***PHYTOCHEMICALS*, ANTIOXIDANT, PHYSICO-CHEMICAL, AND ~~AND~~ SENSORY PROPERTIES OF YAM-BASED ~~BASED~~ COOKIES PRODUCED FROM FLOURS OF FIVE YAM VARIETIES**

PEER REVIED BY KAINAT NISAR

The desire to reduce post-harvest losses of yams via the promotion of utilisation~~utilization~~ of the abundant readily available raw~~yam food raw~~ materials for industrial purposes and production of health-enhancing ~~enhancing~~ foods prompted this research. This work focussed~~focused~~ on evaluating the *phytochemical~~phytochemicals~~*, antioxidant, physicochemical,~~physico chemical~~ and sensory properties of yam-based cookies ~~based Cookies~~ produced from the flours~~flours~~ of five Yam varieties. Established standard procedures were used in all analyses~~the analysis carried out~~. Results showed; Phytochemical compounds such as phenols, flavanoids, alkaloids, saponins, and tannins~~Phenolics, Flavanoids, Alkaloids, Saponins and Tannins~~ were found present in the yam-based cookies ~~based Cookies~~ in the range of 0.24- 0.37mg/100g, 0.26- 0.40 mg/100g, 0.6- 2.13mg/100g, Saponins was not detected in all the yam flour cookies~~flours Cookies~~ and only a trace of 0.05 mg/100g was observed~~observed~~ in wheat flour Cookies (the control), 0.01- 0.17mg/100g. Antioxidant activities of the yam-based cookies ~~based Cookies~~ revealed that DPPH, FRAP, MCA, HRSA, SRSA, and ~~SRSA and~~ GSH (Gluthanion as standard) ranged from 41.19-84.32, 0.29-0.95, 34.15-78.51, 29.64 -69.54 and 24.13- 81.52 accordingly. The general trend observed was that, in all cases; sample HKC had the least antioxidant activities,~~,~~ OGC and ARC had higher antioxidant activities among~~amongst~~ the yam-based cookies ~~based Cookies~~, while GSH (the control) had the highest. The proximate~~highest. proximate~~ values for Moisture, ash, crude fibre~~fiber~~, crude protein, fat, carbohydrate, and ~~and~~ energy of yam-based cookies ~~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~~Yam **based Cookies**~~ **such as** diameter, width, thickness, weight, Spread ratio, spread factor, and ~~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 of cookies and biscuits.~~cookies and biscuits production.~~ Sensory properties such as appearance, texture, crispiness, aroma ~~aroma~~, taste, and ~~and~~ general acceptability of yam-based cookies~~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~~9point~~ hedonic scale. Data from this study proved that it~~it~~ was feasible to produce acceptable Cookies from the flours of the five~~five~~ Yam varieties selected. Overall, samples GBC and ARC Cookies competed favourably~~favorably~~ with the control wheat cookies ~~wheat Cookies~~ and are recommended for~~to be used for~~ mass production. In particular~~Particularly~~, sample ARC also~~which also~~ combined good nutritional, phytochemical quality and strong antioxidant activities that could be of health benefits to consumers.

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Keywords: Post-harvest losses; *Phytochemicals*; Antioxidants; Health benefits, Confectioneries

1. INTRODUCTION

Cookies are biscuits that~~Biscuit which~~ are customarily made from wheat flour, but the escalating~~escalating~~ cost and limited supply of wheat in developing nations demand~~is~~

