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Phytochemicals, Antioxidant, Physico-Chemical and Sensory Properties of Yam-Based Cookies Produced from Flours of Five Yam Varieties

Dorcas Nguemo Kundam [a,b*], Julius K. Ikya [a,c] and Joseph S. Alakali [a]

[a] Centre for Food Technology and Research, Benue State University, Makurdi, Nigeria.
[b] Department of Food Science and Technology, University of Mkar, Mkar, Gboko, Nigeria.
[c] Department of Food Science and Technology, Joseph Sarwuan Tarka University of Agriculture, Makurdi, Nigeria.

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

The aspiration to reduce post-harvest losses of yams via the promotion of utilisation of the abundant readily available raw materials for industrial purposes and production of health-enhancing foods prompted this research. This work focused on evaluating the *phytochemical,* antioxidant, physicochemical and sensory properties of yam-based cookies produced from the flours of five yam varieties. Established standard procedures were used in all analyses. Results showed; Phytochemical compounds such as phenols, flavanoids, alkaloids and tannins were found present in the yam-based cookies in the range of 0.24- 0.37mg/100g, 0.26- 0.40 mg/100g, 0.6-

**Corresponding author: Email: dorcamo@yahoo.com, dnkundam@umm.edu.ng;*

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2.13mg/100g and 0.01- 0.17mg/100g. Saponin was not detected in all the yam flour cookies. Only a trace of 0.05 mg/100g was observed in wheat flour cookies (the control), Antioxidant activities of the yam-based cookies revealed that DPPH, FRAP, MCA, HRSA and SRSA ranged from 41.19-84.32, 0.29-0.95, 34.15-78.51, 29.64-69.54 and 24.13- 81.52 accordingly. Gluthanion was used as standard. The general trend observed was that, in all cases; sample HKC had the least antioxidant activities, OGC and ARC had higher antioxidant activities among the yam-based cookies, while GSH (the control) had the highest. The proximate values for Moisture, ash, crude fiber, crude protein, fat, carbohydrate and energy of yam-based cookies ranged from 7.31- 8.80%, 1.10 - 2.30%, 0.13 – 4.27%, 8.53-10.48%, 2.24 – 3.84%, 73.70-78.38% and 334.06-359.28 Kcal/100g. Physical properties of the Yam-based cookies such as diameter, width, thickness, weight, Spread ratio, spread factor and fragility ranged from 3.70-4.67 cm, 23.93-28.00 cm, 2.63-4.33cm, 5.16-9.67g, 0.83-1.64, 54.63-106.84 and 430.00-790.00g respectively. Cookies from all samples showed good physical quality features for the production cookies and biscuits. Sensory properties such as appearance, texture, crispiness aroma, taste and general acceptability of yam-based cookies ranged from 5.32-8.30, 6.48-8.44, 7.50-8.44, 6.36-7.68, 7.48-8.50, and 6.30-7.84 on a 9-point hedonic scale. Data from this study proved that it was feasible to produce acceptable cookies from the flours of the five yam varieties selected. Overall, samples GBC and ARC cookies competed favorably with the control-wheat cookies and are recommended for mass production. In Particular, sample ARC also combined good nutritional, phytochemical quality and strong antioxidant activities that could be of health benefits to consumers.

Keywords: Post-harvest losses; phytochemicals; antioxidants; health benefits; confectioneries.

1. INTRODUCTION

Cookies are biscuit that are customarily made from wheat flour, but the escalating cost and limited supply of wheat in developing nations demand that consideration be given to the application of indigenous roots and tuber crops to substitute wheat in bakery products [1]. Several authors have reported on the preparation of cookies from wheat flour substituted with fruit pomace, grains, root and tuber crops [2,3,4]. Yams have *industrial* values, so postharvest losses of yams can be reduced by converting highly perishable yam tubers at harvest into shelf-stable yam flours to be used for processing of baked products like biscuits, cookies, cakes, bread, muffins, Shortbread, etc to scale up or diversify uses of yams to reduce postharvest losses of the yams [5,6]. This will resolve the issue of rising cost and limited supply of wheat, post-harvest losses of local crops and production of foods that have improved nutritional value and health benefits [7]. Preparation of a confectionery like cookies from yam flours will transform the bulky yams into convenience food, ease transportation, enable the exportation of yams as finished rather than primary products and also prolong the shelf life of yams [8]. This implies more wealth to the farmers, more productivity and increased capacity to employ more hands leading to a reduction in unemployment and poverty. Also, yam and its byproducts would be obtainable at inexpensive prices at all times, Rural-urban migration would be reduced and reduction of foreign exchange on wheat flour importation would be achieved [9]. Therefore, this research investigated the feasibility of baking nutritious, acceptable and health-benefitting cookies from processed flours of five yam varieties.

