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Quality assessment of acha-based biscuit improved with bambara nut and unripe plantain

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Five value added biscuit products were produced from three different raw materials, namely acha (*Digitaria exilis* Staph), bambara nut and unripe plantain, at different proportions: 100:0:0% (ACH105), 80:10:10% (ACH801), 70:20:10% (ACH702), 60:30:10% (ACH603) and 50:40:10% (ACH504), respectively. The raw materials were cleaned, sorted, dried and milled into flour and used to produce biscuits. Sensory parameters evaluated were taste, texture, colour, flavour, crispness and general acceptability. Result showed that biscuit products ACH801 and ACH702 were acceptable ($p < 0.05$). Physical parameters determined were spread ratio, weight and break strength. The proximate composition for 80:10:10% acha, bambara nut and unripe plantain flour biscuit are 6.20% protein, 2.04% moisture, 20.12% fat, 2.28% ash, 2.27% crude fibre, 69.36% carbohydrate. The energy content is 483.32 Kcal/100 g. Shelf life studies on the bacterial, mould and yeast were also carried out and the results obtained showed a snack product containing nutrients required for diabetic patient with a projected shelf life of one year.

Key words: Quality, biscuit, acha, *Digitaria exilis*, bambara, unripe plantain.

INTRODUCTION

Biscuit may be regarded as a form of confectionary, dried to very low moisture content. Consumption of whole grains is an excellent source of dietary fibre and nutraceutical that are of benefit in the management of obesity and diseases such as diabetes (Jideani and Jideani, 2011). The consumption of cereal foods such as biscuit has become very popular in Nigeria especially among children. Most of these cereal foods are poor in protein content and protein quality (Alobo, 2001). Enrichment of cereal-based foods with other protein sources such as oil seeds and has received considerable attention (Ayo et al., 2007; Dhingra and Jood, 2002; Elkhalifa and El-Tinay, 2002; Ayo and Gaffa, 2002; Ayo and Olawale, 2003). Legumes are high in lysine, an essential limiting amino acid in most cereals (Alobo, 2001).

The production of good quality biscuit would depend on selecting the correct flour for each type and appropriate processes involving steps such as mixing, aeration and fermentation, machining including laminating, baking,

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cooling and packaging (Okaka and Okaka, 2005). The introduction of composite flour into the bakery world has brought about different changes into baked products

Some of the oldest popular cereal grains of *Digitaria* spp., *Digitaria exilis* (acha) and *Digitaria iburua*, (iburu), also known as fonio or hungry rice are indigenous grains of West Africa (Jideani, 2012). Acha and iburu proteins have composition similar to that of white rice (Temple and Bassa, 1991; Jideani and Jideani, 2011), but having relatively higher sulphur amino acids (methionine and cystine) content (de Lumen et al., 1993; Lasekan, 1994; Jideani et al., 1994). These and other attributes of acha and iburu show the uniqueness of the grains and their potential in contributing significantly to whole grain diets. Acha grain can also be grounded into flour to produce biscuit (Jideani, 2012).

However, there is sufficient evidence showing that higher whole grains diet when compared with refined grain diet are beneficial for treating or managing several health problems (Jones, 2009). Recent research has shown that acha helps diabetic patients to recover due to its low glycemic index (Balde et al., 2008). The *in vitro* starch digestibility and glycemic property of acha, iburu and maize porridge has been investigated (Jideani and Podgorski, 2009). The study showed that the total starch (TS) for maize, acha and iburu flours were 45.3, 43.6 and 41.5%, respectively. The resistant starch (RS) was 2.9, 2.1 and 1.2, respectively for maize, acha and iburu flours and the digestible starches (DS) 43.7, 41.4 and 40.0%. The authors concluded that acha and iburu may have potential in a low GI food as porridge from both grains had low estimated value of 40. Low-GI diets may improve both glycemic control and cardiovascular risk factors for patients with type 2 diabetes (Jenkins et al., 2008).

