Federal Polytechnic Ilaro

Journal of Pure & Applied Sciences {FEPI- JOPAS}

Volume 3 Issue 2: December 2021, Edition

Published by:

The School of Pure and Applied Science

The Federal Polytechnic Ilaro, Ogun State, Nigeria.

https://fepi-jopas.federalpolyilaro.edu.ng

E-mail:fepi.jopas@federalpolyilaro.edu.ng

ISSN: 2714-2531

FOREWORD

Compliment of the season to all our contributors, well-wishers and world of Academia in general. I respectfully appreciate and welcome you all to the volume 3 issue 2 of Federal Polytechnic – Journal of Pure and Applied Sciences (FEPI-JOPAS) which is a peer reviewed multi-disciplinary accredited Journal of International repute. It is imperative to re-affirm that FEPI-JOPAS publishes full length research work, short communications, critical reviews and other review articles. In this issue, readers will find a series of manuscripts of top-rated significance in pure and applied sciences, engineering and built environment. This issue is the last of its kind for 2021 calendar year which features findings from basic and applied researches of high societal impacts from the seasoned authors. These articles have been reviewed and packaged for wider readership through the collective efforts of our managing editor, publishing editors, our valuable reviewers and editorial board members.

In this particular issue, you will find that Ilelaboye and Jesusina evaluated the quality of biscuits and chin-chin made from okara enriched plantain-sorghum flour blends. Ojo and Ebisin utlilized convolutional neural network for gender classification through facial analysis. Omotayo and Fafioye investigated antimalarial potential of ethyl acetate fraction of Phyllanthus niruri while Olubodun and Adetona examined landscaping as a strategy for combating air pollution in Lagos megacity. Buoye and Ojuawo provided imperative dataset on Covid-19 crisis management in Nigeria and Brazil. Obun-Andy and Banjo investigated effective communication as a tool for good governance in Nigeria. Yusuff and co-workers conducted a field survey on fish hatcheries in Yewa South and Yewa North Local Government of Ogun State. Akinlade and co-workers meticulously expatiated on the effect of aqueous blend of three herbs on haemato-biochemical indices of broiler chicken at starter phase. Ajeigbe, Sangosina, Ogunseitan, Lawal, & Yusuff analysed the Effects of Neem Leaves (Azadirachta Indica) and Cassava Peels on the Performance of West African Dware Goat. Abdussalam & Adewole in their paper carefully explained the Formulation of Natural Products Repellents for the Control of Cockroaches (Periplaneta americana). Elesin & Obafunmiso gave as Assessment of Public Toilets Facilities Provision and Management in Tertiary Institutions in Nigeria- An Overview of The Federal Polytechnic, Ilaro, Ogun State.

I would like to deeply appreciate and extend my profound gratitude to my co-editors, editorial board members, reviewers, members of FEPI-JOPAS, especially the Managing Editor, as well as all the contributing authors for making the production and publishing of this volume 3 issue 2 a reality. I will like to appreciate the authors in this issue for allowing their works to be subjected to our thorough and rigorous peer-review processes and for taking all the constructive criticism in good fate. The authors are solely responsible for the information, date and authenticity of data provided in their articles submitted for publication in the Federal Polytechnic Ilaro – Journal of Pure and Applied Sciences (FEPI-JOPAS). I am looking forward to receiving your manuscripts for the subsequent publications.

You can visit our website (https://fepi-jopas.federalpolyilaro.edu.ng) for more information, or contact us via e-mail us at fepi.jopas@federalpolyilaro.edu.ng.

Thank you and best regards.

Prof. Olayinka O. AJANI

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Physicochemical Evaluation and Pasting Properties of Flours, Biscuit and Chinchin Prepared from Okara Fortified Plantain – Sorghum Blends.

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Abstract

This study evaluated the quality of biscuits and chin-chin made from okara enriched plantain-sorghum flour blends. The flours of plantain(P), Sorghum (S) and Okara (O) blended in per cent ratios: T1 (100 plantain :0 sorghum); T2 (75 plantain:25 sorghum); T3 (50 plantain:50 sorghum); T4(25 plantain: 75 sorghum); T5 (0 plantain: 100 sorghum:); 5 % okara flour was added to 95 % of each plantain – sorghum flour blend to give samples T6 to T10. Standard analytical procedures were utilized to analyse the flours' proximate composition, energy, functional properties and pasting properties, and sensory attributes of the biscuit and chin-chin were also analysed. The proximate composition results of composite flour, biscuit and chin-chin showed that sample T1 possessed the lowest moisture and fat content and the highest carbohydrate. Sample T10 has the highest protein content, sample T6 has the highest ash and fibre content, and sample T8 has the highest energy value. Substantial variation occurred in functional properties: sample T10 has the highest values of the bulk density, water and oil absorption capacities and the least value in sample T1. Swelling power and solubility index show no significant difference having sample T10 with the highest value and sample T1 having the least value, and foaming stability varied significantly between the samples, with T6 possessing the maximum value and the minimum observed in T10. This study showed that the nutritional results qualities of the biscuit and chin-chin produced from plantain-sorghum composite flour are enhanced by fortification with okara.

Keywords: biscuits, chin-chin, functional properties, okara, physicochemical, pasting properties

INTRODUCTION

Enrichment of food products such as confectioneries can boosts their nutritional and functional components, thereby providing extra benefits to meet consumers' demands (Świeca, Gawlik-Dziki, Dziki, & Baraniak, 2017.). The rapid increase in population and development in many countries have significantly promoted snack consumption, which caters for many consumers' daily nutritional requirements, and played a positive role in every nation's economy (Awoyale, Maziya-Dixon, Sanni, & Shittu, 2011; Lasekan & Akintola, 2002; Ugwuanyi, Eze, & Okoye, 2020). Cereal-based snacks are extensively consumed due to low nutrient density. Snacks are easy to eat, cheap, and effortlessly accessible in public places (Ugwuanyi et al., 2020).