~~demanding~~ that consideration be given to the application of indigenous roots and tuber crops to substitute wheat in bakery products (Amandikwa *et al*., 2015). Several authors have reported on the production of cookies~~production of Cookies~~ from wheat flour substituted with fruit pomace, grains, root, and ~~and~~ tuber crops (Mercy & Ezema, 2016), (Awobusuyi et al., 2020), (Oluseye et al., 2018). Yams ~~Yams~~ have *industrial* values, so postharvest losses of yams can be reduced by converting highly perishable Yam tubers at harvest into shelf-stable ~~stable~~ yam flours to be used for processing of baked products like biscuits, cookies, cakes, bread, muffins, Shortbread, etc. to ~~to~~ scale up or diversify uses of yams to reduce postharvest~~post harvest~~ losses of the yams (Oyeyinka *et al*., 2017), (Zhu, 2015). This will resolve the issue of rising cost and limited supply of wheat, post-harvest losses of local crops, and production~~production~~ of foods that have improved~~improve~~ nutritional value and health benefits (Effah-manu et al., 2022). Production of a confectionery like Cookies from yam flours will transform bulky yams into~~the bulky yams to a~~ convenience food, ease transportation, enable the exportation of yams as finished rather than primary products, and ~~and~~ also prolong the shelf~~shelf~~ life of yams (Awoyale et al., 2015). This implies more wealth to the farmers, more productivity, and ~~and~~ increased capacity to employ more hands, leading to a reduction ~~leading to reduction~~ in unemployment and poverty. Also, Yam and its byproducts would be obtainable at inexpensive prices at all~~all~~ times, Rural-urban migration would~~will~~ be reduced, and a reduction ~~and reduction~~ of foreign exchange on wheat flour importation would be achieved~~achieved~~ (Aighewi, 2015). Therefore, this research investigated the feasibility of baking nutritious, acceptable, and health-beneficial cookies ~~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 the Ukum Local Government area of Benue state in Augustpurchase 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, Disorea rotundata, Discorea rotundata known as Ichi (Akweya), Angwo(Etulo), Ihi (Idoma), Ijuh (Igede), Doya (Hausa), and IyouIyou (Tiv), and water yam, Disorea alata, known and Water yam Discorea alata known as Ipem/Ibem (Akweya), Angumo (Etulo), Ebuna/Obuna (Idoma), Ochua (Igede), Sakata (Hausa), and AgboAgbo (Tiv) (Agishi, 2010). The specific white yam varieties used were Ogoja, Faketsa, Hembankwase, Amura (Discorea rotundata), and and Gwebe (Water yam-Discoreayam - Discorea alata). The yam samples were authenticated by an experienced botanist, J. I. Waya from the Department of Biological Sciences, Benue State University. WheatThe Wheat flour (control) and all other baking ingredients such as eggs, baking powder, fat, and sugar were purchasedpurchase from Wurukum Market Markudi, Benue State, Nigeria.

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2.2 Method

2.2.1 Production of yam flourYam flours

Flours from the five yam varieties were produced using the methodmethod of Oluwole *et al*., (2013) with slight modifications, with slight modification as shown in figure 1. The cookiesAnd Cookies modified recipe is as in table 1.

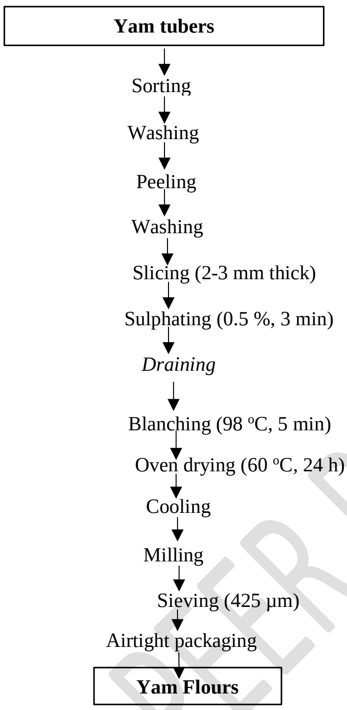

Figure 1. Flow Chart for the Production~~Production~~ of Yam Flours.
Source: (Oluwole *et al*., 2013)

2.2.2 Cookies Recipe.

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	-	1.0
7	Water	-	20.0

Source: Modified Chinma & Gernah, (2007).

2.2.3 Methodology for Production of Cookiesthe Cookies

All dried ingredients were mixed first and thenthen 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 acarried out in the hot air oven (Horizontal Drying Oven, 101-1AB. PEC- MEDICAL USA) at 90°C for 120 min120mins at the University of Mkar, Mkar Gboko Food Science Laboratory. They were cooled for 30 min30mins and stored in airtight containers until needed for analysis. Cookies made from 100% wheat served as a control control (Chinma & Gernah, 2007 and Alfeo et al., 2020).