2. MATERIALS AND METHODS

2.1 Sources of Materials

Five varieties of Yam tubers were purchased from Ukum Local Government area of Benue state in the month August 2022. The five yam varieties used in this research included, four (4) types of white yams-*Discorea rotundata* known as *Ichi* (Akweya), *Angwo* (Etulo), *Ihi* (Idoma), *Ijuh* (Igede), *Doya* (Hausa), and *Iyou* (Tiv) and Water yam-*Discorea alata* known as *Ipem/Ibem* (Akweya), *Angumo* (Etulo), *Ebuna/Obuna* (Idoma), *Ochua* (Igede), *Sakata* (Hausa), and *Agbo* (Tiv) [10]. The specific white yam varieties used were *Ogoja, Faketsa, Hembankwase, Amura* (*Discorea rotundata*) and *Gwebe* (Water yam - *Discorea alata*). An experienced botanist from the Department of Biological Sciences, Benue State University authenticated the yam samples. Wheat flour (control) and all other baking ingredients such as eggs, baking powder, fat, and sugar were purchased from Wurukum Market Markudi, Benue State, Nigeria.

2.2 Methods

2.2.1 Production of yam flour

Flours from the five yam varieties were produced using the method of Oluwole et al. [11], with slight modifications as shown in Fig. 1.

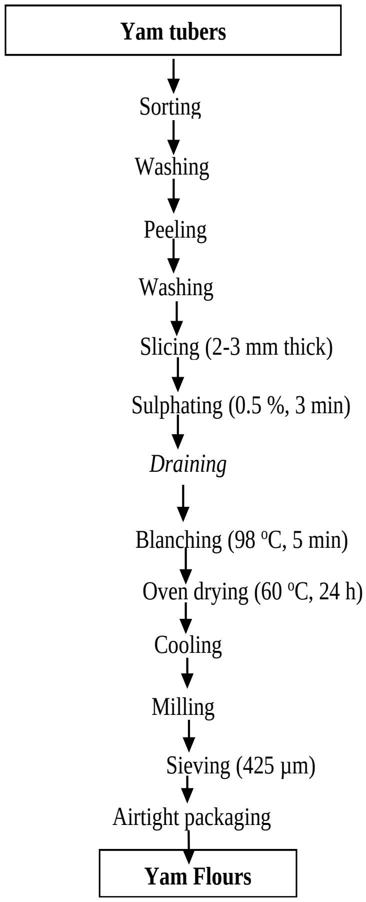

Fig. 1. Flow chart for the production of yam flours
Source: [11]

2.2.2 Cookies recipe

The recipe of cookies produced from flours of five yam varieties was formulated according to the modified recipe of Chinma [12] as shown in Table 1.

Table 1. Cookies Production Formula

SN	INGREDIENT	GRAMS(g)	MODIFIED (g)
1	Flour	49.5	50.0
2	Margarine	20.0	10.0 (**King Vegetable oil**)
3	Beaten eggs	10.0	10.0
4	Sugar	20.0	10.0
5	Sodium Bicarbonate	0.5	0.5
6	Salt	-	0.5
7	Water	-	19.0

Source: Modified [12]

2.2.3 Methodology for production of cookies

All dried ingredients were mixed first and then poured into the liquid ingredients and mixed thoroughly. The batter was kneaded to a uniform thickness of 5.0mm and cut into Cookies shapes. Baking was performed in hot air oven (Horizontal Drying Oven, 101-1AB. PEC- MEDICAL USA) at 90°C for 120min at the University of Mkar, Mkar Gboko Food Science Laboratory. They were cooled for 30min and stored in airtight containers until needed for analysis. Cookies made from 100% wheat served as a control [12] and [13].