Bambara nut (*Vigna subterranea*) is an important legume grain in semi arid Africa. It is resistant to high temperature and suitable for marginal soil where other leguminous crops cannot be grown (Baryeh, 2001). Bambara nut is an important source of high protein value for poorer people in Africa who cannot afford expensive animal protein (Baryeh, 2001; Stading, 2006).

Plantain is the common name for herbaceous plants of the genus *Musa*. Plantains are classified formally as *Musa acuminate* and *Musa balbisiana* depending on their genomic constitution. It provides more than 25% of the carbohydrate requirements for over 70 million people and tends to be firmer and lower in sugar content. Plantains are commonly cooked or otherwise processed and are used either when green or unripe (starchy) or over ripe (sweet) (Oke et al., 1998). An average plantain has about 220 calories and is a good source of potassium and dietary fiber (Randy et al., 2007). It is rich in carbohydrate, dietary fiber, iron, vitamins and minerals. It is ideal for diabetics, children and pregnant women and can also be a good supplement for marasmus patients. Plantain contain small amount of serotonin which has the ability to dilate the arteries and improve blood circulation. Its regular consumption helps to cure anemia and maintain a healthy heart (USDA, 2010). A diet of unripe plantain is filling and can also be a good inclusion in a weight loss diet plan (Oke et al., 1998).

Many countries have produced composite product using other cereals like rice, sorghum, acha, bambara nut, maize and starchy root. Biscuit may be classified either by the degree of enrichment and processing or by the method adopted in shaping them (Okaka and Okaka, 2005). Wheat flour blended with acha flour up to 30% has shown no significant difference in terms of sensory qualities (Ayo and Nkama, 2003). Acha-wheat flour has been fortified with soybean flour to improve the nutritional value when used for production of biscuit (Ayo et al., 2007). Acha-malted soybean has been used for the production of bread and biscuits (Ayo et al., 2014). Acha-based biscuit improved with bambara nut and unripe plantain is a good and cheap source of nutrient than wheat flour used by the baking industry.

Despite the inherent potentials of acha, bambara and unripe plantain, little has been done to incorporate them in most food formulations. The objectives of this research work are (i) production and packaging of acha biscuit, improved with bambara nut and unripe plantain at different proportions, (ii) evaluation of the physical properties of the biscuits, (iii) determination of acceptability of the biscuits and (iv) evaluation of the chemical composition of the acha-based biscuits and microbiological properties of the best two biscuits.

MATERIALS AND METHOD

Source of material

Acha grain (*D. exilis*), bambara nut (*V. subterranea*), unripe plantain (*M. paradisiaca*), Royal baking powder, evaporated peak milk, Simans baking fat, Dangote granulated sugar, and salt were purchased from Wunti Market Bauchi, Nigeria. The equipment and chemicals used were of analytical grade.

Preparation of acha and bambara nut flours

Acha (*D. exilis*) grains were washed with clean water several times in a container in order to remove tiny stones and dust as well as foreign materials. The bambara nut (*V. subterranea*) were dry clean to remove shells and other foreign material such as stones in the grain, Both acha and bambara nut were drained and sun-dried, milled using hammer mill (CD1155-3-1317) and sieved with the aid of a 425 µm sieve (Endecotts Ltd, London, England). The flour was packaged in polyethylene bag and stored at low temperature as acha or bambara flour

Preparation of unripe plantain flour

Unripe matured plantain (*M. paradisiaca*) was washed with clean water and peeled with stain less knife to separate skin from fruit. The peeled fruit was sliced to equal size and dried under the sun. The drying, milling, sieving and storage were as in acha and bambara nut flours.

Table 1. Recipe (%) for acha-based biscuit samples.