Man has been consuming biscuit and biscuit-like products for many hundreds of years. Their beneficial eaten attributes informed the enrichment of their nutritional quality with protein, especially for children and low-income groups (Banureka & Mahendran, 2009). Chin chin is a sweet snack made from wheat flour either by frying or baking and is common in West African countries, especially Nigeria. (Akubor, 2004; Mepba, Achinewhu, & Aso, 2007).

Plantain (*Musa paradisiaca)* originated from India, a leading food crop and energy source in Africa. Commonly called '*Ogede agbagba'* (Yoruba), *'Ayaba'* (Hausa) and '*Ogadejioke'* (Igbo), in Nigeria, and usually eaten boiled, fried or roasted. Also, various processed foods are prepared from unripe plantain flour, containing carbohydrates, minerals, amino acids, fibre, and carotenoids (Ilelaboye & Ogunsina, 2018). Sorghums constitute a significant staple food providing the nutritional needs for over 500 million of people in sub-Saharan Africa and Asia (ICRISAT, 2018). This cereal is mainly regarded as a life-given crop due to its exceptional tolerance to drought and acclimatisation to dry tropical and subtropical environments.

Wheat flour has been the principal raw material for the preparation of snacks (e.g., biscuit and chin chin). In order to reduce the production cost of snacks due to high importation cost of wheat, there is need to explore the suitability of an inexpensive, nutritious and functional composite flours made from readily available agricultural materials for the production of snacks. Therefore, the research aspired to prepare and enrich plantain-sorghum composite flours with okara. To analyse the flours' physical, chemical, functional properties and pasting characteristics, and also to assess the proximate composition and sensory evaluation of biscuit and chin-chin made from okara enriched plantain - Sorghum flour blends.

MATERIALS AND METHODS

In this study, all the ingredients used to produce the flours, biscuit, and chin were purchased from a market in Ilaro, Ogun State, Nigeria. Ilaro is a town in Nigeria, positioned at a North latitude of 6.89°, East longitude of 3.02° and altitude of 68 m. Ilaro ambient temperature ranges between an average of 23° C to 34.2°C.

Plantain and sorghum flours' production

For the production of plantain flour, green plantain fingers (20 kg) were manually peeled, cut into the water to prevent browning and subsequently oven-dried at 80 ºC for 6 hr. The dried slices were milled (Bentall Superb, Model 200L 09) into a fine powder of 75μm particle size and kept in airtight polythene bags at room temperature before use.

Thoroughly cleaned non- tannin sorghum grains (5 kg) were ground using a hammer mill (Bentall Superb Model 200L 09) into a powder of 75 μm particle size and stored at room temperature in airtight plastic containers before use.

Soymilk residue (Okara) flour's production

The thoroughly washed soybean was blanched at 100ºC for 25 min and dehulled. One kilogram (1 kg) of dehulled cotyledons in 5.0 L of water was milled, and the milk was separated from the soybean residue (okara) with a cheesecloth. The residue was oven-dried at 70ºC, ground into a powder of 75μm particle size, and saved in sealed plastic containers at 4 ºC for further use. (Li, Qiao & Lu 2011)

Formulation of composite flours

Ten flour samples were formulated following the formulation in Table 1.

Table 1. Ratio (%) of Plantain, Sorghum and Okara Flour

FLOUR	PLANTAIN(P)	SORGHUM(S)	OKARA(O)
T1	100	0	0
T2	75	25	0
T3	50	50	0
T4	25	75	0
T5	0	100	0
T6	95	0	5
T7	371.25	23.75	5
T8	47.5	47.5	5
T9	23.75	71.25	5
T10	0	95	5

Biscuit Preparation

Biscuits were made using the procedure of AOAC (2016) with some alterations in the recipe. The flour, salt, and baking powder were carefully blended in a bowl for 3 min, eggs and water were added, and the mix was kneaded. The batter was rolled and sliced into small cubes. The cubes were arranged on oiled baking trays at 25 mm intervals in between and oven-baked at 200 ºC for 25min. After attaining ambient temperature, the biscuits were put in polythene bags and saved for subsequent analysis and sensory evaluation (Peter-Ikechukwu et al., 2017).

Table 2. Recipe for Biscuit Production

Ingredient	Quantity
Composite flour	100 g
Salt	2.02 g
Fat	9.64 g
Yeast	3.48 g
Baking Powder	0.16g
Water	50 ml

Production of chin-chin

Using the recipe shown in Table 1, the flour, salt and ground nutmeg were put in a bowl, and a batter was prepared by manually mixing the sugar, powdered milk, baking powder margarine together. The batter was then mixed with the bowl's content, and water was added to the blend and kneaded to form a stiff dough. The dough was pressed to 1 cm thickness and sliced into uniform cubes, fried in vegetable oil at 180 ºC for 8 min to a golden brown. The residual oil on the chin-chin was removed, allowed to cool and packed in an airtight bag for analysis. (Akubor 2004).

Table3. Recipe for chin-chin production

Ingredient	Amount
Composite flour (g)	100

Sugar (g)	5
Fat (g)	3
Egg (g)	10
Baking Powder (g)	10
Water (ml)	70

Chemical analysis

The flours' proximate composition was determined with the Association of Official Analytical Chemists' methods (AOAC, 2016), and the Atwater factor described by Kent (2006) was used to calculate the energy value. The functional properties of the flours were assessed with standard methods (Julianti, Rusmarilin, & Yusraini, 2015; Oyeyinka et al., 2014) technique.

Determination of pasting properties

The flour blends' pasting properties was assessed with the rapid visco analyser (RVA) according to the manufacturers' procedures (Newport scientific, Narrabeen Australia) and reported by Ikegwu, Nwobasi, Odoh and Oledinma (2009).

Sensory evaluation

The organoleptic properties of the biscuit and chinchin were analysed by 20 trained panellists selected from students and staff of the Federal Polytechnic, Ilaro, Ogun State, Nigeria. The 9-points Hedonic scale ranging from 1(most preferable) to 9 dislikes extremely (least preferable) was used (Iwe, 2002).