2.3 Analyses

2.3.1 Proximate Analysis of the flours.

Proximate composition was determined using the AOACAOAC, (2012) methodmethods. Carbohydrate was calculated by the differencedifference. The energyEnergy content of the flours waswere determined using the attwater factor, asattwater factor as shown in equation 1.

$$Energy\ (kcal/100\ g) = 4 \times \%Protein + 9 \times \%Fat + 4 \times \%Carbohydrate \quad (1)$$

2.3.2 *Determination of phytochemicals of cookies Determination of Phytochemicals* of the Cookies produced from flowers of five yamFlours of Five Yam varieties

2.3.2.1 Determination of the totaltotal phenolic content

The total phenolic content of the Samples was carried out using Folin Ciocalteu's phenol reagent as described by (Mujic et al., 2009). The concentrations of the phenolic compounds in the Samples were extrapolated from the standardstandard curve and expressed as mg gallic acid equivalent per g (mg GAE/g), taking taking into consideration the dilution factor of the samples.

2.3.2.2 **T***annin determination*

The tinT*annin* content of the Samples was evaluated as described by Makkar et al., (1996).

2.3.2.3. Determination of the totaltotal flavonoid concentration

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The concentration of flavonoids in the Samples was determined spectrophotometrically according to the procedure of Cong-Hau *et al*., (2021). The The concentrations of flavonoids werethe flavonoids was expressed as milligrammemilligram 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*., (2017).

%ALKALOID = weight before_-weight after/weight before *100

2.3.2.5 Saponin determination

The spectrophotometric method used by Adewole, (2015) for Saponin determination.

2.3.3 Determination of Antioxidant Properties of Cookies Producedthe Cookies produced 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., (2010). The free radical scavenging ability was calculated using the equation below.

$$\% \, DPPH = \frac{Absorbance\ of\ control - Absorbance\ of\ sample}{Absorbance\ of\ control} \quad x \quad 100$$

2.3.3.2 Metal Metal chelating ability assay

The metal-chelating assay of the Samples was carried out according to the method of Pownall et al., (2010). The inhibition of ferrozine–Fe^{+2} complex formationformations was calculated using the following formulaformula:

$$Chelating\ effect = \frac{Acontrol - Asample}{Acontrol} \times 100$$

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

2.3.3.3 Ferric ~~Ferric~~ reducing antioxidant power (FRAP) of the samples

The FRAP of the Samples were determined using the colorimetric~~colorimetric~~ method of Benzie and Strain (1999) and~~used by~~ Firuzi et al., (2005). –The FRAP of the samples obtained in mg AAE/ mL was expressed in mg AAE/ g using the equation

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

2.3.3.4 Superoxide radical scavenging activity (SRSA)

The method described by Pownall et al., (2010) was used to determine the SRSA~~SRSA~~ of the Samples

The superoxide scavenging activity was calculated using the following equation:

$$SRSA = \frac{slope\ of\ blank\ for\ SRSA - slope\ of\ sample\ for\ SRSA}{slope\ of\ absorbance\ per\ minute\ of\ blank\ of\ SRSA}\ x\ 100$$

2.3.3.5 Hydroxyl radical scavenging activity

The hydroxyl~~Hydroxyl~~ radical scavenging activity (HRSA) of the samples was determined using the method described by Olagunju *et al*., (2018). The HRSA value was calculated as follows~~calculated as followed~~:

$$HRSA = \frac{slope\ of\ blank\ for\ HRSA - slope\ of\ sample\ for\ HRSA}{slope\ of\ absorbance\ per\ minute\ of\ blank\ for\ HRSA}\ x\ 100$$

2.3.4 Physical Properties of Cookies

According to Chinma ~~Chinma~~ et al., (2012), 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~~, to get~~ the average width in millimetres~~millimeter~~ (mm). Cookies thickness (T) was measured by stacking six cookies on top of each other, measuring the thickness, restacking in a different order, and ~~and~~ re-measuring them to obtain~~get~~ the thickness in millimetres~~millimeter~~ (mm). Both were done with metre~~meter~~ rule. The spread factor (SF) was determined from the width~~width~~ and thickness figures where; SF= $\frac{W}{T}$ x C.F x 10.

