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Anti-diabetic Potentials of Cookies from Wheat, Sweet Potato and African Yam Beans (*Sphenostylis stenocarpa*) Composite Flour Blends

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Authors' contributions

This work was carried out in collaboration between both authors. Author DAO performed the experiment and wrote the first draft of the manuscript. Author SAM designed the experiment, supervised the study and edited the final manuscript. All authors read and approved the final manuscript. Both authors read and approved the final manuscript.

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ABSTRACT

The consumption of cookies offered reliable advantages to the consumers, which included but not limited to perfect eating ability, prolong shelf live and acceptability among all nations. This study thus, investigated the antioxidant and anti-diabetic properties of cookies obtained from wheat-African yam bean-sweet potato composite flour blends at different ratios. The African yam bean and sweet potato were thoroughly processed, milled, sieved thereafter mixed with the commercial wheat flour. Four blends were prepared by using the trial mixing ratio and 100% wheat flour and later used to bake cookies. The proximate, amino acid compositions, antioxidant, amylase and glucosidase inhibitory activities as well as physical properties of the composite cookies were

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examined while panelists were assigned to assess the cookie samples. The results of the proximate composition showed that the composite flour technology had significant ($p<0.05$) positive effects on the cookies. Meanwhile, the amino acid compositions of the cookies revealed that the cookie samples were of high aromatic and hydrophobic amino acids, respectively with optimum physical properties. No panelist showed a total dislike for the taste of any of the samples. The added soybean seeds flours showed no significant ($p<0.05$) effect on the acceptability and preference of the samples. Hence, it is possible to produce better protein and high nutritional cookies from these flour blends. We therefore concluded that the cookies rich in antioxidants and anti-diabetic potentials could be produced from wheat-African yam bean-sweet potato composite flour.

Keywords: African yam bean; inhibition; amino acid; amylase; glucosidase; cookies.

1. INTRODUCTION

African yam bean (*Phaseolus vulgaris* L) are common legumes consumed worldwide as excellent plant-based source of protein [1]. Endogenous protein displayed anti-inflammatory properties that served as major component in the immune system. For instance, the system contained about 30 plasma proteins that had contributory role in fighting pathogen. This is done through close interaction with other components found in the immune system [1]. It helped anti-bodies and phagocyte to eliminate pathogen. African yam beans (AYB) are good source of proteins and trace mineral, which is essential co-factors in a number of enzymes important in energy production and anti-oxidant defenses, which disarmed free radicals produce within the mitochondria [2]. Therefore, AYB could help in the weight loss as well as promoting colon health-related issues and modulating the blood sugar levels [2]. Sweet potato is an important crop in many parts of the world, which is classified as a storage root rather than as a tuber. Sweet potato served as sources of staple food for human beings and for the animal feed as well [3]. Other utilization involved serving as means of raw materials for expansive industrial purposes like starch and alcohol industrial production [3]. For instance, some households dried sweet potato and ground it into flour to be cooked for human being consumption. Its starch is also used for the production of adhesives for textile and paper industries, even as raw material for the animal feed processing industry. It is being processed in the tropics such as in boiling, baking, roasting and frying before consumption by the consumers, in order to increase its value addition. The most prominent products from soybean were its flour and/or starch, which were employed in the preparation of sweetener, flavourants and dietary fibre for the baked goods and beverages [4].

The consumption of low-carbohydrate diets had been the current trend in the present nutritional studies ongoing in most countries, which included clamoring for slowly digested food products and increased functional foods intake [5]. This is because of the fact that the food producers were faced with the challenges of preparing food products loaded with functional ingredients that could meet the nutritional requirements of individuals living with chronic health challenges. Adequate nutrition, which is achieved through consumption of a balanced healthy diet, is a fundamental pillar of human life, health and development across the entire life spam [6]. Therefore, cookies were known as delivery vehicle of most nutrients to the consumers [7]. Cookies are small flat, baked confectionary which is either crisp or soft but firm [7]. It is majorly produced from wheat flour and other ingredients. Research has shown that cookies can also be produced from other composite flour that are of more health benefits than the regular wheat flour [8]. Currently, there is a great awareness among the consumers in the preventive health care with respect to the development of natural functional foods ingredients from plant materials due to their high bio-digestion rate with no residual or negative side effects that were known with series of synthetic drugs. Hence, the production of cookies from the flour blends obtained from these well-known crops (sweet potato and African yam bean) would serve as basic functional foods aiming to be used in the management of the chronic cardiovascular diseases, such as diabetes, etc. Thus, the main objective of this study is to examine the *in vitro* anti-diabetic potentials of cookies from sweet potato, African yam bean and wheat composite flours. This is done by specifically determining the proximate, amino acid compositions, antioxidant, amylase and glucosidase inhibitory activities as well as physical and organoleptic properties of the composite cookies.

2. MATERIALS AND METHODS

2.1 Materials

The commercial wheat flour, which have been commonly used for all baking processes, was obtained from a commercial baking ingredients store in Ado Ekiti, Nigeria. The sweet potato tubers and African yam bean (AYB) seeds were obtained from the King's market, Ondo, Nigeria. The sweet potato tubers and AYB seeds were then authenticated using the plant's catalog present in the Crop Management Department of the Federal University of Technology, Akure, Ondo State, Nigeria. All the chemicals and reagents used were of scientific analytical grade and they were procured from the Sigma-Aldrich, London, United Kingdom.