2.3 Analyses

2.3.1 Proximate analysis of the cookies from flours of five yam varieties

Proximate composition was determined using the AOAC, [14] method. The samples were analyzed for moisture, ash, crude fiber, crude fat and crude protein. Carbohydrate was calculated by the difference. The energy content of the flours was determined using the attwater factor, as shown in equation (i).

$$Energy\ (kcal/100\ g) = 4 \times \%Protein + 9 \times \%Fat + 4 \times \%Carbohydrate \quad \text{(i)}$$

2.3.2 Determination of phytochemicals of cookies from flours of five yam varieties

2.3.2.1 Determination of total phenolic content

The total phenolic content of the samples was carried out using Folin Ciocalteu's phenol reagent as described by [15]. The concentrations of the phenolic compounds in the samples were extrapolated from the standard curve and expressed as mg gallic acid equivalent per g (mg GAE/g), taking into consideration the dilution factor of the samples.

2.3.2.2 Tannin determination

The t*annin* content of the samples was evaluated as described by Makkar et al. [16].

2.3.2.3 Determination of the total flavonoid concentration

The concentration of flavonoids in the samples was determined spectrophotometrically according to the procedure of Cong-Hau et al. [17]. The concentrations of the flavonoids were expressed as milligramme catechin equivalent per g of extract (mg CA/g extract).

2.3.2.4 Alkaloid determination

The *Alkaloid* content in the samples was determined as described by Nwalo et al. [18] in equation (ii).

$$\%\text{ALKALOID} = \frac{\text{Weight before} - \text{Weight after}}{\text{weight before}} \times 100 \quad \text{(ii)}$$

2.3.2.5 Saponin determination

The spectrophotometric method used by Adewole, [19] for Saponin determination.

2.3.3 Determination of antioxidant properties of the cookies from flours of five yam varieties

2.3.3.1 DPPH radical scavenging activity

The free radical scavenging ability of the Samples were determined using the stable radical DPPH (2, 2-diphenyl-1-picrylhydrazyl hydrate) method described by Pownall et al. [20]

The free radical scavenging ability was calculated using the equation (iii).

$$\%\ DPPH = \frac{Absorbance\ of\ control - Absorbance\ of\ sample}{Absorbance\ of\ control} \times 100 \quad \text{(iii)}$$

2.3.3.2 Metal chelating ability assay

The metal-chelating assay of the samples was carried out according to the method of Pownall et al. [20]. The inhibition of ferrozine–Fe^{+2} complex formation was calculated using the following equation (iv):

$$Chelating\ effect = \frac{Acontrol - Asample}{Acontrol} \times 100 \quad \text{(iv)}$$

Where $A_{control}$ = absorbance of the control sample (the control contained 1 mL each of $FeCl_2$ and ferrozine, complex formation molecules) and A_{sample} = absorbance of the sample.

2.3.3.3 Ferric reducing antioxidant power (FRAP) of the samples

The FRAP of the samples were determined using the colorimetric method of Firuzi et al. [21],[22]. The FRAP of the samples obtained in mg AAE/ mL was expressed in mg AAE/ g using the equation (v).

$$FRAP = \left(\frac{mgAAB}{g}\right) = \left(\frac{mgAAE}{mL}\right) x \left(\frac{mL\ solvent}{g\ sample}\right) x\ dilution\ factor \quad \text{(v)}$$

2.3.3.4 Superoxide radical scavenging activity (SRSA)

The method described by Pownall et al. [20], was used to determine the SRSA of the samples

The superoxide scavenging activity was calculated using the following equation (vi):

$$SRSA = \frac{slope\ of\ blank\ for\ SRSA - slope\ of\ sample\ for\ SRSA}{slope\ of\ absorbance\ per\ minute\ of\ blank\ of\ SRSA} \times 100 \quad \text{(vi)}$$

2.3.3.5 Hydroxyl radical scavenging activity

The hydroxyl radical scavenging activity (HRSA) of the samples was determined using the method described by Olagunju et al. [23]. The HRSA value was calculated using equation (vii):

$$HRSA = \frac{slope\ of\ blank\ for\ HRSA - slope\ of\ sample\ for\ HRSA}{slope\ of\ absorbance\ per\ minute\ of\ blank\ for\ HRSA}\ x\ 100 \quad \text{(vii)}$$

2.3.4 Physical properties of cookies from flours of five yam varieties

According to Chinma et al. [24], Cookies width (w) was measured by placing six cookies edge to edge, measuring their width, rotating them through 90^o and re-measuring them, to obtain the average width in millimetres (mm). Cookies thickness (T) was measured by stacking six cookies on top of each other, measuring the thickness, restacking in a different order and re-measuring them to obtain the thickness in millimetres (mm). Both were done with meter rule. The spread factor (SF) was determined from the width and thickness figures as in equation (viii).

$$SF= \frac{W}{T} \text{ x C.F x 10.} \quad \text{(viii)}$$

Where, C.F is the correction factor for adjusting $\frac{W}{T}$ to constant atmospheric pressure. For this work, correction factor C.F = 1.00.