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

The spread~~Spread~~ ratio was determined by the diameter~~diameter~~ and thickness of the Cookies.

SP = $\frac{Diameter}{Thickness}$ (McWatters27)

Cookies diameter was determined~~determine~~ by the use of Vernier caliper and fragility of the cookies by use of standard weights. Fragility was determined using the method described by Okaka, & Isieh, (1990). A representative sample of cookies from each formulation (of the same~~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~~breaking of the cookie~~ was the~~was regarded as the~~ fragility of the cookie. Three representative samples were analysed~~analyzed~~ from each formulated blend~~blend formulated~~. Cookies weight was determined using an electronic weighing balance.

2.3.5 Sensory Properties of the Cookies.

Sensory evaluation of the cookies was determined with slight modification using the same~~same~~ procedure as Chinma ~~Chinma~~ *et al*., (2012) and Okpala et~~, *et*~~ *al*., (2013) based on six attributes: appearance, aroma, crispiness, texture ~~texture~~, taste, ~~,~~ and overall acceptability on a 9-point hedonic scale, where a higher ~~where higher~~ score indicates better quality attributes. Twenty-four hours after the preparation~~preparation~~ of the cookies, sensory evaluation was carried out. A total of 50 semi-trained panellists~~panelists~~ were recruited from the staff~~staff~~ and students of Benue~~the Benue~~ State University, Makurdi. Each panellist~~panelist~~ evaluated all samples~~the samples~~ prepared for each treatment in one session. The criteria~~Criteria~~ for selection of

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panellists~~panelists~~ were that~~that,~~ panellists~~panelists~~ were regular consumers of cookies and were not allergic to any food. Panellists~~Panelists~~ were instructed to evaluate the appearance~~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 panellists~~panelists~~. The panellists~~panelists~~ were instructed to rinse their mouths with water after every sample and not to make comments during the evaluation~~evaluation to~~ prevent influencing other panellists~~panelists~~. They were also asked to comment freely on samples on the questionnaires administered~~given~~ to them.

3. STATISTICAL ANALYSIS

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

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4. RESULTS AND DISCUSSIONS

4.1 Proximate composition of yam-based cookies~~Yam based Cookies~~ produced from different yam~~the different Yam~~ flour samples

The proximate composition of foods was~~is~~ used to evaluate the nutritive value and acceptability of the food products. The results of the proximate~~result of proximate~~ composition are presented~~as presented~~ in Table 2. The parameters such as Moisture, ash, crude fibre~~fiber~~, crude protein, fat, carbohydrate, and~~ and~~ energy of yam-based cookies~~-based Cookies~~ produced 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~~ respectively~~. There was significant ($p<0.05$) difference between the~~all the~~ samples in their proximate parameters. The lowest~~Lowest~~ moisture content was observed in sample GBC and the highest~~highest~~ in HKC. Crude ash was lowest in FTC; highest in ARC. Lowest crude fibre~~fiber~~ was in WFC (wheat-Control) and the highest~~highest~~ ARC. The crude protein content was~~was~~ lowest in GBC and highest in ARC. The fat content~~contents~~ was lowest in FTC and highest in WFC~~, highest WFC~~. The carbohydrate content was calculated by difference, lowest observed in HKC and~~,~~ highest in GBC. The energy~~Energy~~ value was lowest in HKC and highest recorded in GBC. Some authors have~~had~~ reported lower values of proximate composition of yam flours/products, particularly~~ particularly~~ protein and fat content, compared with~~ compared to~~ 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., (2018) reported the approximate~~-proximate~~ composition of traditionally processed yam products~~ processed yam product~~: chips, flakes, and~~ and~~ flours as ranging from 2.70% to~~–~~ 4.30% (protein) and 0.70% to~~–~~ 1.10% (fat); (Lawal & Akinoso, 2019) produced~~, produced~~ flours from the two Cultivars of Aerial yam (D. bulbifera) at two different stages of maturation with 3.92% to~~–~~ 6.24 % (protein) and 0.52% to~~–~~ 2.20% (Fat); (Gunasekara, *et al.*, 2020) observed the composition~~composition~~ of four selected underutilised~~underutilized~~ yam varieties in Sri Lanka with 3.97% to~~–~~ 5.70% (protein) and 0.36% to~~–~~ 1.09% (fat); while (Ayo, *et al*., 2018) reported the~~, reported~~ protein composition of pre-treated aerial yam (Discorea bulbifera) flour as 5.65% to~~–~~ 7.59% and a fat~~fat~~ content of 2.63% to~~–~~ 3.86% (which falls within the same~~same~~ range of 2.2% to~~2.24 –~~ 3.47 % (fat) in the present work). The increase in the proximate composition of yam-based cookies,~~ based Cookies~~ particularly protein and fat contents compared with~~to~~ the proximate composition of the yam flours (the starting material), could be due to the presence~~presence~~ of eggs and vegetable oil in the ingredients mixed for baking of the Cookies. This is in consonance with the work of Chinma~~ Chinma~~ & Gernah, (2007) where cookies~~ where Cookies~~ produced using 100% cassava flour had higher values of 6.83% (protein) and 2.25% (fat) compared with the