2.2 Preparation of African Yam Bean (AYB) Flour

The AYB flour was obtained according to the method previously described [9]. The seeds were sorted to thoroughly remove the foreign materials, other defected seeds present as well as insects, among others. The beans were washed and conditioned for germination by soaking overnight, drained, spread on flat trays and covered in a closed environment (20-25 ^{o}C) for about 2-3 days for sprouting. The germinated beans were dried to remove the sprouts, dehulled, milled in attrition mill and finally sieved through 0.4 mm wire mesh to obtain the final flour for further analysis.

2.3 Preparation of Sweet Potato Flour

The matured sweet potato tubers were firstly peeled and manually cut into thin pieces using knife. Thereafter, the sweet potato cut slices were fully dipped in the 1% NaCl + 1% potassium metabisulphite + 0.5% citric acid solution for about half an hour so as to minimize the incessant browning reactions as well as enhancing the colour development of the final flour product. They were then dried on perforated trays in the hot air oven dryer (55 ^{0}C) till constant weights of the dried chips were achieved, followed by milling and stored till further use according to the previously described method [4].

2.4 Formulation of Composite Flour Blends

The composite flour blends were formulated as stipulated in the Table 1 *viz:*

2.5 Production of Cookies

Cookies were produced as previously described [4] with the following ingredients, composite flour, margarine, baking powder, salt, beet, eggs and water. The ingredients were thoroughly mixed in a bowl for few minutes followed by adding the margarine and eggs and kneaded to form batter. The batter was then rolled further with flour to obtain a unique thickness and cut with a 50 mm-diameter cookie cutter. The cookies were then placed in the baking trays with a 25 mm space in between the cookie and subjected to baking in the oven at 180 ^{0}C for 10 min. The cookies were then removed from the hot oven and allowed to cool at room temperature, further packaged inside the polyethylene bags and finally stored for the subsequent analysis.

2.6 Proximate Composition Analysis

The proximate compositions of the different flour blends and cookies were determined according to the methods previously described by the AOAC [10]. However, the total carbohydrate content of the flours and cookie samples was estimated by the difference means.

Table 1. Flour blends formulations

Samples	Formulations	Wheat	Sweet potato	African yam beans	Total (%)
WSA 1	Wheat (commercial flour)	100	0	0	100
WSA 2	Wheat + Sweet potato + African yam bean flour	80	10	10	100
WSA 3	Wheat + Sweet potato + African yam bean flour	70	20	10	100
WSA 4	Wheat + Sweet potato + African yam bean flour	60	20	20	100

2.7 Amino Acid Analysis

The amino acid profiles of the cookies were determined by using the High Performance Liquid Chromatography (HPLC) according to the previously described method [11]. For instance, the samples were firstly derivatized for about 20 min using a solvent mixture that contained the following: 95% ethanol:water:triethylamine:phenylisothiocyanate (7:1:l:1). This is done after drying under vacuum and later dissolved in the buffer A prior to the HPLC separation attached to the Pico-Tag column using the scientific at the flow rate of 0.45 mL/min using the 254 nm detection for over 10 min.

2.8 Determination of DPPH Radical Scavenging Activity

The radical scavenging activities of the cookie samples were determined using DPPH (2,2-diphenyl-1-picrylhydrazyl hydrate) radicals as previously described [11]. The changes in colour from the deep violet to light yellow was then spectrophotometrically measured at wavelength of 517 nm. Briefly, 1 ml of different concentrations of the sample or ascorbic acid (used as standard) in the test tube was added to the 1 ml of 0.3 mM DPPH in methanol. The obtained mixture was then thoroughly mixed and further incubated in the dark space for like 30 min and thereafter read its absorbance at wavelength of 517 nm.

2.9 Determination of Ferric Reducing Antioxidant Power (FRAP)

The Ferric reducing antioxidant power of the cookies was determined as previously described [11]. Briefly, 100 µl of the sample was mixed dissolved in the 2.5 ml taken from the mixture of 200 mmol/l phosphate buffer (pH 6.6) and 2.5 ml of 1% potassium ferricyanide, which is then incubated at 50 °C for 20 min. Then, 2.5 ml of 10% trichloroacetic acid was added to the incubated sample while the tubes were later centrifuged at 10,000 rpm for 10 min. Thereafter, 5 ml of the supernatant was then mixed with 5.0 ml of distilled water and 1 ml of 0.1% ferric chloride, followed by reading the absorbance at the wavelength of 700 nm. Meanwhile, the same procedure was done using ascorbic acid as the positive control.

2.10 Determination of Hydroxyl Radical Scavenging Activity

The hydroxyl radical scavenging activity was determined according to the procedures previously described [11]. The reaction mixture was obtained from mixing the $FeCl_3$ (100 µM), EDTA (104 µM), H_2O_2 (1 mM) and 2-deoxy- D-ribose (2.8 mM) to the samples. Then, final volume was made by adding 1 ml of the previous mix and 20 mM potassium phosphate buffer (pH 7.4) and incubated for 1 h under 37 ^{o}C, further heated in water bath (95 ^{o}C; 15 min). The TCA (2.8%) and TBA (0.5% TBA in 0.025 M NaOH having 0.02% BHA) were added together, ice cooled and centrifuged (5000 rpm; 15 min). The absorbance is then read at 532 nm. Meanwhile, the same procedure was done using ascorbic acid as the positive control

2.11 Determination of Iron Chelating Activity

The metal chelating activity was determined according to the previously described method [11]. Briefly, the 0.1 mM $FeSO_4$(0.2 ml) and 0.25 mM ferrozine (0.4 ml) mixture were subsequently added into the sample (0.2 ml). This is subjected to incubation at 25 ^{o}C for 10 min, and the final absorbance was read at the wavelength of 562 nm.

