein substitutes; soyflour and defatted sesame flours respectively.

The diameter of cookies ranged from 4.08 to 4.53cm with cookie sample Ac having the highest value while cookie sample Fc has the lowest value. Addition of Bambara flour to provitamin A cassava flour in the cookie formulation caused a significant (p<0.05) decrease in the diameter. The diameter of the cookies is crucial for selecting the appropriate packaging material (9).

The thickness of the composite cookies exhibited a similar trend to their weight, significantly (p < 0.05) increasing from 0.54 cm in cookie sample Ac to 0.68 cm in cookie sample Fc. The higher bulk density of Bambara could have affected its thickness positively. Moreover, a higher protein content implies a decrease in spread factor and a decrease in spread factor is concurrent to an increase in thickness since both variables are inversely proportional (spread ratio=diameter/thickness).

The spread ratio of the cookie samples showed a similar decreasing trend to the diameter of the cookies. The spread ratio (diameter / thickness) of cookies varied from 6.04 to 8.46; cookie sample Ac had the highest spread factor while cookie sample Fc had the lowest. It was observed that the spread factor of composite cookies

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significantly ($p < 0.05$) reduced with higher levels of Bambara flour substitution. Apotiola and Fashakin, (38) and Chinma *et al*., (39) also observed a reduction in the spread factor with higher protein content in the cookies. According to Nasir *et al*., (40), this is plausible because the higher protein content creates more hydrophilic sites, which compete with the limited free water in the cookie dough, leading to a reduced spread factor. Cookies with greater spread ratios are often viewed as more desirable (41). This is however contrary to the assertion by Olapade and Adeyemo (42). Therefore, controlling the spread ratio of cookies is a significant challenge during production. Cookies that spread excessively may not fit into the packaging, while those with minimal spread can cause slack fill or excess height in the package, leading to issues on the packaging line (43).

The breaking strength of the cookies varied from 4.13 to 5.66 kg, with cookie sample Ac having the highest value at 5.66 kg and cookie sample Fc the lowest at 4.13 kg. The breaking strength refers to the amount of force needed to break the cookies (43). The breaking strength significantly ($p < 0.05$) decreased with increasing levels of Bambara flour substitution in the formulation. The decrease might be explained by the fact that Bambara flour has a lower carbohydrate/starch content than cassava flour, which makes it less hard/strong. Cookies' hardness is a result of hydrogen bonding between proteins and starch (43). Comparatively, this finding aligns with the reports of Ayo *et al*., (41), which observed that using composite flours in cookies reduces their break strength. Furthermore, Adebowale *et al*., (44) noted that greater rigidity results from an increase in carbohydrate and starch granules, which are essential for gel formation and structural integrity in baked products. Higher breaking strength obtained in cookies made from composite flours indicates greater hardness of cookies structure (45, 32).

The results obtained for physical properties of PVAC-BG cookies are in close agreement with those of Offia-Olua and Akubuo, (32) and but lower than the values stated by Chinma *et al*., (39) and Arise *et al*., (7).

Table 3.1: Physical Properties of Cookie Samples

Cookie Samples	**Weight (g)**	**Diameter (cm)**	**Thickness (cm)**	**Spread ratio**	**Breaking Strength (kg)**
Ac	8.31 ± 0.01^{a}	4.53 ± 0.01^{f}	0.54 ± 0.01^{a}	8.46 ± 0.10^{d}	5.66 ± 0.01^{f}
Bc	8.46 ± 0.02^{b}	4.46 ± 0.01^{e}	0.52 ± 0.01^{a}	8.66 ± 0.14^{d}	5.41 ± 0.01^{e}
Cc	8.61 ± 0.01^{c}	4.38 ± 0.00^{d}	0.58 ± 0.01^{b}	7.55 ± 0.18^{c}	5.07 ± 0.02^{d}
Dc	8.69 ± 0.05^{d}	4.29 ± 0.01^{c}	0.64 ± 0.01^{c}	6.80 ± 0.14^{b}	4.85 ± 0.03^{c}
Ec	8.92 ± 0.02^{e}	4.18 ± 0.01^{b}	0.64 ± 0.01^{c}	6.59 ± 0.05^{b}	4.33 ± 0.01^{b}
Fc	9.02 ± 0.01^{f}	4.08 ± 0.02^{a}	0.68 ± 0.01^{d}	6.04 ± 0.09^{a}	4.13 ± 0.01^{a}

Values are means ± standard deviation of duplicate determination

Mean values within the same column followed by different superscripts are significantly different ($P<0.05$).