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values from the 100% cassava flour of 1.10% (protein) and 1.05% (fat). The same trend was~~is~~ reported by Okpala et~~, *et*~~ *al*., (2013), who used 100% Cocoyam flour as one of their samples in the production of cookies~~production of Cookies~~.

Table 2 Proximate composition of yam-based cookies~~Yam based Cookies~~ produced from different~~the different~~ flour samples

Samples	Moisture (%)	Ash (%)	Fibre~~Fiber~~ (%)	Protein (%)	Fat (%)	Cho (%)	Energy Kcal/100g
WFC(Wheat Cookies)	8.43^{cd}±0.13	1.77c±0.03	0.13^{a}±0.01	9.43^{b}±0.02	3.84^{f}±0.19	76.40^{c}±0.58	358.78e±1.16
OGC(Ogoja Cookies)	8.64^{d}±0.02	1.29b±0.01	2.43^{c}±0.04	10.16^{c}±0.05	2.32^{b}±0.17	75.16b±0.31	343.37c±0.82
FTC(Faketsa Cookies)	8.21^{c}±0.01	1.10^{a}±0.04	4.18^{e}±0.03	9.23^{b}±0.03	2.24^{a}±0.10	75.04b±0.26	338.48b±1.23
HKC(Hembakwase Cookies)	8.80^{e}±0.07	2.06d±0.05	4.27^{f}±0.01	8.57^{a}±0.04	2.60^{c}±0.30	73.70a±0.32	334.06a±1.80
ARC(Amura Cookies)	7.67^{b}±0.03	2.30^{f}±0.01	0.98^{b}±0.02	10.48^{d}±0.05	2.72^{d}±0.09	76.26c±0.04	350.74d±0.62
GBC(Gwebe Cookies)	7.31^{a}±0.04	2.17^{e}±0.03	0.14^{a}±0.01	8.53^{a}±0.02	3.47^{e}±0.20	78.38d±0.58	359.28e±0.45

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

4.2 Phytochemical screening of yam-based cookies~~Yam based Cookies~~ produced from differentthe ~~the different~~ yam flour samples.