2.12 Inhibition of α-Amylase Activity

The *in-vitro* α-amylase activity was carried out by using the starch-iodine method [6] whereby a 10 µL of α- amylase solution (0.025 mg/ml) was mixed with 390 µl of phosphate buffer (0.02 M that contained 0.006 M NaCl, pH 7.0) to the samples. This was subjecting to an incubation at 37 °C for 10 min, after which 100 µl of starch solution (1%) was added incubated for another 1 h. This is followed by addition of 0.1 ml of 1% iodine solution and 5 ml distilled water, while the final absorbance was read at the wavelength of 565 nm.

2.13 Inhibition of α-Glucosidase Activity

The *in-vitro* α-glucosidase activity was carried out by using the starch-iodine method [6] whereby a 10 µL of α-glucosidase (0.057 U) solution (0.025 mg/ml) was mixed with 390 µl of phosphate buffer (0.02 M that contained 0.006 M NaCl, pH 7.0) to the samples. This was subjecting to an incubation at 37 °C for 10 min, after which 100 µl of starch solution (1%) was added incubated for another 1 h. This is followed by addition of 0.1 ml of 1% iodine solution and 5 ml distilled water, while the final absorbance was read at the wavelength 400 nm.

2.14 Determination of Physical Properties of Cookies

The cookies were analysed for weight, diameter, thickness (width) and spread factor (diameter/thickness) according to respective procedures previously described [7]. Cookie diameter (D) and thickness (T) were determined using a vernier caliper. Spread factor (SF) was also determined from the diameter and thickness, using a formula:

SF = (D/T X CF) X 10 where CF is correction factor, at constant atmospheric pressure.

2.15 Evaluation of Sensory Attributes

The cookies were coded and presented to twenty (20) semi-trained panelists to be evaluated for their appearance, texture, taste, aroma, mouth feel, crumblings, overall acceptability using the Hedonic scale, where 1 and 9 is dislike extremely and like extremely, respectively as previously described [7].

2.16 Statistical Analysis

All the determinations in the study were carried out in triplicates. However, the data was subjected to the analysis of variance (ANOVA) using SPSS (version 21, USA), while means was separated using New Duncan Multiple Range Test at 5% level of significance (p<0.05).

3. RESULTS AND DISCUSSION

3.1 Proximate Compositions of Cookies

The crude protein contents of the cookies presented in Table 2 showed the ranges of results from 15.16 to 28.15%, which is higher than the 4.50 and 8.90% reported for wheat-potato flour blends-produced biscuit [12]. Their increased protein contents could possibly come from the African yam bean (AYB) fraction of the blended flour that is protein-loaded. The increase in protein value of the cookies indicated high nutritional value. The consumption of 17-25 g of soy protein per day had been reported to reduce serum cholesterol to 9.3% on the average, while the low-density lipoprotein cholesterol reduced to ~13% [13].

The crude fiber ranged between 1.85 and 4.10%. The result is higher than the 0.37 and 1.48% reported for wheat-acha-soybean composite cookies [14]. The higher fiber content could have come from the sweet potato fraction of the flour since the dehulling process was applied to the AYB. The increase in fiber of the cookies as a result of supplementation agreed with the past findings [4]. Crude fibre helped to manage chronic diseases, like CVD, colon cancer and diabetes, among others. The present study has showcased the wheat flour as a low source of fibre due to its significant (p<0.05) low crude fibre content. Therefore, it will be useful if sweet potato is added to it and used in food formulation to help relieve the problems of constipation in the bowel.

The crude fat in the cookies ranged between 5.48 and 7.61%, with highest concentration of fat (7.61%) observed in cookies produced from sample WAS 1, which is lower than the 10.97 - 18.93% previously reported for wheat-potato biscuit [12]. However, cookies with reasonable concentrations of fat were produced from all the composite flour ratios.

The crude ash contents ranged between 2.13 and 2.61%, with the highest value observed in cookies produced from sample WAS 1. The ash content of any food material is an index of

Table 2. Proximate compositions of composite cookies (%) (on dry weight basis)

Samples	Moisture	Crude protein	Crude fiber	Crude fat	Crude ash	Carbohydrate
WAS 1	8.13±0.13^{b}	15.16±0.27^{e}	2.67±0.02^{b}	7.61±1.22^{b}	2.61±0.21^{a}	66.95±1.26^{a}
WAS 2	8.67±0.18^{a}	28.15±0.33^{a}	2.88±0.01^{b}	5.48±0.57^{a}	2.28±0.20^{b}	54.21±1.01^{ab}
WAS 3	8.33±0.12^{b}	22.59±0.12^{b}	2.05±0.03^{b}	6.28±0.56^{c}	2.60±0.19^{ab}	60.49±0.80^{c}
WAS 4	8.31±0.25^{b}	19.52±0.51^{c}	4.10±0.02^{a}	6.31±0.64^{ab}	2.26±0.20^{bc}	60.81±0.66^{bc}
WAS 5	8.20±0.12^{b}	16.58±0.04^{d}	1.85±0.03^{c}	6.12±0.47^{b}	2.13±0.20^{bc}	67.19±0.64^{b}