Figure 3.1: Cookie Samples

305 = Ac, 311 = Bc, 817 = Cc, 502 = Dc, 104 = Ec, 174 = Fc

Colour of the Cookie Samples

Colour is a key organoleptic quality factor that influences the acceptance of food products (46). The colour parameters (l*, a*, and b*) of the cookies' outer surface (crust) are shown in Table 3.2.

The surface colour of cookie samples was measured using the Commission Internationale de l'Eclairage (CIE) L*, a*, b* color system. In this system, L* indicates lightness, a* represents the redness-to-greenness, and b* denotes the yellowness-to-blueness of the colour (47). L* values ranged from 57.44 to 65.64 with cookie sample Ac having the highest value and therefore the lightest while cookie sample Fc had the lowest value. The a* values ranged from 0.96 to 3.41 with sample Fc having the highest value and sample Ac the lowest. The b* values ranged from 16.39 to 17.94 with sample Fc having the lowest value while sample Ac had the highest value.

The surface of the cookie sample Ac was significantly ($p<0.05$) lighter (L= 65.64) and yellower (b=17.94) than in cookie sample Fc made with the highest substitution of BG flour which had its values of lightness and yellowness as L=57.47 and b=16.39 respectively. The result showed that the addition of BG flour decreased the L* and b* values and increased the a* value of the cookies. The addition of the BG flour significantly ($p<0.05$) changed the color from yellow to red. Further substitution communicated darkness to the cookies' surface. This could be due to Maillard reactions that take place during baking, involving interactions between reducing sugars and amino acids (28). It is however, expected that the cookie samples with increased substitution of BG flour will respond to Maillard reaction more since they have higher protein quality than cassava flour as stated in the literature.

Table 3.2: Colour Variations of Cookie Samples

Cookie Samples	Lightness (l*)	Redness (a*)	Yellowness (b*)
Ac	65.64 ± 0.49^{d}	0.96 ± 0.10^{a}	17.94 ± 0.04^{e}
Bc	64.01 ± 0.50^{c}	1.47 ± 0.09^{b}	17.28 ± 0.11^{d}
Cc	63.82 ± 0.28^{c}	1.42 ± 0.04^{b}	17.41 ± 0.05^{d}
Dc	60.55 ± 0.84^{b}	2.29 ± 0.05^{c}	17.04 ± 0.03^{c}
Ec	57.73 ± 0.55^{a}	3.18 ± 0.11^{d}	16.87 ± 0.15^{b}
Fc	57.44 ± 0.72^{a}	3.41 ± 0.32^{d}	16.39 ± 0.03^{a}

Values are means ± standard deviation of triplicate determination

Mean values within the same column followed by different superscripts are significantly different ($P<0.05$).

Proximate Composition of the Cookie Samples

Table 3.3 presents the proximate composition of cookies made from a combination of PVAC and BG. The results indicate that protein, fat, and ash levels rose with an increase in the proportion of Bambara flour varying from 3.46±0.02 to 16.33±0.03%, 21.66 ±0.02 to 24.63±0.02% and 2.64±0.02 to 4.26±0.01% respectively. This suggests that enhancing PVAC flour with Bambara groundnut flour would significantly boost the protein quality of the cookies, which was the main focus of the study. This improvement can likely be attributed to the high protein content found in BG flour (20.94%) as observed in this study. These results are consistent with Honi's (3) research on creating snacks for school children using orange-fleshed sweet potato and Bambara groundnut. A comparable observation was noted in a study by Oluwole and Karim (48), which demonstrated that increasing

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the proportion of Bambara flour in cassava-wheat-bambara flour blends led to a higher protein content in biscuit production.