The phytochemical~~Phytochemical~~ compounds found in the Cookies produced from flours of the five Yam varieties are presented~~as presented~~ in Table 3. The compounds like Phenolics, Flavanoids, Alkaloids, Saponins and Tannins ranged from 0.24-0.37mg/100g, 0.26-0.40 mg/100g, 0.6-2.13mg/100g Saponins were~~was~~ not detected and 0.01-0.17mg/100g accordingly. Significant (P<0.05) difference in the phytochemical contents was observed in all cookies~~the Cookies~~ samples. Phenolic was lowest in HKC, highest in OGC, followed ~~followed~~ by ARC. Flavanoids; lowest in HKC, highest in OGC, followed ~~followed~~ by ARC. Alkaloids recorded lowest in WFC, then HKC; highest in FTC followed by ARC. Saponins; 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). Tannin was lowest in WFC, followed by~~then~~ HKC and highest OGC, followed ~~followed~~ by ARC. The general trend observed among~~amongst~~ the yam samples was that~~,~~ the highest presence of phytochemicals~~the phytochemicals~~ was observed in the OGC sample,~~sample OGC~~ followed by ARC and lowest HKC in all cases. This implies that there~~there~~ might be lower bioactive activities in the sample HKC. These~~This~~ data reveal phytochemical contents in our yam-based cookies~~-based Cookies~~ that contrasted and were higher than values reported by Ugo *et al*., (2022) for Cookies produced from composite flour mixture of wheat, Cocoyam, Groundnut and wheat, Cocoyam, Cashewnut. Same also for~~, for~~ phytochemical values of biscuits produced from composite~~composites~~ flours of wheat enriched with okra pod by Joy, (2019). This pattern could be credited to the longer~~longer~~ baking time at lower temperatures~~temperature~~ that the Cookies samples were subjected to. The~~As~~ relevant literature has~~had~~ indicated that lower baking temperatures and high exposure times~~temperature and the high exposure time~~ promoted starch degradation and the release of bound polyphenols, resulting in~~ resulting to~~ free polyphenols. This agrees with~~is in line with~~ Alfeo et al., (2020), whose~~ whose~~ work showed that a longer~~longer~~ baking time seems to increase the free

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polyphenol fractions, which ~~which~~ could impact antioxidant~~on antioxidant~~ activity. According to them, antioxidant ability is positively affected by increasing baking time, lower temperature, and ~~and~~ sugar amount~~amount,~~ although~~though~~ the principal effect is~~been~~ the baking time. They stressed that the greater~~more,~~ the release of polyphenols from the food matrices, the greater the increase~~more the increases~~ in their bioavailability, making these nutraceutical compounds available for ~~making available these nutraceutical compounds for the~~ intestinal absorption. This indicated that in addition to~~beside~~ HKC, the other Cookies samples exhibited high phytochemical content, implying that our ~~implying our~~ local yams could serve as a rich~~rich~~ source of phytochemical compounds that~~which~~ might be beneficial to consumers'~~consumer's~~ health.

Table 3 Phytochemical screening of yam-based cookies~~Yam based Cookies~~ produced from different~~the different~~ yam flour samples (mg/100g)

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

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

4.3 Antioxidant properties of yam-based cookies~~Yam based Cookies~~ produced from different~~the different~~ yam flour samples (mg/100g)

The antioxidant~~Antioxidant~~ activities of the Cookies produced from the flours of five Yam varieties are presented~~as presented~~ in Table 4.

The general trend observed was that; there was significant ($p<0.05$) difference in the antioxidant activities of the~~all the~~ samples. Among~~Amongst~~ the yam based Cookies; in all cases, sample HKC had the least antioxidant activity, higher observed in the OGC followed by ARC, and ~~and~~ the highest in GSH (the control).