Means (n=3) with different letter in the column are significantly different (p<0.05).
Key: *WAS 1 = 100:0:0% (commercial flour); WAS 2 = 45:20:35%; WAS 3 = 40:30:30%; WAS 4 = 35:40:25%; WAS 5 = 30:50:20% (wheat:sweet potato:African yam bean) flour blends*

mineral constituents of such food. This is because the ash has been depicted as the inorganic residue found remaining during the heat removal of water and organic matter using the presence of a good oxidizing agent [15]. The carbohydrate values ranged between 54.21 and 67.19%, which was higher than the 42.22 to 50.45% previously reported for breadfruit-breadnut-wheat composite bread [16]. This observation could be adduced to the high content of carbohydrate in sweet potato than AYB and wheat hence, the higher carbohydrate content in the cookies, made it a quick source of metabolizable energy and thus, to be assisted in fat metabolism.

3.2 Amino Acids Profiles of Cookies Samples

The results of the amino acids profile of the cookies made from WAS 1 (control), 2, 3, 4 and 5 composite flours were presented in Table 3 with observable significant ($p<0.05$) differences. The result showed that eighteen (18) different amino acids were determined including the nine (9) essential amino acid *viz:* phenylalanine, isoleucine, valine, threonine, leucine, isoleucine, lysine, histidine, methionine. Further observation of the result (Table 3) revealed that the lysine and aspartic acid contents were higher in the composite cookies (WAS 2, 3, 4 and 5) when compared to the control sample (WAS 1). Contrarily, cookie sample WAS 2 has higher amounts of glutamic acid, arginine (a precursor of nitric oxide (good visodilator), proline, cystine and histidine than in cookie samples WAS 4 and 5, respectively. Notably, the well-known aromatic amino acids such as tryptophan, tyrosine and phenylalanine (Table 3) were all significantly ($p<0.05$) higher in sample WAS 2 than in other samples WAS 1, 3, 4 and 5, respectively. This could invariably have a positive contributory effect on its bioactivities and antioxidative effects [4,6,9,11].

3.3 Antioxidant Properties of Cookies

Past studies have reported the significant lowering of antioxidants in the plasma during the pathogenesis of diabetes as well as in its associated complications [17-18]. For instance, a low level of plasma antioxidants was more pronounced in elderly diabetic patients (Polidori *et al.,* 2001). Therefore, this brought a strong rationale for the therapeutic use of antioxidants in the management of diabetes. Although, phytochemicals (such as flavonoids, carotenoids, ascorbic acid and tocopherols) were the main sources of antioxidants [19] but other food crops, like snacks of high protein contents could be found exploitable as good antioxidants. The antioxidants effectively inhibited the production of reactive oxygen species (ROS) through inhibition of the action of several known ROS contributing enzymes, like cyclooxygenase, glutathione-S-transferase, NADH oxidase among others [20].

The hydroxyl (OH) radical scavenging activity of the cookie samples is presented in Fig 1. The properties of the samples were recorded in the ranges of 22.89 to 73.89% when compared to the common and well-known antioxidant, ascorbic acid (78.89%). It was observed that the sample WAS 2 had the significant ($p<0.05$) highest property (~74%) when compared to sample WAS 1 (cookie from wheat flour only) that has ~23% activity.

The DPPH radical scavenging activity of the samples is obtained in the following ranges; 20.34-82.11% as shown in Fig. 2. It was observed that the samples shown significant ($p<0.05$) difference between each other against DPPH activities and when compared to ascorbic acid. It was also observed that the cookie samples were significantly ($p<0.05$) less than ascorbic acid in free radical scavenging activities.

A similar trend of low Fe^{2+} chelation antioxidant activity was observed in WAS 1 (24.22%) when compared to WAS 2 (72.20%) as presented in Fig. 3. It was observed that the antioxidant activities of sample WAS 1, 3, 4 and 5 (with respect to hydroxyl, DPPH radical scavenging and Fe^{2+} chelation antioxidant activities) were significantly ($p<0.05$) lower than WAS 2. This implied that the samples WAS 1, 3, 4 and 5 exhibited less ability to scavenging free radicals against hydroxyl and DPPH radicals thereby having less potential to chelate $Fe^{2+.}$

The result presented in Fig. 4 revealed that the sample WAS 2 also had highest ferric reducing antioxidative potentials (FRAP) when compared to others. For instance, WAS 2 and WAS 1 had 0.78 and 0.49 mmol Fe^{2+}/mg when compared with ascorbic acid (0.88 mmol Fe^{2+}/mg).