Statistical analysis

Triplicate analyses were performed, and data were subjected to one-way analysis of variance (ANOVA) to establish statistical significance. Mean comparison and separation were done using Duncan Multiple range (DMR) test at $p \leq 0.05$, described by the SPSS 20.0 statistical package. (SPSS, 20, 2020).

RESULTS AND DISCUSSION

Proximate composition of floors

Tables 4 shows the per cent proximate compositions of the composite flours. The increase in sorghum proportion and the inclusion of okara powder in the mixed flour caused a significant ($p < 0.05$) increase in the flours' moisture content. T1 had the lowest moisture content (5.61%), while T10 had the highest value (7.51%). The composite flours shelf life was stable because their moisture contents were below the recommended maximum limit (15 %) for flours, hence no spoilage through chemical changes or by microorganisms (Shahzadi, Butt, Reh man, & Sharif, 2005; Akomolafe, & Aborisade, 2007; Codex, 2016.).

The flour blends protein content varied significantly ($p< 0.05$), ranging from T1(2.81%) to T10 (6.11%) and are lower than the value reported by Nneka & Charles (2016) for wheat flour (10.12%). Also, the okara supplement in the flour blends improved their protein content. A rise in the per cent ratio of sorghum and the okara supplementation in the flours caused a rise in fat content. Flour with low-fat content impacts low calories on the product and has longer shelf stability because rancidity is reduced (Fasasi, 2009). A significant (P< 0.05) decline in the flour blends' fibre content occurred with the rise in sorghum quantity, but adding 5 % okara raised the fibre content. The highest per cent fibre in T6 (4.01 %) is caused by the high fibre content in plantain and okara (Kiin-Kabari, Eke-Ejiofor & Giami, 2015). The composite flours ash content varied significantly ($p < 0.05$), ranging from T5 (1.71 %) to T6 (2.62%). A rise in the sorghum level of the flour blends caused a reduction of its ash content. The inclusion of okara slightly increased the ash content, and this observation agrees with the findings of Porcel (2017). T6 sample will have the highest mineral content. because the per cent ash of food indicates the number of minerals present in the product.

The flour blends' carbohydrate content in this study differed significantly ($p< 0.05$), ranging from T10 (79.34 %) to T1 (83.91 %) and higher than the carbohydrate content of wheat (76.30%) recorded by Nneka and Charles (2016). The blends' carbohydrate contents are reduced by okara enrichment and an increase in sorghum level. The calorific value of the composite flours of the current study increased significantly ($p< 0.05$) with the okara supplementation and rise in sorghum level in the flours. The energy value of the flour blends ranged from T1 (360.11 .24 kcal/100g) to T10 (370 kcal/100 g). Wheat flour energy value (382.64 kcal/100 g) is more than this study results (Nneka, & Charles, 2016)

Table 4: The proximate composition (%) and energy (kcal/100g) values of the okara fortified plantain-sorghum composite flour blends

Sample	Moisture	Protein	Fat	Fibre	Ash	Carbohydrate	Energy
T1	5.61 ^{a}±.22	2.81 ^{a}±.06	2.01 ^{a}±.08	3.91 ^{g}±.16	2.41 ^{e}±.06	83.91 ^{i}±.02	360.11 ^{a}±09
T2	6.11 ^{c}±.09	2.98 ^{a}±.28	2.21 ^{b}±.05	3.41 ^{e}±.15	2.11 ^{d}±.08	83.51 ^{h}±.05	362.41 ^{a}±.07
T3	6.51 ^{d}±.06	4.01 ^{c}±.05	2.31 ^{c}±.06	3.11 ^{c}±.11	1.91 ^{c}±.05	82.81 ^{g}±.06	367.61 ^{b}±.04
T4	6.91 ^{e}±.08	4.51 ^{de}±.08	2.31 ^{c}±.14	2.91 ^{b}±.02	1.71 ^{ab}±.02	82.31 ^{f}±.09	364.31 ^{ab}±.20
T5	7.81 ^{g}±.03	5.71 ^{f}±.09	2.41 ^{cd}±.12	2.61 ^{a}±.07	1.6 ^{a} ±.15	80.51 ^{c}±.05	364.81^{ab}±.09
T6	5.65 ^{a}±.05	3.31 ^{b}±.10	2.56 ^{e}±.09	4.01 ^{g}±.03	2.62 ^{e}±.07	82.73 ^{g}±.03	365.16 ^{ab}±.04
T7	5.91 ^{b}±.10	4.32 ^{cd}±.11	2.73 ^{ef}±.07	3.71 ^{f}±.04	2.11 ^{d}±.11	81.72 ^{e}±.04	366.29 ^{ab}±.08
T8	6.54 ^{d}±.12	4.71 ^{e}±.13	2.82 ^{fg}±.02	3.51 ^{e}±.09	1.91 ^{c}±.04	81.17 ^{d}±.012	367.26 ^{b}±.07
T9	6.89 ^{e}±.04	5.81 ^{fg}±.15	2.92 ^{gh}±.06	3.31 ^{d}±.05	1.81 ^{bc}±.13	80.31 ^{b}±.11	369 ^{b}±.06
T10	7.51 ^{f}±.07	6.11 ^{g}±.05	3.00 ^{h}±.08	2.91 ^{b}±.08	1.71 ^{ab}±.03	79.34 ^{a}±.15	370.24 ^{b}±.05

Means with the same superscripts in a column are not significantly different ($p \leq 0.05$)
Sample Key = T1 [[100P:0S]; T2 [75P: 25S]; T3 [50P: 50S] T4 [25P: 75S]; T5 [0P: 100S]; T6 [95P:0S: 5O]; T7 [71.25P:23.75S:0.05O]; T8 [47.5P: 47.5S: 5O]; T9 [23.75P:71.25S: 5O]; T10 [0P :95S: 5O] P [Plantain Flour], S [sorghum Flour], O[Okara]