Diameter and thickness of the cookies was used to determine the spread ratio (SP) as described by (McWatters et al. [25], in equation (ix).

$$SP = \frac{Diameter}{Thickness} \quad \text{(ix)}$$

The vernier caliper was used to determine cookies diameter and fragility of the cookies by use of standard weights [26]. Fragility was determined using the method described by Okaka, & Isieh, [27]. A representative sample of cookies from each formulation (of the same average weight) was placed centrally between two parallel wooden bars. Standard weights were then placed on the bar incrementally until the cookie fractured. The least weight that caused the cookie to break was the fragility of the cookie. Three representative samples were analyzed from each formulated blend. Cookies weight was determined using an electronic weighing balance.

2.3.5 Sensory properties of the cookies from flours of five yam varieties

Sensory evaluation of the cookies was determined with slight modification using the same procedure as Chinma et al. [24] and Okpala, et al. [28] based on six attributes: appearance, aroma, crispiness, texture, taste and overall acceptability on a 9-point hedonic scale where a higher score indicates better quality attributes. Twenty-four hours after preparation of the cookies, sensory evaluation was carried out. A total of 50 semi-trained panelists were recruited from staff and students of the University of Mkar, Mkar. Each panelist evaluated all the samples prepared for each treatment in one session. The criteria for selection of panelists were that, panelists were regular consumers of cookies and were not allergic to any food. Panelists were instructed to evaluate the appearance, taste, texture, crispness, and general acceptability of the cookies. A nine-point Hedonic scale was neither like nor dislike, and = dislike extremely = 1 used, with 9 = like extremely10 Samples were identified with three-digit code numbers and presented in a random sequence to panelists. The panelists were instructed to rinse their mouths with water after every sample and not to make comments during evaluation to prevent influencing other panelists. They were also asked to comment freely on samples on the questionnaires administered to them.

2.4 Statistical Analysis

Determinations were performed in triplicate. Results are presented as mean value ± standard deviation and analyzed by analysis of variance (ANOVA) using SPSS software package vision 26. Significant differences between means were determined by Duncan's multiple range test (DMRT) at a 95 % confidence limit.

3. RESULTS AND DISCUSSION

3.1 Proximate Composition of Yam-based Cookies from Flours of Five Yam Varieties

The proximate composition of foods is used to evaluate the nutritive value and acceptability of the food products. The result of proximate composition are presented in Table 2. The parameters such as Moisture, ash, crude fiber, crude protein, fat, carbohydrate and energy of yam-based Cookies from the flours of five yam varieties ranged from 7.3-8.80%, 1.10-2.30%, 0.13-4.27%, 8.53-10.48%, 2.24-3.84%, 73.70-78.38% and 334.06-359.28 Kcal/100g respectively. There was significant ($p<0.05$) difference between the samples in their proximate parameters. The lowest moisture content was observed in sample GBC and the highest in HKC. Crude ash was lowest in FTC; highest in ARC. Lowest crude fiber was in WFC (wheat-Control) and the highest ARC. The crude protein content was lowest in GBC and highest in ARC. The fat content was lowest in FTC and highest in WFC. The carbohydrate content was calculated by difference, lowest observed in HKC and highest in GBC. The energy value was lowest in HKC and highest recorded in GBC. Some authors have reported lower values of proximate composition of yam flours/products, particularly protein and fat content compared with the higher values 8.53 - 10.48% (proteins) and 2.24 - 3.47 % (fats) observed in the Cookies produced in this work. For instance; Omohimi et al. [29], reported the proximate composition of traditionally-processed yam products: chips, flakes and flours as ranging from 2.70 - 4.30% (protein) and 0.70 - 1.10% (fat). Lawal & Akinoso [30], produced flours from the two Cultivars of Aerial yam (D. bulbifera) at two different stages of maturation with 3.92-6.24% (protein) and 0.52-2.20% (Fat). Gunasekara et al. [31], observed the composition of four selected underutilized yam varieties in Sri Lanka with 3.97-5.70% (protein) and 0.36-1.09% (fat). While Ayo et al. [32], reported protein composition of pre-treated aerial yam (*Discorea bulbifera*) flour as 5.65 - 7.59% and a fat content of 2.63 - 3.86% (which falls within the same range of 2.24 - 3.47% (fat) in the present work). The increase in the proximate composition of yam-based cookies particularly protein and fat contents compared with the proximate composition of the yam flours (the starting material), could be due to the presence of eggs and vegetable oil in the ingredients mixed for baking of the cookies. This is in consonance with the work of Chinma & Gernah, [12], where Cookies produced using 100% cassava flour had higher values of 6.83% (protein) and 2.25% (fat) compared with the values from the 100% cassava flour of 1.10% (protein) and 1.05% (fat). The same trend was reported by Okpala et al.[28], who used 100% Cocoyam flour as one of their samples in production of cookies.