Sample code	Acha flour	Bambara nut flour	Unripe plantain flour	Fat	Egg	Sugar	Salt	Baking powder
ACH105	100	0	0	49	30	45	0.6	3.6
ACH801	80	10	10	49	30	45	0.6	3.6
ACH702	70	20	10	49	30	45	0.6	3.6
ACH603	60	30	10	49	30	45	0.6	3.6
ACH504	50	40	10	49	30	45	0.6	3.6

Source: Department of Food Technology, Kaduna Polytechnic, Kaduna, Nigeria (2004).

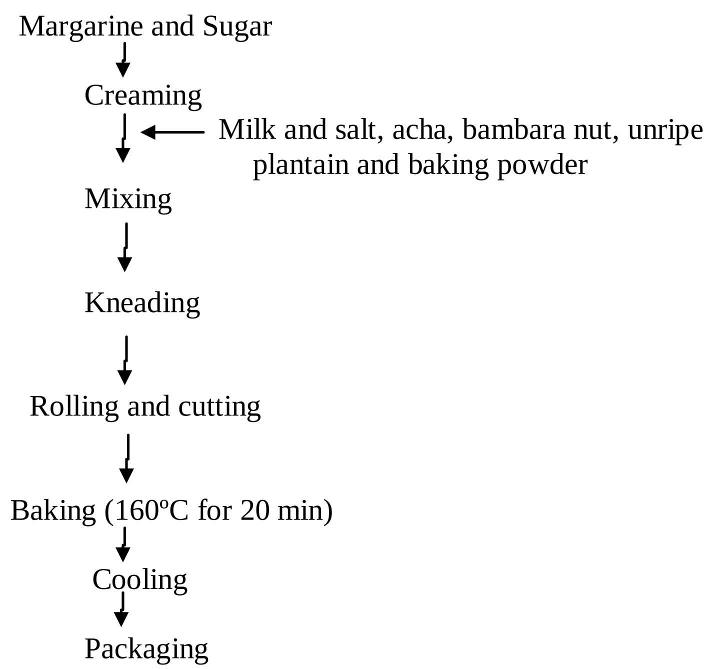

Figure 1. Production of acha, bambara nut and unripe plantain biscuit.

Production of acha, bambara and unripe plantain flour biscuit

The essential ingredients for the production of composite biscuit and their various proportions are shown in Table 1. The acha, bambara nut and unripe plantain flours were used at various proportions while the milk, fat, baking powder, sugar and salt were the same for all the proportions. The recipe for the composite biscuit was chosen based on the Department of Food Technology Kaduna Polytechnic, Kaduna, Nigeria (2004) manual with slight moderations. The flow chart for production of composite biscuit from acha, bambara nut and unripe plantain is shown in Figure 1. After weighing with an electric weighing balance (Sauter, RC 8021 model), the fat was manually mixed vigorously with sugar for 10 min to form a cream. The acha, bambara nut and unripe plantain flours at different levels as shown in the recipe in Table 1 was added with the other ingredients like salt, baking powder. The mixing was done properly and the method of Okaka (1997) was used to produce the biscuits.

Physical analysis

For spread ratio, two rows of five well formed biscuits were made and the height measured. They were also arranged horizontally edge to edge and the sum of the diameters measured. The spread ratio was calculated as diameter divided by height (Gomez et al., 1997). Break strength was determined using break strength device (Okaka and Isieh, 1990). Biscuit sample of 0.4 cm thickness was placed centrally between two parallel metal bars 2 cm apart and weights were applied until the biscuit snapped. The least weight that caused the breaking of the biscuit was regarded as the break strength of the biscuit.

Sensory evaluation of the biscuit samples

The biscuits were subjected to sensory evaluation using twenty panelists from the Federal Polytechnic, Bauchi, Nigeria based on their familiarity with the product. The products, appropriately coded and of the same size and temperature (29 ± 3°C) were placed in white plastic plates. The panelist rinsed their mouths with bottled water after tasting each sample (Larmond, 1977) served to the in different boots under the florescent light. A nine-point Hedonic scale with one (1) representing “extremely dislike” and nine (9) “extremely like” was used. The qualities assessed were color, texture, taste, flavor, crispness and general acceptability (Akinjayeju, 2009).