The 1,1-diphenyl-2-picrylhydrazyl (DPPH) radical scavenging activity (DPPH) of the yam-based cookies ~~based Cookies~~ samples ranged from 41.19% to ~~-~~84.32%. HKC had~~having~~ the least antioxidant activity, the highest recorded in OGC~~the OGC~~ followed by ARC. Ferric reducing antioxidant properties (FRAP):0.29-0.95%. HKC had the least, highest in the OGC, followed by ~~then~~ ARC. Metal chelating activities (MCA): 34.15-78.51%. HKC had the least and~~,~~ highest activity in the OGC, followed ~~followed~~ by ARC. Hydroxyl radical scavenging activities (HRSA):29.64-69.54%. HKC had the least, the highest in the OGC, followed by ~~then~~ ARC. Superoxide~~And Superoxide~~ radical scavenging activities (SRSA):24.13- 81.52 %. HKC had the least and~~, and~~ the highest in the OGC, followed ~~followed~~ by ARC. The antioxidant~~result of the Antioxidant~~ activities of yam flour-based cookies~~Yam flour based Cookies~~ showed appreciable antioxidant activities. However,~~But~~ the lowest was observed in the sample HKC (Cookies), indicating that ~~indicating,~~ HKC might have the~~had~~ least free radical scavenging activities. The~~While the~~ highest antioxidant activity was observed in the OGC sample followed by the ARC. This could be a result of interspecies~~their inter specie~~ variation. The result of (%RSA) for the yam-based cookies samples, which ~~based Cookies samples which~~ ranged from 29.64% to 35.36 %, aligned with the antioxidant ~~aligned with antioxidant~~ activity in Cookies made from purple yam flour and peanuts reported by Ibdal, S. & Defita Fajar, (2023), where ~~where~~ the percentage of radical scavenging activity (%RSA) was around 39.7%. Hence, thesethis data revealed that some of our local yams can be processed into antioxidant-rich flours and subsequently into antioxidant-richantioxidant rich finished

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

food products.

Table 4 Antioxidant activities of yam-based cookiesYam based Cookies produced from differentthe different yam flour samples (mg/100g)

Values are mean ± SD of triplicate determinationsdetermination. Samples with different superscripts within the same column were significantly ($p<0.05$) different. * *GSH- (Gluthanion as standard)

4.4 Physical properties **of yam-based cookies~~Yam based Cookies~~ produced from differentthe ~~different~~ yam flour samples**

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

The results~~result~~ showed that the physical characteristics of the prepared cookies varied with the variation of individual flours. The diameter of the cookie~~cookies~~ samples ranged from 3.70 to~~3.70 -~~ 4.67 cm. Width ranged from 23.93 to~~23.93 -~~ 28.00 cm. The thickness ranged from 2.63 to 4.33 ~~2.63 - 4.33~~cm. Weight ranged from 5.16 to 9.67 g.~~- 9.67g.~~ The spread ratio ranged from 0.83 to ~~0.83 -~~1.64. The spread factor ranged from 54.63 to 106.84, and~~54.63-106.84.And~~ the fragility of ranged from 430.00 to 790.00 g.~~430.00 – 790.00g.~~ Cookies from all samples showed good quality physical features for the production of cookies and biscuits.~~cookies and biscuits production.~~ The results showed that the physical characteristics of the yam-based~~-based~~ cookies varied with the variation of individual flours. Similar observations have~~had~~ been reported by other authors (Okpala, et al., 2013); (N et al., 2014); (Igbabul et al., 2015). 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 ~~thus~~

preventing spreading. This finding agrees~~agree~~ with the observation of Belorio et al., (2019), who ~~who~~ reported a decrease in cookie diameter in wheat flour cookies. According to Orisa et~~,~~ ~~*et*~~ *al*., (2023) doughs~~dough's~~ with lower viscosity cause cookies to spread at a faster~~faster~~ rate and vice versa, hence ~~hence~~ the greater spread in yam flour cookies. Nugraheni *et al*., (2019) had earlier documented that the spread ratio of cookies increased with an increase~~increase~~ in the content of non-wheat protein. An increase in the spread~~Increase in spread~~ ratio could also be attributed to an increase~~increase~~ in the hydrophilic sites in the dough mixture, leading to an increase ~~leading to increase~~ in water absorption and swelling index (Hussein *et al*., 2011)

Table 5 Physical properties of yam-based cookies~~Yam based Cookies~~ produced from different~~the different~~ yam flour samples