3.2 Phytochemical Screening of Yam-Based Cookies from Flours of five Yam Varieties

The phytochemical compounds found in the Cookies produced from flours of the five Yam varieties are presented in Table 3. The compounds like Phenolics, Flavanoids, Alkaloids and Tannins ranged from 0.24-0.37mg/100g, 0.26-0.40 mg/100g, 0.6-2.13mg/100g and 0.01-0.17mg/100g accordingly. Significant ($P<0.05$) difference in the phytochemical contents was observed in all the cookies samples. Phenolic was lowest in HKC, highest in OGC, followed by ARC. Flavanoids; lowest in HKC, highest in OGC, followed by ARC. Alkaloids recorded lowest in WFC, then HKC; highest in FTC, followed by ARC. Tannin was lowest in WFC, followed by HKC and highest in OGC, followed by ARC. Saponins were not detected in all the cookies samples and only a trace of 0.05 mg/100g was observed in the wheat flour cookies (the control). The general trend observed among the cookies samples was, the highest presence of phytochemicals was observed in the OGC sample, followed by ARC and lowest HKC in all cases. This implies that, there might be lower bioactive activities in the sample HKC. These data reveal phytochemical contents in our yam-based cookies that contrasted and were higher than values reported by Ugo et al. [33], for cookies produced from composite flour mixture of wheat, Cocoyam, Groundnut and wheat, Cocoyam, Cashew-nut. Same also for, phytochemical values of biscuits produced from composite flours of wheat enriched with okra pod by Joy, [34]. This pattern could be credited to the longer baking time at lower temperature that the cookies samples were subjected to. As relevant literature had indicated that lower baking temperatures and the high exposure times promoted starch degradation and the release of bound polyphenols resulting in free polyphenols. This agrees with Alfeo et al. [13], whose work showed that a longer baking time increase the free polyphenol fractions which could impact antioxidant activity. According to them, antioxidant ability is positively affected by increasing baking time, lower temperature, and sugar amount, although the principal effect is the baking time. They stressed that the greater, the release of polyphenols from the food matrices, the greater the increases in their bioavailability making available these nutraceutical compounds for intestinal absorption. This indicated that with exception of HKC sample, the other Cookies samples exhibited high phytochemical content, implying that our local yams could serve as a rich source of phytochemical compounds which might be beneficial to consumers' health.

3.3 Antioxidant Properties of Yam-based Cookies from Flours of five Yam Varieties (mg/100g)

The antioxidant activities of the cookies produced from the flours of five yam varieties are presented in Table 4. The general trend observed was that; there was significant ($p<0.05$) difference in the antioxidant activities of the samples. Among the yam-based cookies; in all cases, sample HKC had the least antioxidant activity, higher observed in the OGC followed by ARC, and the highest in GSH (the control).

The 1,1-diphenyl-2-picrylhydrazyl (DPPH) radical scavenging activity (DPPH) of the yam-based cookies samples ranged from 41.19-84.32%. HKC had the least antioxidant activity, the highest recorded in OGC followed by ARC. Ferric reducing antioxidant power (FRAP):0.29-0.95%. HKC had the least, highest in the OGC followed by ARC. Metal chelating activities (MCA): 34.15-78.51%. HKC had the least, highest activity in the OGC, followed by ARC. Hydroxyl radical scavenging activities (HRSA):29.64-69.54%. HKC had the least, the highest in the OGC, followed by ARC. Superoxide radical scavenging activities (SRSA):24.13- 81.52 %. HKC had the least, and the highest in the OGC followed by ARC. The antioxidant activities of yam-based cookies showed appreciable antioxidant activities. However, the lowest was observed in the sample HKC indicating that, HKC might have the least free radical scavenging activities. The highest antioxidant activity was observed in the OGC sample followed by the ARC. This could be a result of inter-specie variation. The result of (%RSA) for the yam based-cookies samples ranged from 29.64% to 35.36 %, aligned with antioxidant activity in cookies made from purple yam flour and peanuts reported by Ibdal & Fajar, [35], where the percentage of radical scavenging activity (%RSA) was 39.7%. Hence, these data revealed that some of our local yams can be processed into antioxidant-rich flours and subsequently antioxidant-rich finished food products.