Although, the panelists were not trained, their selection was based on basic requirements of a panelist, such as availability for

Table 2. Physical quality of acha-based biscuit samples.

Sample code	Acha flour (%)	Bambara nut flour (%)	Unripe plantain flour (%)	Weight (g)	Spread ratio	Break strength (g)
ACH105	100	0	0	10.0	9.15	900
ACH801	80	10	10	10.0	9.30	600
ACH702	70	20	10	9.50	9.50	700
ACH603	60	30	10	9.50	10.32	700
ACH504	50	40	10	9.20	11.22	850

the entire period of evaluation, interest, willingness to serve, good health (not suffering from colds), not allergic or sensitive to the products evaluated (Penfield and Campbell, 1990).

Proximate composition

The moisture, protein, fat, ash and crude fibre contents were determined according to AOAC (2000). The total carbohydrate (CHO) was determined by difference: CHO = 100 – (% moisture + % protein + % fat + % ash). Food energy (kcal/100 g) was calculated according to the method of Marero et al. (1988) using the factor: [(4 x % Protein) + (4 x % Carbohydrate) + (9 x % Fat)]

Microbiological analysis

The pour plate method was adopted as described by Jideani and Jideani (2006). Nutrient agar and potato dextrose agar were prepared as specified by the manufacture for bacteria and fungi respectively. Serial dilution was carried out on suspension of the biscuit samples using quarter strength peptone water before plating on the media. Incubation was done for 24 h at 37°C for bacteria, and 3 to 4 days for yeast and mould at room temperature of 25°C. The colonies were counted using an electronic colony counter (Gallenkamp, 443 300 66087, UK).

Statistical analysis

The results obtained were subjected to analysis of variance (ANOVA) and Duncan multiple range test (Duncan, 1955) was used to separate means where significant differences existed. The software used for the statistical analysis was MINITAB ver. 16.

RESULTS AND DISCUSSION

The physical analysis of the biscuits is shown in Table 2. The weight of the biscuits ranged from 9.2 - 10.0 g. The control sample ACH105 (100:0:0% acha, bambara nut and unripe plantain flour biscuit) had the highest weight. The weight of the biscuits decreased with increase in bambara nut flour with sample ACH801 (80:10:10% acha, bambara nut and unripe plantain flour biscuit) having the highest weight and sample ACH504 (50:40:10% acha, bambara nut and unripe plantain flour biscuit) having the lowest. The decrease in weight could be due to the increase in the fat content of the blended bambara nut flour, as fat is lighter in weight (Ayo et al., 2007). These results were similar to those for bambara groundnut-maize flour (Akpapunam and Darbe, 1994), millet-sesame flour (Alobo, 2001) and amaranth-wheat flour (Ayo, 2001).

The spread ratio of the biscuit increased from 9.30 - 11.22. The increase is an indication of the binding properties of the flour and of the texture of the biscuits. The increase in the fats content (Table 4) could also affect the spread ratio (Ayo et al., 2007). The break strength decreased from 900 - 600 g with increase in percentage of bambara nut flour. The decrease could be due to the increase in the percentage of fats (19.70-20.12%) with increase in percentage of bambara nut flour added, diluting the protein and carbohydrate level which are the principal compounds responsible for hardness in biscuits (Okaka and Isieh, 1990).

The mean scores for the sensory evaluation of the biscuits are shown in Table 3. There was no significant difference ($p < 0.05$) in crispness and flavour of the biscuits while significant differences ($p < 0.05$) existed in taste, texture, colour and overall acceptability. The biscuits compared favourably with 100% acha biscuit which significantly differed ($p < 0.05$) from the other biscuits except in flavor and crispness.