Functional properties

Table 5. The functional properties of the composite flour

Samples	BD (g/cm^3)	WAC (%)	OAC (%)	SP (g/g)	SI (%)	FC (%)	FS (%)	EC (%)	ES (%)
T1	0.51±0.02^{a}	198.29±6.63^{i}	185.51±4. 35j	5.05±0.98^{a}	35.83±0.74^{a}	3.77±0.15^{b}	51.9±0.29^{f}	37.75±0.29^{a}	39.12±0.28^{a}
T2	0.55±0.02^{b}	184.02±4.17^{g}	168.30±6.70^{g}	5.94±0.40^{b}	36.06±0.89^{b}	4.4 ±0.06^{c}	54 ±0.29^{g}	39.20±0.29^{b}	41.25±0.28^{b}
T3	0.58±0.04^{c}	176.99±4.55^{e}	152.88±6.45^{e}	6.21±0.70^{bc}	37.41±1.60^{c}	5.65±0.13^{d}	56.1±0.29^{h}	41.12 ±0.29^{c}	43.32±0.28^{c}
T4	0.61±0.02^{d}	166.52±1.42^{c}	131.11±7.04^{c}	6.55±0.90^{c}	38.21±0.94^{d}	6.6 ±0.06^{e}	58.5±0.29^{i}	43.25±0.29^{d}	45.57±0.28^{d}
T5	0.65±0.03^{e}	151.15±1O.73^{a}	120.37±3.46^{a}	7.12±0.30^{d}	39.97±2.02^{e}	7.9 ±0.06^{f}	59.7±0.29^{j}	44.31±0.29^{de}	49.15±0.28^{e}
T6	0.59±0.03^{ab}	201.41±10.41^{j}	183.59±8.65i	7.84±0.60^{e}	41.28±1.02^{f}	4.0±0.006^{f}	48.1±0.29^{e}	54.25±0.29^{e}	43.53±0.28^{c}
T7	0.62±0.04^{bc}	187.78±9.42^{h}	170.79±9.00^{h}	8.18±0.5^{ef}	42.24±1.47^{g}	5.5 ±0.06^{a}	45.9±0.29^{d}	56.75±0.29^{f}	44.55±0.28^{cd}
T8	0.65±0.02^{cd}	180.06±5.34^{f}	156.56±5.92^{f}	8.56±0.13^{f}	44.34±1.03^{h}	10.07 ±0.16^{h}	42.3±0.29^{c}	59.5 ±0.29^{g}	46.15±0.28^{d}
T9	0.69±0.03^{de}	170.52±3.18^{d}	134.85±5.53^{d}	9.04±0.30^{fg}	47.49±1.53^{i}	12.13 ±0.16^{j}	39.06±0.29^{b}	61.25±0.29^{h}	50.00 ±0.25^{e}
T10	0.72±0.01^{ef}	158.45±2.12^{b}	125.49±4.49b	9.68±0.23^{g}	49.07±1.85^{j}	14.55 ±0.16^{g}	30.9 ±0.29^{a}	65.75±0.29^{i}	54.45±0.25^{f}

Means with the same superscripts in a column are not significantly different ($p \leq 0.05$)
Sample
Key = T1 [[100P:0S]; T2 [75P: 25S]; T3 [50P: 50S] T4 [25P: 75S]; T5 [0P: 100S]; T6 [95P:0S: 5O]; T7 [71.25P:23.75S:0.05O]; T8 [47.5P: 47.5S: 5O]; T9 [23.75P:71.25S: 5O]; T10 [0P :95S: 5O] P [Plantain Flour], S [sorghum Flour], O[Okara]

Table 5 shows the functional properties of okara enriched plantain–sorghum flour blends. Functional attributes of flour are crucial determinants for the behaviour and suitability of a flour product to substitute conventional flour in specific systems (Kaur, & Singh, 2006; Siddiq, Nasir, Ravi, Dolan, & Butt, 2009). The bulk density values reported by other workers (Abioye, Ade-Omowaye, Babarinde & Adesigbin, 2011; Kiin-Kabari, Eke-Ejiofor & Giami, 2015) were comparable with the values obtained in the present study (0.51 g/cm^3 to 0. 72 g/cm^3). The rise in sorghum flour proportion and the inclusion of okara in the flour mix led to high bulk density. Bulk density governs the packaging materials price and selection for flour. Also, the flour bulk density influenced its treatment and usage in the food industry (Ajanaku, Edobor-Osoh & Nwinyi, 2012). Flour T10, having the highest bulk density, will be most suitable for feeding a recuperating child because it can quickly disperse and form a less viscous paste.

The water absorption capacity (WAC) of the experimental flour varied significantly (p>0.05), ranging from T5 (151.15 g/100 g) to T6 (201.41 g/100 g). The result signified that a high proportion of sorghum flour in the blends reduced their WAC due to its starch polymer structure (Oladipupo & Nwokocha, 2011). Also, the presence of okara improved the flours WAC, which corroborated the reports of Uzo-Peters and Ola (2020); Butt and Batool (2010) and Kiin-Kabari et al. (2015) because its protein content controls the WAC of flours. Sample T6 with the highest WAC will be more suitable for bakery products that need moisten to enhance dough handling qualities. The okara fortified plantain-sorghum composite flours' oil absorption capacity (OAC) followed the same pattern. The flours' protein content and oil content positively influence their OAC (Uzo-Peters, & Ola 2020). Hence, sample T6 will be most suitable for making food products because high OAC conveys better flavour retention and improved mouthfeel to the product (Adegunwa, Adebowale, Bakare, Adelekan, & Alamu, 2017).