The relative higher antioxidant potentials 82.11%) of the cookie sample WKB4 may be attributed to its higher protein content (28.20%), glutamic acid (14.01%) and arginine amino acids (3.88%) when compared to other samples. This observation agreed with other findings, that reported the efficacy of protein and amino acids profiles to enhance the antioxidant capacity, which was related to the release of bioactive peptides [21]. This finding also agreed with past study that reported on the contributions of antioxidants in diabetes and its complications [22]. Several studies have demonstrated significant decrease of cardiovascular disease such as diabetes and hypertension with consumption of foods that were rich in antioxidants [22, 23-24]. Hence, sample WAS 2 could potentially help in reducing the risk of chronic cardiovascular diseases.

Table 3. Amino acid compositions of cookies (%)

Samples/AA	WAS 1	WAS 2	WAS 3	WAS 4	WAS 5	Average	± Std	#LSD (p<0.05)
Aspartic acid	7.62	12.87	10.58	9.27	9.16	9.90	1.11	0.37
Threonine	2.53	3.92	3.59	2.23	2.73	3.00	0.35	1.00
Serine	4.34	4.44	3.23	4.85	3.56	4.08	0.27	0.33
Glutamic acid	8.52	14.01	12.49	11.36	11.27	11.53	1.60	1.00
Proline	2.10	2.78	2.26	2.04	2.19	2.27	0.41	1.00
Glycine	3.18	3.21	2.27	2.28	2.22	2.63	0.05	0.15
Alanine	2.58	3.52	2.89	2.18	2.58	2.75	0.36	1.00
Cystine	0.22	1.39	0.95	0.51	0.31	0.68	0.58	1.00
Valine	4.28	4.76	4.53	3.64	3.11	4.06	0.25	1.00
Methionine	2.14	2.62	2.45	2.91	2.14	2.45	0.39	1.00
Isoleucine	2.67	3.70	3.75	2.69	2.67	3.10	0.02	0.09
Leucine	3.48	3.91	2.90	2.62	2.44	3.07	0.58	1.00
Tyrosine	3.03	3.49	2.74	2.31	2.03	2.72	0.65	1.00
Phenylalanine	2.32	7.42	6.58	2.98	2.32	4.32	0.08	1.00
Histidine	3.02	5.72	3.39	3.13	3.31	3.71	0.37	1.00
Lysine	3.03	4.70	3.77	3.72	3.68	3.78	0.81	1.00
Arginine	2.31	3.88	3.42	2.61	2.54	2.95	0.52	1.00
Tryptophan	0.80	1.91	0.76	0.82	0.87	1.03	0.30	1.00

Key: *WAS 1 = 100:0:0% (commercial flour); WAS 2 = 45:20:35%; WAS 3 = 40:30:30%; WAS 4 = 35:40:25%; WAS 5 = 30:50:20% (wheat:sweet potato:African yam bean) flour blends. ± Std = Standard deviation; #LSD (p<0.05) = Least significant difference at 5% level of significance*

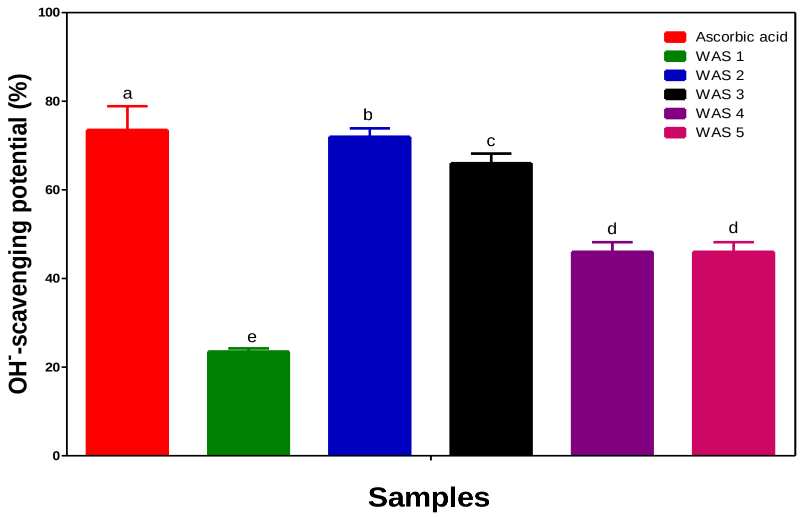

Fig. 1. Hydroxyl (OH) radical scavenging potential of cookies

Bars (n=3) with different letter are significantly different (p<0.05).

Key: *WAS 1 = 100:0:0% (commercial flour); WAS 2 = 45:20:35%; WAS 3 = 40:30:30%; WAS 4 = 35:40:25%; WAS 5 = 30:50:20% (wheat:sweet potato:African yam bean) flour blends*