Cookie sample Ac produced from 100% Provitamin A cassava flour was found to be the least in protein content (3.46%), which is expected because cassava is a poor source of protein (48, 46). As Bambara groundnut substitution increased, an increase in protein content was observed, indicating a fortifying effect of Bambara groundnut flour on the cookies. Fortification of the cookies with up to 40% Bambara flour substitution resulted in about 98% increase (6.85-3.46/3.46 x 100/1=97.97%) in the protein content of the formulated cookie. It was however observed that the protein content of cookies was lower than that recorded from the respective flour blends. The reduction in protein content in the flour after baking cookies could be due to heat and Maillard browning reactions (28).

While fat serves as a flavor enhancer and helps to improve the sensory qualities of baked goods (49); increases the energy content of foods (Abayomi *et al*., 2013); as well as improves bioavailability of beta carotene content of the food therein (15). However, high fat levels in food products should be kept at 25% or less, as exceeding this limit can cause rancidity and the formation of unpleasant, odorous compounds and could also mean reduced storage potential (50, 43, 51). It was noted from this research that all the cookie samples had fat content (21.66 to 24.63%) below this recommended fat content in food products.

The ash content of a food sample indicates its mineral composition (51). The increase in ash content with resultant increase in Bambara groundnut could mean higher mineral content. The cookie samples differed significantly ($p<0.05$) in the protein, fat and ash content respectively.

However, an opposite trend was observed for moisture, crude fibre and carbohydrate which decreased with increased Bambara flour substitution ranging from 5.75±0.04 to 6.74±0.04%, 0.61±0.01 to 2.98±0.04% and 48.44±0.01 to 62.54±0.03% respectively. The decrease observed may be due to the higher levels of Bambara groundnut flour substitution in the cookies. Moisture content in food indicates its shelf-life and nutritional value (51). All the cookie samples had adequate moisture content, suggesting they have the potential for a longer shelf life. Significant differences ($p<0.05$) existed in the moisture content, crude fibre and carbohydrate content of the cookie samples respectively. With exception for cookie samples Ec and Fc which showed no significant difference ($p>0.05$) in their crude fibre content.

Energy content is a key parameter for assessing food quality, particularly for formulations intended for adults with high energy needs. Food energy represents the calories available from food through oxidation. Fats provide the highest energy at 9 kcal/g, while proteins and carbohydrates offer about 4 kcal/g each (5). The calorie content of the cookies has been increased from 458.88±0.01 to 480.69±0.28kcal/100g with the inclusion of Bambara groundnut flour having relatively higher amount of fat. Significant differences ($p<0.05$) exist in the energy content of the cookie samples. Consuming 100 g of the composite cookie with 40% Bambara groundnut flour would provide approximately 22% of the daily requirement of 2100 kcal for a healthy adult (468.72/2100 x 100/1 = 22.32%).

Table 3.3 Proximate Composition of Cookies from Flour Blends of pro-vitamin A cassava and Bambara groundnut

Sample Code	**Moisture (%)**	**Protein (%)**	**Crude Fat (%)**	**Ash (%)**	**Crude Fiber (%)**	**Carbohydrate (%)**	**Energy value (Kcal/ 100g)**
Ac	6.74±0.04^{f}	3.46±0.02^{a}	21.66±0.02^{a}	2.64±0.02^{a}	2.98±0.04^{f}	62.54±0.03^{f}	458.88±0.01^{a}
Bc	6.43±0.03^{e}	4.13±0.01^{b}	22.35±0.02^{b}	2.97±0.03^{b}	2.67±0.00^{e}	61.46±0.05^{e}	463.45±0.33^{b}
Cc	6.04±0.03^{d}	6.85±0.04^{c}	22.74±0.02^{c}	3.22±0.02^{c}	1.99±0.02^{d}	59.18±0.04^{d}	468.72±0.22^{c}
Dc	5.95±0.02^{c}	9.04±0.02^{d}	23.86±0.05^{d}	3.54±0.05^{d}	1.32±0.02^{c}	56.32±0.12^{c}	476.10±0.05^{d}

Ec	5.83±0.02[b]	12.51±0.03[e]	24.02±0.01[e]	4.02±0.01[e]	0.67±0.00[b]	52.96±0.02[b]	478.04±0.07[e]
Fc	5.75±0.04[a]	16.33±0.03[f]	24.63±0.02[f]	4.26±0.01[f]	0.61±0.01[a]	48.44±0.01[a]	480.69±0.28[f]