3.4 Physical Properties of Yam-Based Cookies from Flours of Five Yam Varieties

Physical properties such as diameter, width, thickness, fragility, weight, spread ratio and spread factor of cookies produced from the five Yam varieties flours are presented in Table 5.

The result showed that the physical characteristics of the prepared cookies varied with the variation of individual flours. The diameter of cookies samples ranged from 3.70 to 4.67 cm. Width: 23.93 to 28.00 cm. Thickness: 2.63 to 4.33cm. Weight: 5.16 to 9.67g. Spread ratio: 0.83 to 1.64. Spread factor: 54.63 to 106.84. And fragility: 430.00 to 790.00g. Cookies from all samples showed good quality physical features for the production of cookies and biscuits. The results showed that the physical characteristics of the yam-based cookies varied with the variation of individual flours. Similar observations have been reported by other authors Okpala, et al., [28]; JN et al. [36]; Igbabul et al. [37]. The diameter of the wheat Cookies was the smallest. This could be due to the presence of gluten protein in wheat that aids in binding the particles together, giving it the elastic nature, thus preventing spreading. This finding agrees with the observation of Belorio et al. [38] , who reported a decrease in cookie diameter in wheat flour cookies. According to Orisa et al. [39], doughs with lower viscosity cause cookies to spread at a faster rate and vice versa, hence the greater spread in yam flour cookies. Nugraheni et al. [40], had earlier documented that the spread ratio of cookies increased with an increase in the content of non-wheat protein. Increase in spread ratio could also be attributed to increase in the hydrophilic sites in the dough mixture leading to increase in water absorption and swelling index [41].

3.5 Sensory Properties of Yam-based Cookies from Flours of Five Yam Varieties

Sensory properties such as appearance, aroma, taste, crispiness, texture and general acceptability of cookies from the five yam varieties flours are presented in the Table 6. Sensory evaluation is an important tool for determining the overall characteristics of a product. Traditionally sensory attributes are evaluated independently of each other by receptors of the different senses, although the possibility of a multimodal perception by human beings has recently been suggested [42]. Industries and academia have embraced sensory evaluation as an invaluable tool for creating successful products and understanding the sensory properties of materials. Appearance ranged from 5.32 to 8.30, texture: 6.48-8.44, crisipiness: 7.50-8.44, aroma: 6.36-7.68, taste:7.48-8.50, and overall acceptability: 6.30-7.84 respectively. All sensory parameters differed significantly among samples. It was observed that sample HKC had noticeable trace of yam taste; samples FTC and OGC had a bitter after taste; while samples GBC and ARC had no noticeable taste (bland taste like the control-wheat flour). Taste is an important sensory attribute of any food because of its influence on acceptability. In terms of taste, Samples ARC (*Amura* Cookies) and GBC (*Gwebe* Cookies) competed favourably with wheat cookies which was the control. Hence, samples GBC and ARC could be used for the mass production of cookies.

Table 2. Proximate composition of yam-based cookies from flours of five yam varieties