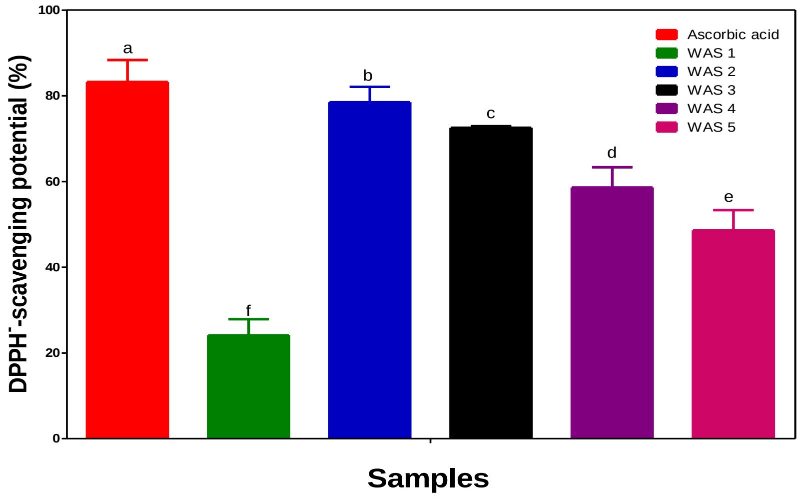

Fig. 2. DPPH radical scavenging potential of cookies

Bars (n=3) with different letter are significantly different (p<0.05).
***Key:** WAS 1 = 100:0:0% (commercial flour); WAS 2 = 45:20:35%; WAS 3 = 40:30:30%; WAS 4 = 35:40:25%; WAS 5 = 30:50:20% (wheat:sweet potato:African yam bean) flour blends*

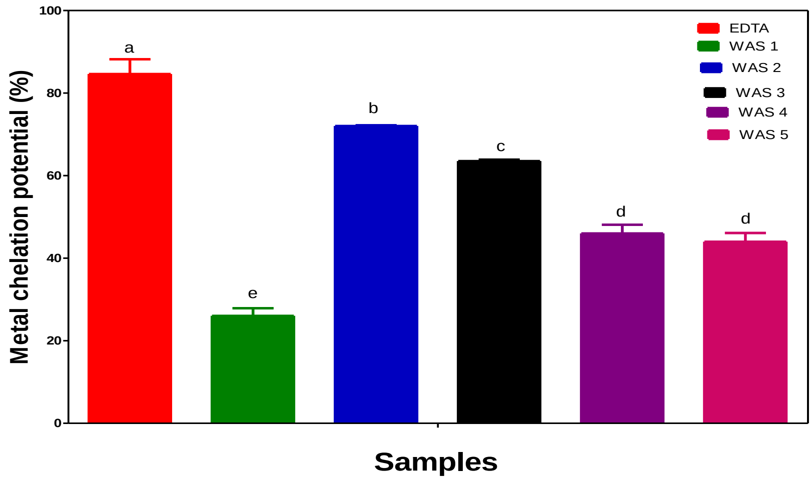

Fig. 3. Metal chelation potential of cookies

Bars (n=3) with different letter are significantly different (p<0.05).
***Key:** WAS 1 = 100:0:0% (commercial flour); WAS 2 = 45:20:35%; WAS 3 = 40:30:30%; WAS 4 = 35:40:25%; WAS 5 = 30:50:20% (wheat:sweet potato:African yam bean) flour blends*

3.4 Anti-Diabetic Properties (α-Amylase and α-Glucosidase Inhibition Potentials) of Cookies

The main management employed in the treatment of diabetes mellitus (DM), especially the type-2 one, is the effective control of the metabolic activities of the key enzymes that have been implicated in the pathogenesis of the type-2 DM. for instance, the inhibition of carbohydrases (α-amylase and α-glucosidase) has practically aided the effective hyperglycemia control of most diabetic individuals [25]. This is because the well-known pancreatic α-amylase and intestinal α-glucosidase played adequate roles of carbohydrate hydrolysis and absorption in the body [26]. Therefore, their metabolic activities had to be practically managed in order to maintain the blood glucose in the body [27]. The data revealed in Fig. 5 is the α-amylase inhibition abilities of the composite wheat, African yam bean and sweet potato (WAS) cookie samples. The percentage α –amylase inhibition of the cookie samples ranged from 28.11% (WAS 1) to

58.89% (WAS 2). The cookie WAS 2 had significant ($p<0.05$) higher α–amylase inhibition than the other samples (WAS 1, 3, 4 and 5) but lower than the activity obtained (68.12%) for acarbose, a common anti-diabetic drug. The higher proline, glutamic and aspartic amino acids obtained for WAS 2 (Table 3) might be accounted for its higher α–amylase inhibition [28]. The highest α–amylase inhibition (58.89%) exhibited by WAS 2 could enhance its usage as a potential anti-diabetic agent with no negative side-effect as non-insulin dependent diabetic mellitus (NIDDM) diet. The results presented in Fig. 6 showed the potential of the cookie samples to inhibit α- glucosidase activities. The inhibition potentials ranged from 24.22% (WAS 1) to 49.89% (WAS 2). The other composite cookie samples (WAS 1, 3, 4 and 5) have significant ($p<0.05$) less α- glucosidase inhibition than the WAS 2.

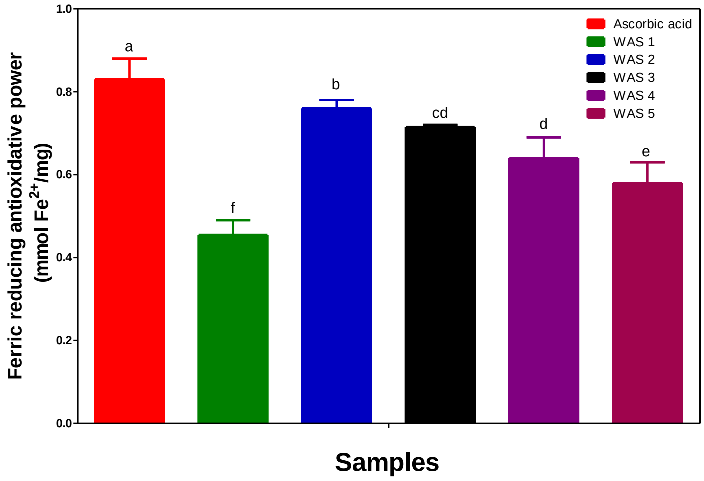

Fig. 4. Ferric reducing properties of cookies

Bars (n=3) with different letter are significantly different (p<0.05).