Values are Means ± standard deviation of duplicate determinations [a-f] Means with the same superscripts within the same columns are not significantly ($p>0.05$) different. Where PVAC: Pro-vitamin A Cassava flour, BF: Bambara groundnut flour

Mineral Analysis of the Cookie Samples

The result of the mineral analysis of the cookie samples are shown in Table 3.4. The calcium content of the cookies varied from 241.36±0.02 to 272.62±0.02mg/100g. There was significant ($p<0.05$) difference in the calcium content of the cookies except for sample Bc which was not significantly ($p>0.05$) different from samples Cc and Dc. The calcium content increased as the proportion of cassava flour was raised. This observation may be due to the fact that Cassava is reasonably rich in calcium (52). Honi (3) also observed a decrease in calcium with increased proportion of Bambara flour in a prepared snack. Calcium is crucial for bone formation, blood clotting and muscle contraction (53). Calcium deficiency can result to bone weakness (osteopenia) and fractures (osteoporosis); while excessive intake can cause hypercalcemia (metabolic alkalosis and loss of kidney function) and kidney stone formation (54, 34). The recommended daily intake of calcium for a child aged 1–3 years is 500 mg (Institute of Medicine 2006), and considering 70% calcium bioavailability (55), the consumption of 100g of the PVAC60%BG40% formulated cookie can contribute 32.7% (233.21 × 70/100 = 163.25; then, 163.25/500 × 100 = 32.65%) of calcium for the daily intake.

The sodium content of the cookies varied from 19.15±0.01 to 36.07±0.01mg/100g. The sodium content was found to decrease with increased Bambara substitution. Significant ($p<0.05$) difference existed in the sodium content of the cookies. The composite cookies recorded relatively low sodium content. The low sodium content of the cookies could be advantageous, as a low-sodium diet has been reported to help prevent high blood pressure (56).

The magnesium content of the cookies varied from 72.14±0.01 to 107.05±0.02 mg/100g with sample Fc having the highest value and Ac the lowest value respectively. The cookies differed significantly ($p<0.05$) in magnesium content. Increasing the proportion of Bambara flour led to a rise in the magnesium content of the composite cookies. The values suggest that consuming 100 g of the cookie would fulfil the FAO/WHO recommended daily intake of magnesium for infants and children (26 to 100 mg/day). However, the values obtained fall short of the recommended nutrient intake for adolescents (230 mg/day for females and 220 mg/day for males) and adults (220 mg/day for females and 260 mg/day for males) (57).

The phosphorus content of the cookies ranged from 353.13±0.05 to 596.43±0.01mg/100g. Sample Fc (100% Bambara flour cookie) had the highest phosphorus content (596.43 mg/100g) while Sample Ac (100% Provitamin A cassava flour cookie) had the lowest. Significant ($p<0.05$) difference existed in the phosphorus content of the cookies. The phosphorus content of the cookie increased with increased Bambara flour substitution. Phosphorus helps in bone growth, proper kidney function and cell growth (58). The increased phosphorus content suggests that the mineral content of food products could be enhanced by developing composite products.

Potassium is an essential mineral for all human body cells, tissues, and organs to function properly. It is essential for proper muscular and digestive function since it is involved in the contraction of both skeletal and smooth muscles (53). Additionally, potassium is necessary to keep the body's acid-alkaline equilibrium intact (Musah *et al.*, 2021). The potassium content of the cookies ranged from 182.12±0.01 (Ac) to 273.13±0.02mg/100g (Fc). Significant ($p<0.05$) rise was noticed in increased substitution with Bambara flour. The results indicated that the cookie samples had a high potassium content and could be excellent sources of potassium.

The iron content of the cookies varied from 1.44±0.03 to 14.28±0.37mg/100g. Sample Fc (100% Bambara flour cookie) had the highest iron value (14.28mg/100g) which suggested that the formulation of composite cookies from Bambara groundnut and Provitamin A cassava flours improved the iron content of the end product.

