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Original Research Article

Sensory Qualities, Nutritional Properties and Glycaemic Indices of Biscuits Produced from Processed Fonio Millet Flour

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ABSRTACT

Fonio millet is commonly consumed in different forms as food and is often eaten by diabetic patients without full scientific basis for its consumption. This work examined the outcome of processing on the sensory qualities, nutritional properties and glycaemic indices of Fonio millet flour. Fonio millet grains were pulverized into flour (raw flour). A portion of the Fonio millet grains were subjected to roasting and subsequently milled (roasted flour), while the other portion was subjected to fermentation (fermented flour) prior to biscuit production. The flours were rich in carbohydrate and protein but low in fat, ash and fibre, and these exhibited significant different ($p<0.05$). The sensory, nutritional, and glycaemic qualities of the biscuits prepared were determined. The sensory evaluation showed a significant difference ($p< 0.05$) in the colour, taste, texture, and general acceptability, while there was no significant difference ($p > 0.05$) in the aroma of the biscuits when compared with the control. The proximate composition of the biscuits revealed that there was a significant difference ($p< 0.05$) in the percentage of moisture, fat, crude fibre, and ash content of the biscuits. The result showed that the biscuits produced had low amylose, sugar, and glycaemic index. This indicates that Fonio millet grain flour can be used in biscuit production as a healthier substitute for wheat flour in the production of health-promoting and disease-preventing snacks.

Keywords: Fonio millet, Biscuits, amylose, amylopectin, glycaemic index.

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Introduction

Fonio millet (*Digitaria exilis*) is the smallest early grain that belongs to the *Poaceae* family [1] and is in the same grain family with maize, sorghum, and pearl millet.[2]. Fonio millet is a cereal, and it is currently in high demand and widely cultivated across West Africa because of its nutritional properties.[3]. Fonio millet is reported to be rich in methionine and lysine contents [1] as well as manganese, calcium, magnesium, iron, thiamine (vitamin B1), riboflavin (vitamin B2), phosphorous, and zinc.[4] Fonio millet is a very important potential source of nutraceuticals like antioxidants, cholesterol-lowering waxes and phenolics.[2] Fonio millet consumption as an entire grain is a magnificent source of dietary fibre, making it appropriate for the control of obesity and diabetes.[5]. Wholegrain cereal products are beneficial to health due to the existence of a variety of bioactive components, as well as phytochemicals and dietary fiber.[3]. The evolution of recently developed and acceptable products plays a key role in the food industry.[6]. Consumers like better healthful food products, as it enables them to gain additional health benefits.[7, 8] Biscuit is one of the well accepted and globally eaten processed foods. Among ready – prepared snacks, biscuits have several inviting characteristics, including an extensive consumption base, a long shelf-life, more suitability, and good eating quality.[9, 10]

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The reasons for the wide acceptance of biscuits are diverse taste, low weight, texture profile, easy accessibility in eye-catching packed form and long shelf-life to suit easy marketing. [11].
Traditionally, biscuits are prepared using wheat flour, fat and sugar other minor ingredients like milk powder, flavor, etc. Many researchers have given account of the use of other flours to replace wheat flour. Ishera *et al.*[12] explored the making of biscuit with breadfruit flour; Adefegha and Oboh[13] made biscuits with good sensory, antidiabetic, antioxidant, and nutritional potential from wheat-bambara groundnut flour blends. As well, Adeola and Ohizua[14] assessed the chemical, physical and sensory properties of biscuits made from flour of unripe cooking plantain, sweet potato and pigeon pea. Furthermore Omah and Okafor[15] assessed the quality of cookies made from blends of pigeon pea and millet flours, Adanse *et al.*[16] made healthy biscuits with rice bran and soy flour. Omobuwajo[17] made biscuits from breadfruit, and Agu *et al.*[18] assessed Fonio millet-based biscuits improved with Bambara nuts and unripe plantain. More lately, there has been exploration for local substitutes to wheat flour however seeking a very nourishing substitute.
Starch is a nutritive carbohydrates found in many food plants and is made up of amylopectin and amylose.[19]. Amylose is a linear α-(1, 4)-linked polymer chain of D-glucopyranosyl units, while amylopectin is highly branched polymer of D-glucopyranosyl units with α-(1, 4) and α-(1, 6) linkages.[20, 19] Splitting occurs with α-(1,6)-bonds after every 24–30 glucose units, resulting in a highly branched polymer which cannot be rapidly broken down as it contains several end points on which enzymes can fasten. Conversely, amylose has a small number of α-(1, 6)-bonds or none at all.[21] This causes amylose to be broken down more quickly.[22]. Starchy foods are broken down to glucose and are widely used in producing cakes, biscuits and bread. [13].
The glycaemic index (GI) of food is quantified as per the proportion of incremental area under the curve (IAUC) of the blood glucose response as a result of the eating of a definite amount of accessible carbohydrate foods after a 12-hour fast.[23] The IAUC of food is given as the IAUC of