Samples	Moisture (%)	Ash (%)	Fiber (%)	Protein (%)	Fat (%)	Cho (%)	Energy Kcal/100g
WFC(Wheat Cookies)	$8.43^{bc}\pm0.13$	$1.77^{d}\pm0.03$	$0.13^{f}\pm0.01$	$9.43^{c}\pm0.02$	$3.84^{a}\pm0.19$	$76.40^{b}\pm0.58$	$358.78^{a}\pm1.16$
OGC(*Ogoja* Cookies)	$8.64^{b}\pm0.02$	$1.29^{e}\pm0.01$	$2.43^{d}\pm0.04$	$10.16^{b}\pm0.05$	$2.32^{e}\pm0.17$	$75.16^{c}\pm0.31$	$343.37^{c}\pm0.82$
FTC(*Faketsa* Cookies)	$8.21^{c}\pm0.01$	$1.10^{f}\pm0.04$	$4.18^{b}\pm0.03$	$9.23^{c}\pm0.03$	$2.24^{f}\pm0.10$	$75.04^{c}\pm0.26$	$338.48^{d}\pm1.23$
HKC(*Hembakwas* Cookies)	$8.80^{a}\pm0.07$	$2.06^{c}\pm0.05$	$4.27^{a}\pm0.01$	$8.57^{d}\pm0.04$	$2.60^{d}\pm0.30$	$73.70^{d}\pm0.32$	$334.06^{e}\pm1.80$
ARC(*Amura* Cookies)	$7.67^{d}\pm0.03$	$2.30^{a}\pm0.01$	$0.98^{e}\pm0.02$	$10.48^{a}\pm0.05$	$2.72^{c}\pm0.09$	$76.26^{b}\pm0.04$	$350.74^{b}\pm0.62$
GBC(*Gwebe* Cookies)	$7.31^{e}\pm0.04$	$2.17^{b}\pm0.03$	$0.14^{f}\pm0.01$	$8.53^{d}\pm0.02$	$3.47^{b}\pm0.20$	$78.38^{a}\pm0.58$	$359.28^{a}\pm0.45$

Values are mean ± SD of triplicate determinations. Samples with different superscripts within the same column were significantly (p<0.05) different

Table 3. Phytochemical screening of yam-based cookies from flours of five yam varieties (mg/100g)

SAMPLES	Phenolics	Flavanoids	Alkaloids	Saponins	Tannins
WFC	$0.28^{d}\pm0.01$	$0.25^{e}\pm0.00$	$0.16^{f}\pm0.03$	$0.05^{a}\pm0.01$	$0.10^{d}\pm0.00$
OGC	$0.57^{a}\pm0.03$	$0.40^{a}\pm0.00$	$1.03^{d}\pm0.01$	$0.00^{b}\pm0.00$	$0.17^{a}\pm0.00$
FTC	$0.34^{c}\pm0.00$	$0.30^{c}\pm0.00$	$2.13^{a}\pm0.02$	$0.00^{b}\pm0.00$	$0.12^{b}\pm0.00$
HKC	$0.24^{e}\pm0.01$	$0.24^{f}\pm0.00$	$0.86^{e}\pm0.02$	$0.00^{b}\pm0.00$	$0.11^{c}\pm0.00$
ARC	$0.37^{b}\pm0.01$	$0.31^{b}\pm0.00$	$1.25^{b}\pm0.04$	$0.00^{b}\pm0.00$	$0.12^{b}\pm0.00$
GBC	$0.28^{d}\pm0.00$	$0.26^{d}\pm0.00$	$1.12^{c}\pm0.04$	$0.00^{b}\pm0.00$	$0.11^{c}\pm0.00$

Values are mean ± SD of triplicate determination. Samples with different superscripts within the same column were significantly (p<0.05) different

Table 4. Antioxidant activities of yam-based cookies from flours of five yam varieties (mg/100g)

SAMPLES	DPPH	FRAP	MCA	HRSA	SRSA
WFC	$43.60^{e}\pm0.37$	$0.30^{f}\pm0.00$	$35.32^{f}\pm0.10$	$31.48^{d}\pm0.60$	$24.54^{e}\pm0.02$
OGC	$51.39^{b}\pm0.06$	$0.52^{b}\pm0.00$	$40.18^{b}\pm0.03$	$34.05^{b}\pm0.04$	$35.36^{b}\pm0.07$
FTC	$42.58^{f}\pm0.23$	$0.31^{e}\pm0.00$	$35.51^{e}\pm0.13$	$31.53^{d}\pm0.11$	$27.26^{d}\pm0.16$
HKC	$41.19^{g}\pm0.02$	$0.29^{g}\pm0.00$	$34.15^{g}\pm0.05$	$29.64^{e}\pm0.02$	$24.13^{f}\pm0.02$
ARC	$46.23^{c}\pm0.02$	$0.41^{c}\pm0.00$	$38.43^{c}\pm0.01$	$32.09^{c}\pm0.03$	$27.44^{c}\pm0.01$
GBC	$45.63^{d}\pm0.17$	$0.36^{d}\pm0.00$	$38.10^{d}\pm0.02$	$31.87^{cd}\pm0.16$	$27.27^{d}\pm0.06$
GSH	$84.32^{a}\pm0.01$	$0.95^{a}\pm0.01$	$78.51^{a}\pm0.07$	$69.54^{a}\pm0.22$	$81.52^{a}\pm0.06$

Values are mean ± SD of triplicate determinations. Samples with different superscripts within the same column were significantly (p<0.05) different.