Inclusion of BG at 40% revealed an increase of 362.8% (3.98-0.86/0.86 x 100/1) iron content from the control sample A; this is because BG was determined to have a high iron content as 5.45 mg/100g by Abdualrahman *et al*., (59) and 8.8 mg/100 g by Semba *et al*., (60). For children aged 1-3, the recommended daily amount (RDA) for iron is 7 mg (54). Plant-based diets can have iron bioavailability ranging from 5 to 10% (55), and presuming 10% bioavailability, the consumption of 100g of the PVAC60%BG40% formulated cookies can supply about 5.7% (3.98 × 10/100 = 0.398; then, 0.398/7.0 × 100 = 5.69%) of iron for a child of about 1–3 years of age. This indicates that, although the composite cookie provides some improvement in iron content, additional dietary sources rich in iron are needed to ensure adequate iron intake along with consuming the cookie.

The zinc values of the cookies varied between 0.82±0.01 to 6.84±0.16 mg/100g with sample Fc having the highest value while Ac having the lowest. Inclusion of the Bambara flour raised the zinc value of the cookie samples. This is because Bambara is said to have a high zinc content (2.14 to 19.73mg/100g) (61). For growth and development, zinc is a necessary mineral, and also appears to improve immune function (53). At PVAC60%BG40%, the zinc content of cookies was increased by 190.8% from the control (100% PVAC cookie sample). For children aged 1-3, the recommended daily allowance (RDA) for zinc is 3.0 mg (54). With consideration of a moderate zinc bioavailability diet (30% bioavailability that takes phytate zinc binding into account) (55), the consumption of 100g of PVAC60%BG40% formulated cookies would supply about 22.1% of the zinc (2.21 × 30/100 = 0.66 mg; then, 0.66/3×100=22.1%) for the daily requirement. The mineral contents of the formulated cookies all showed significant ($p<0.05$) differences for all the analysed minerals.

Table 3.4 Mineral Composition and β-carotene content of Cookies from Flour Blends of pro-vitamin A cassava and Bambara groundnut

Sample Code	Calcium (mg/100g)	Sodium (mg/100g)	Magnesium (mg/100g)	Phosphorus (mg/100g)	Potassium (mg/100g)	Iron (mg/100g)	Zinc (mg/100g)
Ac	272.62±0.02^{e}	36.07±0.01^{f}	70.71±0.01^{a}	353.13±0.05^{a}	182.12±0.01^{a}	1.44±0.03^{a}	0.82±0.01^{a}
Bc	268.21±1.40^{cd}	31.32±0.01^{e}	72.14±0.01^{b}	406.02±1.43^{b}	194.72±0.01^{b}	3.14±0.01^{b}	1.60±0.34^{b}
Cc	269.68±0.72^{d}	24.05±0.01^{d}	79.14±0.01^{c}	437.12±7.75^{c}	201.03±0.02^{c}	4.22±0.02^{c}	2.84±0.06^{c}
Dc	266.72±0.03^{c}	21.23±0.01^{c}	80.41±0.02^{d}	484.56±0.69^{d}	209.72±0.01^{d}	6.52±0.02^{d}	3.65±0.01^{d}
Ec	249.92±0.01^{b}	19.82±0.01^{b}	104.14±0.01^{e}	527.86±0.02^{e}	223.18±0.01^{e}	9.88±0.02^{e}	5.55±0.01^{e}
Fc	241.36±0.02^{a}	19.15±0.01^{a}	107.05±0.02^{f}	596.43±0.01^{f}	273.13±0.02^{f}	14.28±0.37^{f}	6.84±0.16^{f}

Values are Means ± standard deviation of duplicate determinations $^{a-f}$ Means with the same superscripts within the same columns are not significantly ($p>0.05$) different. Where PVAC: Pro-vitamin A Cassava flour, BF: Bambara groundnut flour