Key: *WAS 1 = 100:0:0% (commercial flour); WAS 2 = 45:20:35%; WAS 3 = 40:30:30%; WAS 4 = 35:40:25%; WAS 5 = 30:50:20% (wheat:sweet potato:African yam bean) flour blends*

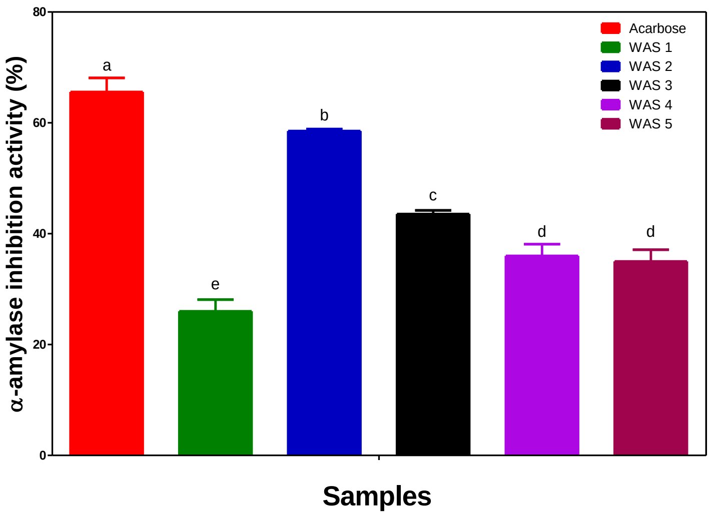

Fig. 5. *In vitro* α-amylase inhibition activities of cookies

Bars (n=3) with different letter are significantly different (p<0.05).

Key: *WAS 1 = 100:0:0% (commercial flour); WAS 2 = 45:20:35%; WAS 3 = 40:30:30%; WAS 4 = 35:40:25%; WAS 5 = 30:50:20% (wheat:sweet potato:African yam bean) flour blends*

However, the result (Fig. 6) showed no significant difference (p>0.05) between cookie sample WAS 2 and acarbose, a well-known anti-diabetic drug. Hence, the cookie sample WAS 2 has potential to be used to modulate the type 2 diabetes. The cookie sample WAS 2 obtained from 45% wheat flour + 20% sweet potato flour + 35% African yam bean flour has improved inhibition of α-glucosidase and this might be due to its higher protein content as well as its better glutamic amino acids, when compared to other samples [28].

3.5 Physical Properties of Cookies

The result of the physical properties of cookies produced was shown in Table 4. The weights of the cookie samples WAS 2 and 5 were significantly (p<0.05) highest (14 g) when compared to WAS 1 (12.72 g). However, there seemed no significant difference between the diameters and thickness of the cookie samples, which ranged between 5.23 – 5.52 mm and 0.43 – 0.50 mm, respectively. There was increase in thickness as the levels of substitution of sweet potato increased but found contrary to the trends observed with the present results for the spread ratio, which is dependent on the amount of dry ingredients to the water available [4, 7]. Thus, the spread ratio results could be significantly (p<0.05) by the amount of protein and fat present in the African yam bean flour. The observable occurrences on the spread ratio of cookies in this current study seemed not to be due to competition over available water by ingredients as both African yam bean and sweet potato flours absorbed water during dough mixing. The differences might be traced to the blend's protein and fat contents, which is found affected by the rise in the cookies in the baking oven. Above all, the composite cookies showcased attractive physical properties.

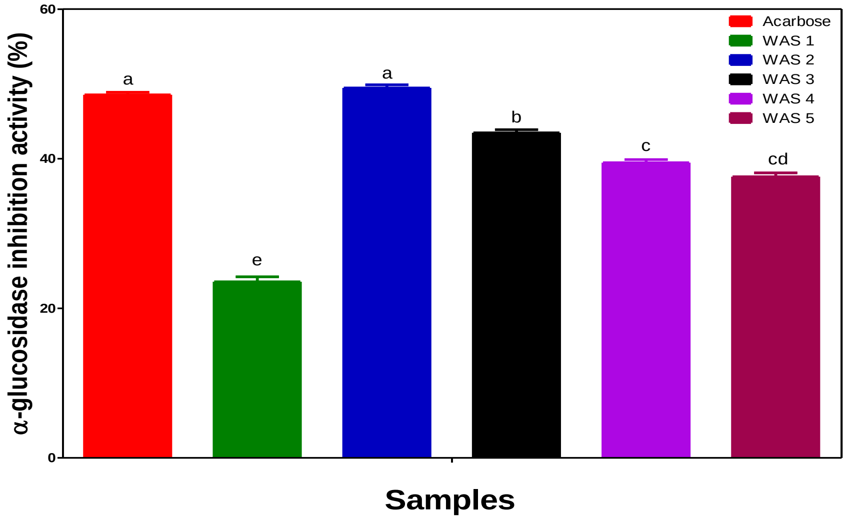

Fig. 6. *In vitro* α-glucosidase inhibition activities of cookies
Bars (n=3) with different letter are significantly different (p<0.05).
***Key:** WAS 1 = 100:0:0% (commercial flour); WAS 2 = 45:20:35%; WAS 3 = 40:30:30%; WAS 4 = 35:40:25%; WAS 5 = 30:50:20% (wheat:sweet potato:African yam bean) flour blends*