SAMPLES	Diameter (Mm)	Width (Mm)	Thickness (Mm)	Weight (g)	Spread Ratio (D/T)	Spread Factor (W/T*10*1)	Fragility (g)
WFC	3.70^{a}± 0.46	23.93^{a}± 0.15	4.43^{d}±0 .15	9.67^{c}±1 .53	0.83^{a}±0 .12	54.03^{a}±1 .81	790.00^{c}± 10.00
OGC	4.47^{b}± 0.31	28.60^{c}± 0.92	3.73^{c}±0 .15	6.67^{b}± 0.57	1.20^{b}± 0.11	76.76^{b}±5 .53	620.00^{b}± 98.49
FTC	4.30^{b}± 0.10	27.73^{bc}± 0.61	2.90^{ab}± 0.26	6.32^{ab}± 0.19	1.49^{bc}± 0.20	96.02^{cd}± 6.39	510.00^{a}± 10.00
HKC	4.30^{b}± 0.10	28.00^{c}± 0.27	3.23^{abc}± 0.51	6.77^{b}± 0.64	1.35^{bc}± 0.17	88.08^{bc}± 14.09	490.00^{a}± 10.00
ARC	4.30^{b}± 0.10	28.00^{c}± 0.44	2.63^{a}±0 .21	5.16^{a}±0 .17	1.64^{c}±0 .11	106.84^{d}± 9.80	430.00^{a}± 60.83
GBC	4.67^{b}± 0.15	26.87^{b}± 0.35	3.47^{bc}± 0.49	6.18^{ab}± 0.03	1.37^{bc}± 0.26	78.73^{bc}± 13.05	490.00^{a}± 10.00

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

4.5 Sensory properties of yam-based cookies~~Yam based Cookies~~ produced from different~~the different~~ yam flour samples

Sensory properties such as appearance, aroma, taste, crispiness, texture, and ~~and~~ general acceptability of Cookies produced from the five Yam varieties flours are presented in Table~~respectively are as presented in the Table~~ 6. Sensory evaluation is an important tool for~~in~~ 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 (Abdus-salaam *et al*., 2022) . 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 5.32to~~-~~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~~the sensory parameter~~ differed significantly among~~amongst~~ samples. It was observed that samplessamples 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 termsterm of taste, Samples ARC (Amura Cookies) and GBC (Gwebe Cookies) competed favourably with wheat cookies, which which was the control. Hence, samples GBC and ARC could be used for the massmass production of Cookies.

Table 6 Sensory properties of yam-based cookies~~Yam based Cookies~~ produced from different~~the different~~ yam flour samples

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

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

5. CONCLUSION

Industrial production of Yam flours to be used in~~for~~ confectioneries should be encouraged to reduce dependence on imported wheat flour for baking. The yam-based cookies were of~~-based Cookies showed~~ good quality in terms of phytochemical content, antioxidant activities, physical properties, and~~ and~~ nutritional composition. However, Sample HKC exhibited the lowest~~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 favourably~~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 of GBC~~GBC~~ and ARC Cookies are suggested for~~to be used for~~ mass production. Particularly, sample ARC also~~which 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 overall~~over-all~~ acceptance of cookies~~the Cookies~~, the use of yam flours in production of cookies~~the Cookies~~ may enhance the nutritional and health status of the consumers, increase utilisation~~utilization~~ of yams kerbing~~curbing~~ post-harvest losses of the same, and reduce~~reduce~~ total dependence on wheat flour and prevalent incidences of chronic illnesses like diabetes, coeliac~~celiac~~ disease etc.

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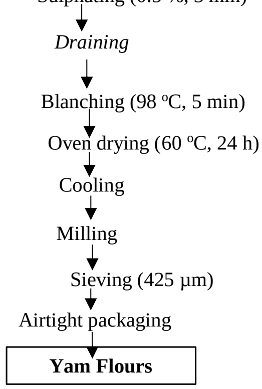
Conjunctions	0
Difficult-to-read Sentence	0
Enhancement	0
Fragment	0
Idioms	0
Number Style	0
Plain Language	0
Prepositions	15
Pronouns & Determiners	0
Punctuation	46
Redundancy & Conciseness	0
Run-on Sentence	0
Sensitive Language	0
Singular-Plural nouns	11
Spelling & Typos	12
Style	0
Subject-Verb Agreement	3
Symbols/Notations	0
Syntax	2
Tense	6

Verbs	5
Word Form	8
Word Order	0
Word/Phrase Choice	10
Writing Advisor	0
Other	170
Style Guide - None	0
Total	**356**



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