There was a general decrease in the mean scores of all the parameters with increase in bambara nut and unripe plantain flours except for texture which increased. Sample ACH801 (80:10:10% acha, bambara nut and unripe plantain flour biscuit) had the highest mean value in most of the parameters monitored while sample ACH105 (100:0:0%) acha, bambara nut and unripe plantain flour biscuit) had the lowest mean value in all the parameters with the exception of texture. The crust texture was related to the external appearance of the biscuit top, which is the smoothness or roughness of the crust (Ayo et al., 2007). The texture reduced from 7.30 for 100% acha flour biscuit to 6.85 for 80:10:10% acha, bambara nut and unripe plantain flour biscuit and gradually increased as the proportion of bambara nut and unripe plantain flour increased.

There was a general decrease in the overall acceptability of the biscuits with decrease in acha flour and increase in bambara nut flour and unripe plantain flour. Sample ACH801 (80:10:10% acha, bambara nut and unripe plantain flour biscuit) had the highest mean

Table 3. Sensory evaluation of the biscuit samples.

Sample code	Proportion of flours (%)			Taste	Crispness	Flavour	Texture	Colour	Overall Acceptability
	Acha	Bambara nut	Unripe plantain						
ACH 105	100	0	0	6.80^{a} ± 1.39	7.15^{a} ± 1.53	6.35^{a} ± 1.63	7.30^{a} ± 1.46	6.95^{a} ± 1.43	6.90^{ab} ± 1.58
ACH 801	80	10	10	7.30^{a} ± 1.63	7.20^{a} ± 1.80	7.25^{a} ± 1.48	6.85^{a} ± 1 .95	7.50^{a} ± 1.61	8.00^{a} ± 0.85
ACH 702	70	20	10	7.00^{a} ± 1.65	7.05^{a} ± 2.01	6.85^{a} ± 1.42	7.05^{a} ± 1.28	7.40^{a} ± 1.67	7.50^{ab} ± 1.49
ACH 603	60	30	10	6.95^{a} ± 1.82	7.50^{a} ± 1.64	6.85^{a} ± 1.63	7.25^{a} ± 1.21	7.30^{a} ± 1.56	6.40^{b} ± 1.78
ACH 504	50	40	10	6.35^{a} ± 1.60	7.05^{a} ± 2.04	6.65^{a}± 1.76	7.35^{a} ± 1.46	7.25^{a} ± 1.83	6.80^{ab} ± 1.79

Values are mean ± standard deviation of twenty panelists. Means within each column not followed by the same superscript are significantly different ($p < 0.05$) from each other using Duncan multiple range test.

Table 4. Proximate (%) and energy compositions of acha based biscuit improved with bambara nut and unripe plantain.

Parameter	Samples				
	ACH 105	ACH 801	ACH 702	ACH 603	ACH 504
Acha	100	80	70	60	50
Bambara nut	0	10	20	30	40
Unripe Plantain	0	10	10	10	10
Moisture	2.06^{a} ± 0.05	2.04^{a} ± 0.10	2.03^{a}± 0.00	2.08^{a} ± 0.01	2.07^{a} ± 0.09
Protein	5.30^{d} ± 0.13	6.20^{c} ± 0.02	6.43^{c} ± 0.11	7.00^{b} ± 0.15	7.51^{a} ± 0.03
Fat	19.86^{a} ± 0.14	20.12^{a} ± 0.02	20.10 ^{a} ± 0.07	20.08^{a} ± 0.06	19.70^{a} ± 0.57
Ash	2.31^{d} ± 0.02	2.28^{d} ± 0.14	2.67^{c} ± 0.06	3.41^{a} ± 0.02	3.09^{b} ± 0.05
Crude fibre	3.56^{a} ± 0.05	2.27^{ab} ± 0.02	2.43^{a} ± 0.06	2.08^{b} ± 0.04	2.40^{a} ± 0.13
Carbohydrate	71.47^{a} ± 0.15	69.36^{ab} ± 0.15	68.77^{abc} ±0 .06	67.43^{bc} ± 0.06	67.63^{bc} ± 1.02
Energy (Kcal/100 g)	485.82^{a} ±1.22	483.32^{a} ±0.56	481.70^{ab} ± 0.83	478.44^{b} ± 0.21	477.86^{b} ± 1.75

Values are mean ± standard deviation. Any mean not followed by the same letter on each column are significantly different ($p < 0.05$).

value of 8.0 in overall acceptability which made the biscuit most acceptable (Figure 2). This is an indication that the improvement was acceptable to the consumers. Therefore, the two best biscuits based on the overall acceptability of sensory properties were ACH801 and ACH702 (Table 3).