Beta Carotene Content of the Cookie Samples

The level of β-carotene in the prepared cookies is revealed in Table 3.5. β-carotene content ranged from 47.06±0.05 (Fc) to 91.39±1.64µg/100g (Ac). No significant ($p>0.05$) difference was observed in the beta carotene content among cookie samples Ac, Bc and Cc and also no significant ($p>0.05$) difference between samples Dc and Ec. Other samples however showed significant difference. This study showed that an increase in the PVAC flour increased the level of β-carotene in the cookies. These reports were comparable to that of Okoye and Ezeugwu, (4) and Ubbor *et al*., (9) who stated that the higher the PVAC flour inclusion in foods, the higher the β-carotene content. This is plausible because Pro-vitamin A rich crops have shown to be an effective remedy for vitamin A deficiency (62, 15). Beta-carotene is recognized as one of the pro-vitamin A carotenoids that imparts high vitamin A activity (12 µg beta-carotene = 1 µg retinol activity equivalent (RAE) (34)**.** Therefore, Adequate consumption of beta-carotene and other carotenoids is essential for healthy eyesight, immune system defense against viral diseases, gene regulation, and antioxidant defense against oxidative stress damage to cell

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constituents (DNA, RNA, proteins, and lipids) (63).

Moreover, food systems are shielded from oxidative reactions by the potent antioxidant β-carotene. The polyene frameworks of β-carotene have been linked to its antioxidant action (64). This implies that the formulated cookies might have an advantage of improved shelf life.

Table 3.5 Beta Carotene Content of the Cookie Samples

Sample Code	B-carotene (µg/100g)
Ac	91.39 ± 1.64^{c}
Bc	90.40 ± 0.16^{c}
Cc	85.73 ± 0.12^{c}
Dc	76.75 ± 8.06^{b}
Ec	75.44 ± 0.46^{b}
Fc	47.06 ± 0.05^{a}

Values are Means ± standard deviation of duplicate determinations $^{a-f}$ Means with the same superscripts within the same columns are not significantly (p>0.05) different. Where PVAC: Pro-vitamin A Cassava flour, BF: Bambara groundnut flour

Anti-nutritional Composition of the Cookie Samples

The levels of antinutritional factors found in the cookies are shown in Table 3.6. The results of hydrogen cyanide ranged from 0.02±0.00 to 0.14±0.00mg/100g with cookie sample Ac having the highest. The results indicated that the hydrogen cyanide found in the formulated samples originated exclusively from the provitamin A cassava flour. This is evident because the cookie sample Ac, which consisted of 100% provitamin A cassava flour, had the highest hydrogen cyanide content, and this was significantly different from the other samples (p<0.05). An increase in the proportion of cassava flour led to a higher hydrogen cyanide content in the formulated cookies. Nonetheless, the hydrogen cyanide levels in the cookies remained below the lethal threshold of >10 mg/kg, as specified by the Codex Alimentarius Commission (65).

The tannin content varied between 0.04±0.01 and 0.21±0.01 mg/100g. As the proportion of BG flour increased, the tannin content in the cookies also increased. Tannins impair protein digestibility by either hindering the activity of proteolytic enzymes or binding with dietary proteins to form indigestible complexes (66). Nonetheless, the tannin content in the cookies was well below the reported lethal dose of 90 mg/100g (67). Therefore, it is unlikely that the tannin levels would adversely affect digestion, as only high tannin concentrations are known to inhibit microbial enzyme activities, including those required for cellulose breakdown, potentially leading to impaired intestinal digestion (53).

Table 3.6: Anti-nutritional Composition of Cookies (mg/100g)

Cookie Samples	Hydrogen cyanide	Tannin	Phytate
Ac	0.14 ± 0.00^{d}	0.04 ± 0.01^{a}	0.54 ± 0.01^{e}
Bc	0.12 ± 0.00^{c}	0.05 ± 0.00^{b}	0.53 ± 0.00^{e}
Cc	0.07 ± 0.01^{b}	0.07 ± 0.01^{c}	0.48 ± 0.01^{d}

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Dc	0.07±0.01^{b}	0.08±0.00^{d}	0.42±0.01^{c}
Ec	0.04±0.01^{a}	0.12±0.01^{e}	0.39±0.01^{b}
Fc	0.02±0.00^{a}	0.21±0.01^{f}	0.32±0.01^{a}

Values are means ± standard deviation of duplicate determination

Mean Values within the same column followed by different superscripts are significantly different (P<0.05).