The swelling power of flour depends on its per cent protein, which enhances the affinity of starch granules to water (Aprianita, Purwandari, Watson, & Vasiljevic, 2009). Also, the flour’s swelling power was regulated by the proportion of amylose to amylopectin and the bonding forces within the granules. (Onitilo, Sanni, Daniel, Maziya-Dixon, & Dixon 2007). The swelling power of the okara fortified plantain – sorghum blends increased significantly (P>0.05), from T1 (5.05g/g) to T10 (9.68g/g), which has the highest per cent protein. The swelling power reported for sole plantain flour (8.22g/g) by Abioye, Ade-Omowaye, Babarinde and Adesigbin (2011) is higher than the value obtained in this study. The solubility index of the flour mix exhibited a similar trend ranging from T1(35.83 %) to T10 (49.07 %). Starch solubility of most starch-based products resulted from the leaching of starch amylose, which is increased by hydrolysis of starch to amylose during soaking (Ikegwu, Okechukwu, Ekumankama, & Egbedike. 2009).

The flour blends’ foaming capacity and foam stability, as presented in Table 5, differed significantly (p<0.05). T10 has the highest foam capacity (14.55 g/100 g), while T1 gave the lowest value (3.77 g/100 g). The foam stability of T1(30.9 g/100 g) was the lowest, and the highest was obtained in T5 (59.7 g/100 g). This study revealed a rise in sorghum proportion, and the inclusion of okara in the mix increased the foaming capacity, while the opposite was the case for foam stability. The surface tension of the air-water interfacial film formed by protein inversely affects the foamability of flours (Mepba et al., 2007). The values of emulsion capacity (37.75 g/100 g - 65.75 g/100 g) and emulsion stability (39.12 g/100g - 54.45 g/100 g) of the composite flours in this research work is directly proportional to the flour blends’ protein, a surfactant that forms and stabilizes the emulsion by creating electrostatic repulsion on oil droplet surface (Kaushal et al. 2012). The flour samples produced in this study could serve as an excellent emulsifier because they possess moderate to high emulsion capacity.

Pasting properties.

Its starch pasting properties assess the aptness of flour usage as an efficient raw material in food and other industries (Iwe, Linus-Chibuezeh, Ngadi, Asumugha, & Obasi, 2017). Table 6 depicted the pasting properties of okara enriched composite flours, which varied significantly (p < 0.05). The peak viscosity of the flour mix varied from T10 (426.00 RVU) to T1 (3282.50 RVU) and showed that both sorghum substitution and okara addition to the flour blends reduced the peak viscosity**.** Peak viscosity signifies the starch swelling capability before its physical breakdown and is often evaluated with the final product quality (Sanni, Adebowale, Maziya – Dixon & Dixon 2008). The trough or hot paste viscosity was the minimum viscosity when the samples were subjected to a period of constant temperature and mechanical shear stress. (Kiin-Kabari, et al., 2015). Sample T1 possessed the highest holding capacity (2473.50 RVU), while the lowest trough value (336.50 RVU) was observed in sample T10. Hence

sole plantain flour can resist breakdown during cooling. (Jude-Ojei , Lola, Ajayi. & Ilemobayo 2017).
The stability of starch pastes or the extent of its granule's disintegration is determined by breakdown viscosity, which is the peak viscosity minus trough viscosity. (Newport Scientific, 1998). The breakdown viscosity values in this study ranged between samples T10 (89.50 RVU) and T1 (809.00 RVU), and this shows that 100 % plantain flour had the highest starch stability.

As depicted in Table 6, final viscosity reduced significantly (*p*>0.05) with a rise in sorghum substitution and okara inclusion in the flour mix. It indicates that flours with high protein content have a lower ability to form a gel or viscous paste during processing (Offia-Olua, 2014). Setback viscosity is the retrogradation of starch molecules, which happens when the flour paste temperature is reduced to 50 °C. It also signifies the tendency of the starch particles to diffuse in a hot paste and re-combine quickly during cooling (Chinma, Abu, & Ojo, 2010). The flour samples setback values ranged from T10 (580.00) to T1 (1344.50), showing that the lower the level of sorghum substitution, the less the retrogradation during cooling. The peak time (min) evaluates the cooking time and when the peak viscosity occurred (Adebowale, Adeyemi, & Oshodi, 2005). Slight significant variation was observed in the composite flours peak time ranging from 5.00 min – 5.17 min.

The pasting temperature is the time initial gelatinisation occurred, and noticeable thickness is observed during processing due to the swelling of the starch (Alamu, Therese, Mdziniso, & Bussie, 2017). The pasting temperature value of sole plantain flour was the least (82.28 ˚C), and the highest was observed in okara fortified sorghum flour (88.40 ˚C), which is similar to Awolu, (2017) report on the pasting temperature (89.60 °C) of pearl millet-based composite flour.

Table 6: Pasting properties of okara fortified plantain – sorghum flours

SAMPLE	Peak	Trough	Breakdown	Final Viscosity	Setback	Peak Time	Pasting Temp
T1	3282.50±146.37^{i}	2473.50±20.51^{i}	809.00±125.87^{e}	3818.00±203.65^{g}	1344.50±183.14^{de}	5.17±05^{c}	82.28±.11^{a}
T2	2443.50±4.95^{g}	1778.00±2.83^{h}	665.50±2.12^{d}	3307.00±202.63^{f}	1529.00±19.80^{g}	5.00±.00^{a}	82.73±.60^{ab}
T3	1879.00±164.05^{e}	1378.50±103.94^{e}	500.50±60.10^{c}	2864.00±239.00^{e}	1485.50±135.06^{ef}	5.00±.00^{a}	83.10±.07^{ab}
T4	934.50±7.78^{c}	750.50±4.95^{c}	184.00±2.83^{a}	1853.50±14.85^{c}	1103.00±9.90^{c}	5.07±.00^{ab}	83.60±.57^{b}
T5	497.00±.00^{a}	380.00±1.41^{a}	117.00±1.41^{a}	1145.00±2.83^{a}	765.00±4.24^{b}	5.00±.00^{a}	86.35±.00^{c}
T6	2988.50±84.15^{h}	2220.00±46.67^{h}	768.50±37.48^{e}	3489.50±94.05^{f}	1269.50±47.38^{cd}	5.07±.00^{ab}	82.75±.57^{ab}
T7	2109.50±27.58^{f}	1587.00±28.28^{f}	522.50±.71^{c}	2811.00±33.94^{e}	1224.00±5.66^{cd}	5.04±.05^{ab}	83.08±.04^{ab}
T8	1378.50±7.78^{d}	1064.50±21.92^{d}	314.00±14.14^{b}	2186.00±56.00^{d}	1121.50±21.92^{c}	5.07±.00^{ab}	83.20±.00^{ab}
T9	766.50±.71^{b}	619.00±1.41^{b}	147.50±.71^{a}	1489.00±7.07^{b}	870.00±5.66^{b}	5.10±.04^{bc}	83.90±1.06^{b}
T10	426.00±11.31a	336.50±12.02^{a}	89.50±.71^{a}	916.50±6.36^{a}	580.00±5.66^{a}	5.10±.04^{bc}	88.40±.49^{d}