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the glucose standard times 100. [23]. GI was first proposed for persons with diabetes as a mean of making proper choice of food, advising a choice of low GI foods.[24] Foods with low GI were assumed to be beneficial owing to their lower glycaemic response after eating when equated to high GI foods. The GI idea came from Jenkins *et al*.[25] as a grading pattern for carbohydrates centred on their instant influence on blood glucose levels. The idea of glycaemic response was made known to categorise foods with starchy components depending on the stages in which their breakdown and ingestion occur.[26].According to the stage of breakdown and ingestion in the system, starchy foods are categorised as small, average, or great GI.[27, 28] Foods containing carbohydrates that are simply broken down, have a great GI (GI> 70) while small-GI foods gradually digestible carbohydrates that stimulate abridged postprandial glucose response are low (GI< 55) and average-GI are within 56 to 69, on the glucose scale.[29]. Consumption of foods which provoke a great glycaemic index is associated with the progress of certain diseases like type 2 diabetes [30, 31] and certain emergences of cancer.[32, 33] The intake of small GI foods can aid weight regulation and be valuable in the handling of obesity.[34]. Subsequently, the breakdown of small GI foods remains an essential element intended for the maintenance of a good nutrition.[35] Presently, food and daily life are the chief tools of diabetes prevention; so, selecting diets with a small GI has slight clinically valuable influence on average-term glycaemic control in diabetic patients.[36].
The nutritional and nutraceutical potentials of Fonio millet flour have been extensively evaluated.[3,37] However, there is a dearth of information on the snacks or food products developed from Fonio millet with regards to their nutritional and nutraceutical potential. Thus, this work is designed to produce biscuits from flour of different processed Fonio millet and wheat, assess their sensory qualities, nutritional composition and glycaemic indices.

Materials and Methods

Materials
Fonio millet grains was obtained from Kontagora in Niger State and authenticated at the University of Ibadan Herbarium, with a voucher number (UIH 22902). Cocoa butter was obtained from the Ile-Oluji Cocoa Industry, while aspartame was purchased at Pascal Scientific Limited, Akure. Skimmed milk, wheat flour, and eggs were obtained from Bodija market, Ibadan.

Processing of Fonio millet flours
The grains were sorted to remove dirt, air dried, and processed as described in Figure 1, and sealed container.

Proximate composition of the Fonio Millet flours
The proximate composition of the grain flours was determined by the method of AOAC.[38].

Moisture content
Flour (2g) was dried to a constant weight,[38] and moisture content calculated in percentage thus:
% Moisture content = (Weight loss/weight of flour) x 100

Ash content
Samples from moisture determination were used for ash content determination following AOAC method.[38]. The percentage ash was calculated thus:
% Ash = (Ash weight/Sample weight) x 100

Crude protein
Crude protein was determined following the standard micro-Kjeldahl method for nitrogen.[38].
%Nitrogen = (HCl molarity x0.014xTitre value x Dilution factor/sample weight)
(% Crude protein = %Nitrogen multiplied by 6.25)

Fat content
Fat was determined by standard method [38] using Soxhlet extraction and calculated as:
% Fat = (Weight Loss /Weight of flour) x 100

Crude fibre content
Crude fibre was determined by standard method.[38] using acid digestion followed by ignition loss.
% Crude Fibre = (Ignition loss/Origin weight of flour) x 100

Carbohydrate content
Carbohydrate content (dry basis) was determined by difference.
% Carbohydrate = (100% - % (protein +fat + ash + fibre + moisture)).

Determination of sugar, starch, amylose contents
The sugar and starch contents in the flour were quantified by the modified method of Dona *et al.*,[39] while amylose was by the method of Gbenga-Fabusiwa *et al.*[40]

Preparation of Fonio Millet and Wheat Flours Biscuits
The biscuits were produced according to the adapted method of Gbenga-Fabusiwa *et al.*[40] as presented in Table 1 and Figure 2 for Fonio millet biscuits.

Sensory evaluation of the biscuits
The sensory evaluation of the formulated biscuits were carried out using the adapted method of Potter.[41] and the attributed mean score was calculated.[42]

Proximate composition
The biscuit samples were pulverized by using a domestic blender. The proximate composition of each biscuit powder was determined using the standard AOAC [38] methods.