Sensory Evaluation of the Cookie Samples

Table 3.7 displays the findings of the sensory evaluation. The panellists gave the cookies a score between 7.15-7.80 for appearance, with sample Ac receiving the highest rating (7.80) and sample Fc receiving the lowest (7.15). This might be because cookies with a higher proportion of cassava flour turned out lighter than those with a higher amount of Bambara. This is plausible since the darkening/browning is an expected effect of caramelization and Maillard reactions, and the higher proteins influenced by Bambara flour must have reacted better with sugar during baking (68, 28). Nonetheless statistically, no significant (p>0.05) difference was noticed up to 100% inclusion with Bambara flour substitution in terms of appearance as they were all liked moderately by the panellists.

Taste is the main determinant of any food product's acceptability and has the biggest influence on the product's market success (5). The preferences for taste of the samples revealed a significant (p<0.05) decrease in increasing substitution of Bambara flour in the cookies. Sample Ac and Bc were liked moderately by the panellists, Cc and Dc were liked slightly while samples Ec and Fc were neither liked nor disliked. Sample Ac was the most preferred in taste (7.35) while Fc was the least preferred (5.05). This could be attributed to the fact that compared to most white-flesh cassava varieties, the majority of biofortified yellow-flesh variants taste sweeter and have mild-to-moderately poisonous cyanogenic glucosides (69).

The aroma ratings of the cookies ranged from 7.00 for sample Ac to 6.40 for sample Fc, with sample Ac receiving the highest rating and being rated as moderately liked by the panellists. In contrast, the other cookie samples were only slightly liked by the panellists. However, no significant difference (p>0.05) was observed in aroma among the samples.

As the amount of Bambara flour increased, the cookies' crispness and texture dropped, from 6.60 to 6.40. Sample A of cookies got the maximum crispness score of 6.60, and sample Fc had the lowest crispness value. It was observed that crispness reduced with increased Bambara flour substitution. It might be implied that the presence of Bambara flour affected the crispiness of the cookies. The marginal reduction in crispness seen upon increasing the substitution of Bambara flour could potentially be attributed to the comparatively elevated total fat content of Bambara, approximately 6.6% (70). Abayomi *et al.*, (5) also attributed decrease in crispness to increased fat content of Soybean (a legume). On the contrary, Eke-Ejiofor *et al.*, (71) in a recently conducted research reported higher mean scores for crispness of cookies with increased Bambara groundnut substitution which was attributed to the elevated fat content of the Bambara groundnut flour as opposed to cassava flour. The study suggests that the cohesiveness of the starch matrix found in cassava flour is responsible for the enhanced crispness and texture of cookies containing a higher proportion of cassava flour. Onwuzuruike *et al.*, (53) made a comparable observation. Nonetheless, no statistically significant (p>0.05) difference was noted, as the panellists found all of the cookie samples to be fairly crisp.

The results of overall acceptability showed that samples Ac, Bc, and Cc were moderately accepted while sample Dc was slightly accepted by the panellist with ratings 7.70, 7.40, 7.15 and 6.50 respectively. Sample Ec and Fc were neither liked nor disliked by the panellists with ratings 5.85 and 5.50 respectively. It was observed that the overall acceptability of the cookies increased with the addition of Bambara flour, with cookie samples containing up to 40% Bambara flour substitution receiving ratings equal to or greater than "like moderately" (7). Thus, it was concluded that cookies with up to 40% Bambara flour substitution can be baked with satisfactory performance and moderate acceptance.

Table 3.7: Sensory properties of Cookies Produced from Blends of Provitamin A Cassava and Bambara Groundnut Flour blends

Sample Code	Appearance	Taste	Aroma	Texture	Overall Acceptability
Ac	7.80±0.83[a]	7.35±0.93[d]	7.00±1.49[a]	6.60±1.31[a]	7.70±0.66[c]
Bc	7.40±1.05[a]	7.30±0.98[d]	6.90±1.59[a]	6.70±1.34[a]	7.40±0.88[c]
Cc	7.55±0.61[a]	6.75±0.91[cd]	6.40±1.35[a]	6.40±1.27[a]	7.15±0.67[c]
Dc	7.45±0.83[a]	6.55±0.89[c]	6.40±1.27[a]	6.20±1.40[a]	6.50±0.89[b]
Ec	7.45±1.10[a]	5.80±1.01[b]	6.60±1.10[a]	6.40±1.57[a]	5.85±1.04[a]
Fc	7.15±1.18[a]	5.05±0.91[a]	6.40±1.31[a]	6.40±0.88[a]	5.50±1.24[a]

Mean Values within the same column followed by different superscripts are significantly different ($P<0.05$).