Means with the same superscripts in a column are not significantly different ($p \leq 0.05$)
Sample
Key = T1 [[100P:0S]; T2 [75P: 25S]; T3 [50P: 50S] T4 [25P: 75S]; T5 [0P: 100S]; T6 [95P:0S: 5O]; T7 [71.25P:23.75S:0.05O]; T8 [47.5P: 47.5S: 5O]; T9 [23.75P:71.25S: 5O]; T10 [0P :95S: 5O] P [Plantain Flour], S [sorghum Flour], O[Okara]

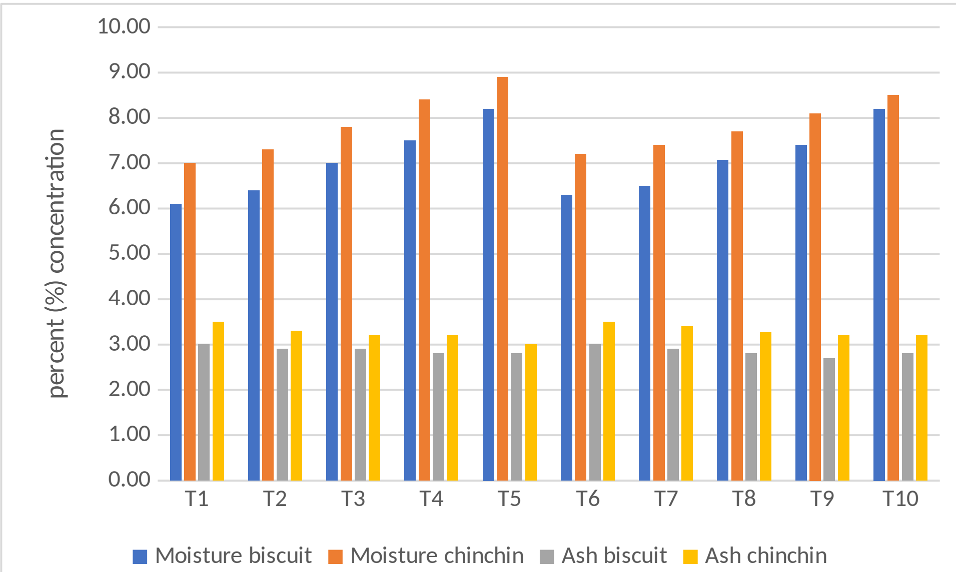

Figure 1: Moisture and Ash content of Biscuit and Chin-chin

As depicted in Figure 1, the moisture (6.10 - 8.20 %) and the per cent ash (2.80 - 3.00 %) of the biscuits and chin chin prepared from the experimental composite flour is higher than that of wheat biscuit (3.65 %) and wheat chin chin (4.9 %), as recorded by Ajibola, Oyerinde and Adeniyan (2015). These observed results might be credited to the high per cent moisture of sorghum and okara in the composite flour (Adegunwa, Ovie, Bakare & Adebowale, 2014). The products prepared using the composite flours will have good shelf stability because snacks with moisture contents below 10% will not be destroyed by microorganisms on the shelf (Udensi & Akaniyo, 2004; Okpala, & Okoli, 2013). The percentage of ash in the biscuits (2.70 - 3.00%) is lower than that of chin chin (3.00 - 3.50 %), and these values decrease significantly as the quantity of sorghum flour increases. In contrast, the addition of okara in the flours mix has no significant impact on the biscuits and chin-chin (Figure 1). Adegunwa et al. (2014) reported higher ash content (4.97%.) wheat chin-chin, while wheat biscuit ash content (2.31%.) recorded by Ajibola et al. (2015) is lower than this study result.

The amount of protein and fat in the biscuits and chin-chin increased significantly ($p < 0.05$), with the increase in the composite flours' sorghum proportion. Also, the okara addition raised the protein and fat contents of the products; however, the chin-chin possessed higher protein and fat content than the biscuit (Figure 2). The per cent fat and protein of chin-chin made in this experiment are lesser than those recorded by Adegunwa et al. (2014) for wheat chin-chin (8.13 % protein and 19.99 % fat). Ajibola et al. (2015) reported higher values for wheat biscuit fat (14.39 %) and protein (10.99 %) than the amount observed in the biscuit produced in this study.