The proximate and energy compositions of acha biscuit improved with bambara nut and unripe plantain flours are shown in Table 4. The moisture content (%) of the acha based biscuit increased from 2.03-2.08 with addition of bambara nut and unripe plantain. The low moisture content of the biscuit will require a unique packaging material to prevent reabsorption of moisture. The protein content (%) of the biscuit increased from 5.30 - 7.51 with increase in bambara nut and unripe plantain. Sample ACH105 had no addition of bambara nut hence had lowest protein content. Bambara nut is a rich source of protein. Legume was used and they are known to be high in both fat and protein (Dhringa and Jood, 2002). The fat

Figure 2. Acha based biscuit (80:10:10% acha, bambara nut and unripe plantain flours) in polyethylene bag and paperboard.

content (%) ranged from o 19.70 - 20.12 with increase in bambara nut and because of added baking fat. The baking fat could be reduced in subsequent baking as to elongate the shelf life of the biscuits. The ash content (%) increased from 2.28 - 3.09 with increase in bambara nut and added unripe plantain flour which is a rich source of mineral.

Ash content indicates the presence of mineral matter in food. Ash is a non organic compound containing the mineral content of food. It aids in the metabolism of other compound such as protein fat and carbohydrate (Okaka and Ene, 2005). The crude fibre (%) decreased from 3.56-2.08 with increase in bambara nut and unripe plantain flour. Also, decrease was observed in the carbohydrate and energy contents.

The microbial analysis for first week showed no growth in bacteria, mould and yeast. This could be because the product is freshly produced and packaged but growth began at the second week with 1.0×10^4 cfu/g for sample ACH 801 and at fourth week it increased to 3.5×10^4 cfu/g (Table 5). This increase could be due to make up of the product which contained protein. From the result, it could be concluded that mould and yeast are the possible spoilage organism associated with dry product. Bacteria growth in the product was as a result of handling during processing.

Conclusion

High quality biscuit was produced from acha, bambara nut and unripe plantain. The addition of bambara nut and unripe plantain improved the physical, proximate and sensory quality of acha biscuit. Nutritionally, the protein

Table 5. Microbial count of the two acceptable biscuit.

Sample	No. of viable count		
	Weeks	Bacteria (cfu/g)	Mould/yeast (cfu/g)
ACH801 (80% acha,10% bambara nut & 10% unripe plantain)	1^{st}	Nil	Nil
	2^{nd}	1.0×10^4	1.0×10^4
	3^{rd}	2.0×10^4	3.0×10^4
	4^{th}	2.1×10^4	$4.\ 0 \times 10^4$
ACH702 (70% acha, 20% bambara nut & 10% unripe plantain)	1^{st}	Nil	Nil
	2^{nd}	1.0×10^4	2.0×10^4
	3^{rd}	2.0×10^4	3.0×10^4
	4^{th}	3.5×10^4	$5.\ 0 \times 10^4$

content increased from 5.30 - 7.51%, fat from 19.86 - 20.12%, ash 2.28 - 3.09%, crude fibre 2.27 - 2.39% at different proportions. The sensory qualities were significantly different with addition of unripe plantain and bambara nut flours. For ACH801 (80: 10: 10% acha, bambara nut and unripe plantain flours), the biscuit was generally acceptable. The production of biscuit from acha could reduce the use of wheat importation for baking. The authors recommend acha based biscuit improved with bambara nut and unripe plantain for both children and diabetic patients.

Conflict of Interests

The author(s) have not declared any conflict of interests.

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