In-vitro protein digestibility of the Cookie Samples

Protein digestibility is one of the major protein's quality determinants. Decrease in pH during the digestion process is an indication of increased protein digestibility which is attributed to the release of hydrogen ions by the hydrolyzed peptide bonds in the protein molecule (37). Fig. 3.1 shows the *in-vitro* protein digestibility of the formulated cookies. The percentage *in-vitro* protein digestibility ranged from 76.05±0.04 to 81.06±0.01% with cookie sample Ac having the lowest value and Fc the highest value respectively. Significant ($P < 0.05$) increases were observed with increased BG flour substitution. The increase in *in-vitro* protein digestibility of the fortified cookies might be ascribed to incorporation of the Bambara groundnut protein which is characterized by high digestibility (59) compared with cassava protein. Chinma *et al.*, (39) also attributed increase in *in-vitro* protein digestibility of formulated cookies to increased protein content.

The relatively high protein digestibility of the selected cookies shows that the cookies are highly digestible and may be attributed to the low levels of tannins found in the cookies; since dietary tannins are often responsible for the poor digestibility of dietary proteins (30). Also, the elimination of phytic acid contributes to the improvement in protein digestibility (72) especially with regards to the soaking/natural fermentation which was carried out in the process of production of BG flour the main source of protein in the cookies. Oyeyinka *et al.*, (26) also attributed increase in in-vitro protein digestibility of cooked Bambara grains to decrease in tannin and phytic acid contents. Cooking methods like baking can also improve the digestibility of foods. Kiers *et al.* (73) reported that digestibility of cereals and legumes increased during cooking and fermentation. This could be attributed to the partial degradation of complex storage proteins into more simpler and soluble products (72). The percentage *in-vitro* protein digestibility obtained in this study was comparable to the range 75.07 to 79.17% recorded for Bambara-based bread meal (59).

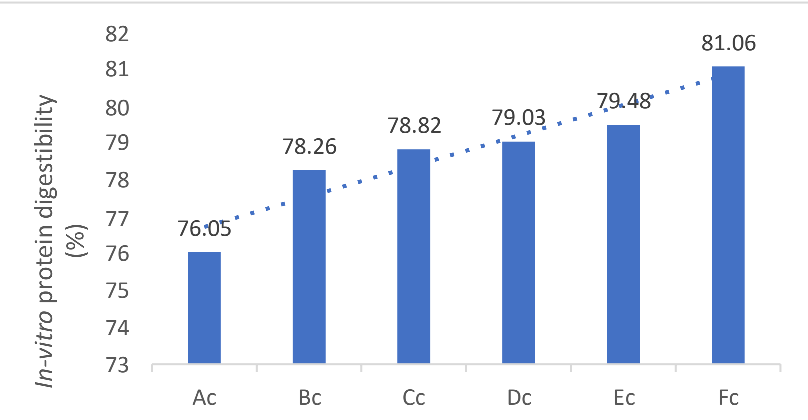

Figure 3.2: *In-vitro* protein digestibility of cookie samples

CONCLUSION

The findings of this research revealed that the cookies produced with Bambara flour substitution up to 40% were moderately acceptable and nutritionally superior to that of the whole cassava flour and whole Bambara flour cookies respectively. The high protein content in the provitamin A-Bambara supplemented cookies would be of nutritional importance in most developing countries like Nigeria where many people can hardly afford high proteinous foods because of their high cost.

The economic impact of utilization of flour produced from indigenous crops (provitamin A cassava-Bambara flour) will enhance gross domestic products in Nigeria and bring about reduction in foreign exchange on wheat importation and thus enhance the industrial utilization of local crops It can also be suggested in the snacking pattern of children and adults in Nigeria

In addition, Incorporation of provitamin A cassava in ready to eat foods could diversify food intake and ensure food and nutrition security. This cookie will be highly appreciated by people having celiac diseases as this is a gluten-free cookie.

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