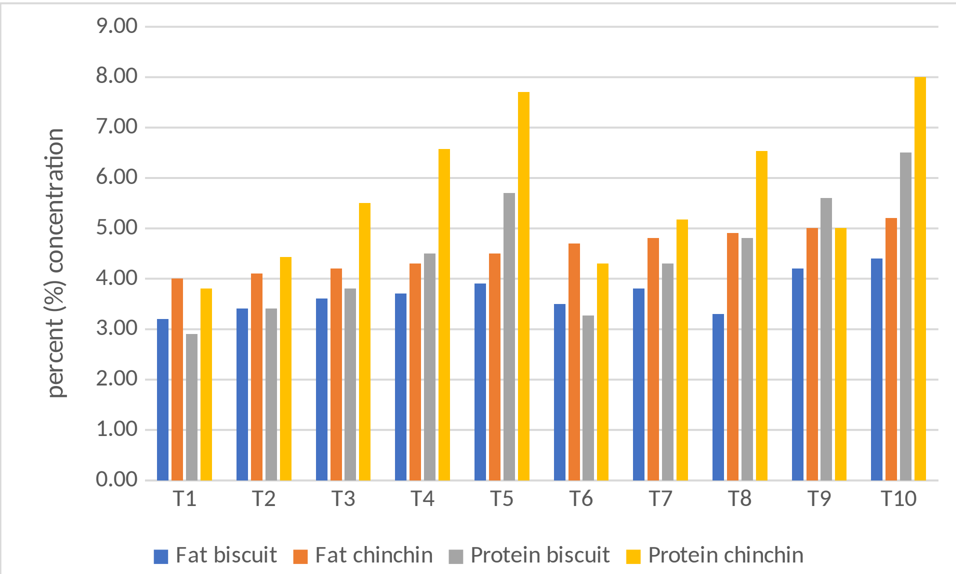

Figure 2: Fat and Protein content of Biscuit and Chin-chin

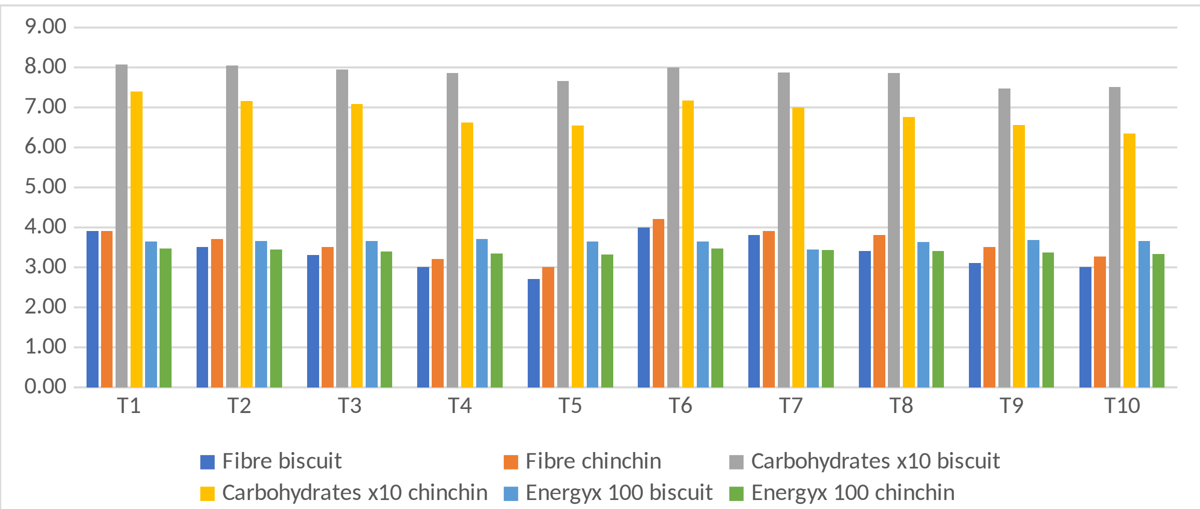

Figure 3: fibre and carbohydrate content, and energy value of Biscuit and Chin chin

The chin-chin fibre content is higher than biscuits' fibre content (Figure 3); however, both products exhibited a significant ($p< 0.05$) reduction in per cent fibre with a rise in sorghum level. Also, the inclusion of okara in the flours resulted in the elevation of chin-chin and biscuits' fibre content because of the okara high fibre contents (Kiin-Kabari et al, 2015). Adegunwa et al. (2014) reported higher fibre content (5.23 %) of wheat chin-chin, while Ajibola et al., 2015, found lower per cent fibre (2.45 %) in wheat biscuits than the results obtained in this study. Increasing the amount of sorghum flour in the mix and adding okara to the flour blend reduced the per cent carbohydrate in the biscuit and chin-chin. Biscuit carbohydrate (75.1 -80.8 %) is higher than chin-chin carbohydrate (63.5 -74.0 %). The energy value of chin chin made from the okara fortified plantain – sorghum flours range from 333.16 to 347.2 kcal/100 g, while that of biscuit is 363.3 to 370.5 kcal/100 g. Food energy derivable from biscuit is higher than chin-chin energy (Figure 3) and similar to that of Okoye, Ojimelukwe and Ukom, (2016).