Table 4. Physical properties of cookies

Samples	Weight (g)	Diameter (cm)	Thickness (cm)	Spread ratio
WAS 1	12.72±0.59^{c}	5.23±0.07^{ab}	0.50±0.10^{a}	10.46±2.51^{ab}
WAS 2	14.67±1.08^{a}	5.34±0.20^{a}	0.43±0.03^{ab}	12.42±1.21^{c}
WAS 3	13.93±0.01^{b}	5.39±0.14^{a}	0.46±0.09^{ab}	11.72±2.06^{b}
WAS 4	13.99±0.58^{b}	5.44±0.09^{a}	0.45±0.03^{ab}	12.09±0.97^{b}
WAS 5	14.09±0.79^{a}	5.52±0.15^{a}	0.59±0.10^{a}	9.36±2.62^{a}

Means (n=3) with different letter in the column are significantly different (p<0.05).
***Key:** WAS 1 = 100:0:0% (commercial flour); WAS 2 = 45:20:35%; WAS 3 = 40:30:30%; WAS 4 = 35:40:25%; WAS 5 = 30:50:20% (wheat:sweet potato:African yam bean) flour blends*

Table 5. Sensory attributes of different cookies

Samples	Appearance	Aroma	Taste	Texture	Mouthfeel	Overall acceptability
WAS 1	6.47^{b}	6.03^{ab}	5.70^{c}	5.53^{b}	5.30^{b}	6.03^{b}
WAS 2	7.37^{a}	6.63^{a}	7.40^{a}	7.40^{a}	7.90^{a}	7.80^{a}
WAS 3	6.63^{b}	6.03^{ab}	7.33^{a}	7.77^{a}	7.20^{a}	6.83^{b}
WAS 4	6.40^{b}	6.07^{ab}	5.17^{c}	5.27^{b}	5.20^{b}	5.80^{c}
WAS 5	6.40^{b}	6.07^{ab}	6.83^{b}	6.53^{b}	5.03^{bc}	6.27^{b}

Means (n=3) with different letter in the column are significantly different (p<0.05).
Key: *WAS 1 = 100:0:0% (commercial flour); WAS 2 = 45:20:35%; WAS 3 = 40:30:30%; WAS 4 = 35:40:25%; WAS 5 = 30:50:20% (wheat:sweet potato:African yam bean) flour blends*

3.6 Sensory Attributes of Cookies

The mean scores for sensory qualities of cookies given in Table 5 revealed that there were significant differences (p≤0.05) in the appearance, aroma, taste, texture, mouth feel and overall acceptability of the cookies. This current result agreed with the past report that baked goods using sweet potato as ingredient, provided one of the most attractive possibilities because it increased dough yield and contributed to attractive crumb and crust of the baked products [14]. It has also been reported that African yam bean flour also added to the improved crumb quality of the baked products [29]. All these have been indicated by the reaction of panelist in the evaluation of the appearance of the cookies (Table 5). Legumes, such as African yam beans have been reported to be rich in lysine, which produced darker brown colouration during baking [9].

Mean for taste revealed that the WAS had highest score (7.40), which is not significantly different from the WAS 3 with 7.33, while WAS 4 (5.17) had least score. The remarkable feeling grits (texture and mouthfeel) in cookies WAS 2 could be associated to its small particle size. These grits could probably be from African yam bean fraction of the composite flour, which possessed high tendency to absorb water to make cookies with higher proportion of both dampness and crispness. The mean overall acceptability of the cookies revealed that the WAS 2 from 45% wheat flour + 20% sweet potato flour + 35% African yam bean flour was overall acceptable (7.80) while the least acceptable product is sample WAS 1 from 100% wheat flour (6.03). The high acceptability of WAS 2 might be probably due to its improved appearance, taste and mouthfeel.

4. CONCLUSION

The findings from this study have shown the wheat, sweet potato and African yam bean composite flours as potential ingredients for the production of acceptable quality and nutritious cookies. The cookies produced from blends of 45% wheat flour + 20% sweet potato flour + 35% African yam bean flours possessed high crude protein, high crude fibre, low crude fat contents as being highly preferred by the consumers, when compared to others. However, all the composite cookies had rich amino acid profiles, improved antioxidant properties and enhanced inhibition potentials against the activities of the dual carbohydrate hydrolyzing enzymes that have been implicated in the pathogenesis of diabetes. This therefore, showed their helpful effects in reducing insulin demand, improving satiety and blood glucose control in diabetic people. In any case, adoption of this cookie production technology would result in production of better protein and fibre-enriched products to the ever-increasing number of diet-conscious consumers. We therefore concluded that the consumption of functional cookies from these composite flour blends is nutritionally superior to those from whole-wheat flour only in terms of improving the nutritional status of the consumers; thus, serving as a vehicle for protein and other nutrient fortification in Nigeria.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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