**GSH- (Gluthanion as standard)*

Table 5. Physical properties of yam-based cookies from flours of five yam varieties

Samples	Diameter (Mm)	Width (Mm)	Thickness (Mm)	Weight (g)	Spread Ratio (D/T)	Spread Factor (W/T*10*1)	Fragility (g)
WFC	3.70^{b}±0.46	23.93^{c}±0.15	4.43^{a}±0.15	9.67^{a}±1.53	0.83^{c}±0.12	54.03^{d}±1.81	790.00^{a}±10.00
OGC	4.47^{a}±0.31	28.60^{a}±0.92	3.73^{b}±0.15	6.67^{b}±0.57	1.20^{b}±0.11	76.76^{c}±5.53	620.00^{b}±98.49
FTC	4.30^{a}±0.10	27.73^{ab}±0.61	2.90^{bc}±0.26	6.32^{bc}±0.19	1.49^{ab}±0.20	96.02^{bc}±6.39	510.00^{c}±10.00
HKC	4.30^{a}±0.10	28.00^{a}±0.27	3.23^{dcb}±0.51	6.77^{b}±0.64	1.35^{ab}±0.17	88.08^{ab}±14.09	490.00^{c}±10.00
ARC	4.30^{a}±0.10	28.00^{a}±0.44	2.63^{d}±0.21	5.16^{c}±0.17	1.64^{a}±0.11	106.84^{a}±9.80	430.00^{c}±60.83
GBC	4.67^{a}±0.15	26.87^{b}±0.35	3.47^{cd}±0.49	6.18^{bc}±0.03	1.37^{ab}±0.26	78.73^{ab}±13.05	490.00^{c}±10.00

Values are mean ± SD of triplicate determinations. Samples with different superscripts within the same column were significantly (p<0.05) different

Table 6. Sensory properties of Yam-based Cookies from Flours of five Yam varieties

Samples	Appearance	Texture	Crispy	Aroma	Taste	General Acceptability
WFC	5.56^{d}±1.18	6.48^{c}±0.50	7.50^{b}±0.51	8.02^{a}±0.59	8.50^{a}±0.51	7.84^{a}±0.37
OGC	5.36^{d}±0.48	8.38^{a}±0.49	8.38^{a}±0.49	6.36^{e}±0.49	7.48^{b}±0.50	6.30^{c}±0.99
FTC	6.50^{c}±0.51	8.00^{b}±0.57	8.50^{a}±0.51	6.84^{d}±0.37	7.68^{b}±0.47	6.82^{b}±0.89
HKC	5.32^{d}±0.47	8.50^{a}±0.51	8.50^{a}±0.51	7.68^{b}±0.47	7.68^{b}±0.47	6.54^{bc}±1.11
ARC	7.58^{b}±0.49	8.00^{b}±0.53	8.58^{a}±0.49	7.42^{c}±0.49	8.26^{a}±0.83	7.70^{a}±0.84
GBC	8.30^{a}±0.71	8.44^{a}±0.50	8.44^{a}±0.50	7.42^{c}±0.49	8.38^{a}±0.90	7.74^{a}±0.92

Values are mean ± SD of triplicate determinations. Samples with different superscripts within the same column were significantly (p<0.05) different

4. CONCLUSION

Industrial production of yam flours to be used in confectioneries should be encouraged to reduce dependence on imported wheat flour for baking. The yam-based cookies showed good quality in terms of phytochemical content, antioxidant activities, physical properties, and nutritional composition. However, Sample HKC exhibited the lowest phytochemical and antioxidant activities potential. Based on sensory evaluation; only sample samples GBC and ARC had no noticeable taste of yam or any bitter after taste so competed favorably with the control sample WFC (wheat Cookies). Since taste is an important sensory attribute of any food because of its influence on acceptability, samples GBC and ARC should be preferred for mass production. Particularly, sample ARC also combined good nutritional, phytochemical quality and strong antioxidant activities that are desirable characteristics in food products where bioactive composition is of great importance and could be beneficial to consumer's health. Generally, considering the over-all acceptance of cookies, the use of yam flours in production of cookies may enhance the nutritional and health status of the consumers, increase utilization of yams curbing post-harvest losses of the same, reduce total dependence on wheat flour and prevalent incidences of chronic illnesses like diabetes, coeliac disease etc.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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