Sensory evaluation

Sample	Colour	Texture	Aroma	Taste	After Taste	Overall Acceptability
biscuit						
T1	3.55 ± 0.31^{abc}	3.55 ± 0.28^{a}	1.40 ± 0.11^{a}	3.15 ± 0.46^{a}	3.45 ± 0.53^{a}	3.60 ± 0.21^{a}
T2	4.00 ± 0.2^{8bc}	3.55 ± 0.52^{a}	4.00 ± 0.49^{d}	3.80 ± 0.48^{b}	4.05 ± 0.39^{b}	4.50 ± 0.41^{b}
T3	4.60 ± 0.23^{c}	6.35 ± 0.62^{cd}	4.95 ± 0.43^{de}	3.25 ± 0.24^{a}	3.60 ± 0.35^{a}	4.90 ± 0.34^{c}
T4	4.05 ± 0.52^{bc}	6.95 ± 0.40^{d}	5.15 ± 0.52^{e}	4.05 ± 0.21^{b}	3.85 ± 0.35^{a}	5.10 ± 0.39^{d}
T5	4.45 ± 0.27^{c}	5.45 ± 0.17^{bc}	2.90 ± 0.48^{b}	5.10 ± 0.34^{c}	4.90 ± 0.59^{c}	5.00 ± 0.34^{cd}
T6	3.20 ± 0.34^{ab}	5.10 ± 0.5^{bc}	3.50 ± 0.34^{c}	4.00 ± 0.42^{b}	3.90 ± 0.37^{a}	5.00 ± 0.36^{cd}
T7	3.95 ± 0.38^{bc}	4.90 ± 0.38^{b}	3.30 ± 0.33^{bc}	4.05 ± 0.03^{b}	3.75 ± 0.50^{a}	5.20 ± 0.33^{d}
T8	4.20 ± 0.32^{bc}	5.15 ± 0.48^{bc}	3.20 ± 0.32^{bc}	3.20 ± 0.19^{a}	3.75 ± 0.46^{a}	4.70 ± 0.37^{bc}
T9	3.25 ± 0.32^{ab}	5.85 ± 0.43^{bcd}	3.60 ± 0.44^{c}	3.60 ± 0.40^{ab}	4.15 ± 0.44^{b}	4.05 ± 0.29^{b}
T10	22.75 ± 0.31^{a}	44.95 ± 0.51^{b}	33.55 ± 0.38^{c}	33.55 ± 0.44^{ab}	33.50 ± 0.48^{a}	44.95 ± 0.31^{c}
chinchin						
T1	4.80 ± 0.35^{ab}	5.55 ± 0.34^{a}	6.15 ± 0.15^{bcd}	6.20 ± 0.30^{a}	5.65 ± 0.27^{bc}	5.80 ± 0.25^{a}
T2	4.60 ± 0.31^{a}	$5.58c\pm0.30^{b}$	5.45 ± 0.18^{abcd}	6.25 ± 0.22^{a}	5.79 ± 0.15^{d}	6.50 ± 0.21^{ab}
T3	5.30 ± 0.39^{ab}	5.60 ± 0.30^{a}	5.20 ± 0.32^{cd}	6.30 ± 0.22^{a}	6.00 ± 0.16^{cd}	6.30 ± 0.33^{ab}
T4	5.10 ± 0.30^{ab}	5.69 ± 0.39^{abc}	5.16 ± 0.28^{d}	6.45 ± 0.34^{a}	6.30 ± 0.25^{bcd}	6.50 ± 0.28^{ab}
T5	5.05 ± 0.26^{ab}	5.80 ± 0.31^{a}	5.00 ± 0.22^{ab}	6.55 ± 0.27^{a}	6.60 ± 0.20^{d}	6.50 ± 0.27^{ab}
T6	4.50 ± 0.30^{a}	5.70 ± 0.18^{ab}	6.20 ± 0.30^{abcd}	6.27 ± 0.22^{a}	5.00 ± 0.31^{a}	5.90 ± 0.25^{a}
T7	5.25 ± 0.38^{ab}	5.75 ± 0.26^{a}	5.59 ± 0.26^{abc}	6.32 ± 0.19^{a}	5.30 ± 0.23^{b}	6.80 ± 0.19^{b}
T8	5.20 ± 0.40^{ab}	6.30 ± 0.17^{abc}	5.45 ± 0.39^{a}	6.45 ± 0.14^{a}	5.55 ± 0.21^{d}	6.55 ± 0.31^{ab}
T9	5.55 ± 0.26^{ab}	6.70 ± 0.21^{bc}	5.32 ± 0.33^{abcd}	6.50 ± 0.37^{a}	6.15 ± 0.28^{bcd}	6.55 ± 0.29^{ab}
T10	5.85 ± 0.26^{ab}	6.95 ± 0.18^{c}	5.10 ± 0.31^{abcd}	6.55 ± 0.32^{a}	6.90 ± 0.30^{bcd}	6.95 ± 0.23^{b}

Table 7: Sensory evaluation of biscuit and chinchin from okara-fortified plantain-sorghum composite flours

Means with the same superscripts in a column are not significantly different ($p\leq0.05$)
Sample

Key = T1 [[100P:0S]; T2 [75P: 25S]; T3 [50P: 50S] T4 [25P: 75S]; T5 [0P: 100S]; T6 [95P:0S: 5O]; T7 [71.25P:23.75S:0.05O]; T8 [47.5P: 47.5S: 5O]; T9 [23.75P:71.25S: 5O]; T10 [0P :95S: 5O] P [Plantain Flour], S [sorghum Flour], O[Okara]

Sensory property is an important determinant of food approval since consumers often examine detailed sensory attributes of food. The food product may have adequate proximate composition and high energy value, but without good sensory quality, such a product is likely to be unacceptable. The results of the organoleptic test carried out on the biscuit and chin chin made from the experimental flours, as presented in Table 7, revealed a significant variation in all the parameters assessed. The 20 – member panellists recorded better sensory scores for biscuit (colour 3.55 – 4.3; texture 3.05 -4.09; aroma 1.40 – 3.95; taste 3.25 – 4.35; aftertaste 3.5 – 3.6; overall acceptability 4.6 – 5.35) than chin-chin (colour 4.8 – 5.25; texture 5.58 -6.95; aroma 4.8 – 5.82; taste 4.2 – 4.55; aftertaste 5.65 –6.41; overall acceptability 5.8 – 6.95). Also, an increase in sorghum substitution and the addition of okara in the flour mix reduced the products' sensory quality. Biscuit made with 100 % plantain flour was most acceptable in terms of colour, texture, aroma, taste, after taste, and overall acceptability.

CONCLUSION

The okara enriched plantain-sorghum flours and their corresponding biscuit and chin-chin in this study are nutritionally better in protein, fat, and crude fibre than wheat flour. The fortification of the plantain - sorghum with 5% okara shows a notable increase in protein content. As revealed in the results above, highly nutritious food can be produced from a plantain-sorghum blend fortified with okara. The composite flours could serve as a substitute for wheat flour in making baked products that can fight protein malnutrition in developing countries. The study reveals that the inclusion of okara flour in the plantain-sorghum blend increase the protein level, hence, enhance the functional properties of the flours, which are required attributes for the production of starchy meals, and could serve as an advantage in both the domestic and industrial use of these crops.

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Uzo-Peters, P.I., & Ola, S.T. *(2020)* Proximate composition and functional properties of composite sorghum-okara flour and sensory evaluation of local snack product *(sosa) Agrosearch, 20(1): 158-167* https://doi.org/10.4314/agrosh.v20i1.14S