Estimated glycaemic index
The estimated glycaemic index (eGI) of the flours and biscuits were determined according to the modified method of Goni *et al.*[43].
The eGI was therefore calculated as: eGI = 39.71 + (0.549 HI)

Statistical evaluation
Results were reported as mean of replicate determinations and the standard deviation. Analysis of variance (ANOVA) and least significant difference (LSD) were used to determine the confidence level at 95% using the SPSS statistical software, version 17.

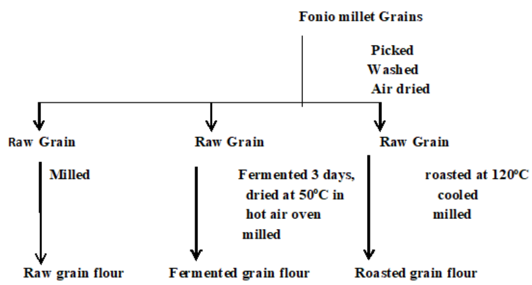

Figure 1: Processing of Fonio millet into flour

Table 1: Composition of the formulated Fonio Millet Biscuit

Fonio Millet Biscuit Ingredients	Percentage (g/100g)
Fonio Millet Flour	74.12
Skimmed milk	7.50
Cocoa butter	2.00
Aspartame	0,50
Egg albumin	4.00
Water	11.88

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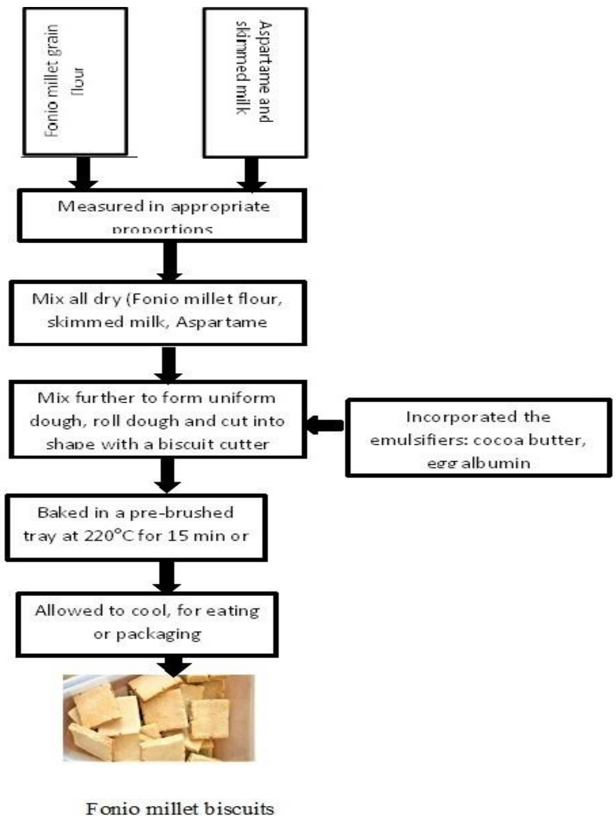

Figure 2: Flow chart for the production of Fonio millet flour biscuit

Results and Discussion

Composition of the processed Fonio millet grains flours

The composition of the processed grain flours are shown in Table 2. The fermented sample had the highest moisture content (6.94%) whereas roasted had the lowest (6.53%). The crude protein contents were low, ranging from 13.39% (fermented) to 14.22% (roasted) and differed significantly ($p < 0.05$). Ash content also varied significantly ($p < 0.05$), ranging from 4.03% (roasted) to 6.60% (raw). Fermented flour had the lowest fat content (2.50%) whereas the raw had the highest (3.00%). The crude fiber content was highest in the fermented sample (2.96%) and lowest in the roasted flour (1.59%). There was significant difference ($p < 0.05$) in the carbohydrate contents of the samples, the roasted sample had the highest carbohydrate (71.18%) and the raw had the least (68.10 %).

This study revealed in Table 2 that the crude protein and fat contents of the studied samples were within normal analytical values for grains.[44]. Though the crude protein of Fonio millet is low, its protein is unique because it has high methionine and lysine content, both are essential amino acids needed for human health and are deficient in common cereals[1] suggesting that Fonio millet could serve as supplements to improve deficiency in these essential amino acids. The fat content being within the recommended limit range depicts those grains as good a source of low fat diet required for patients that are diabetic. The moisture content of the Fonio millet grain flours fall less the typified range (11 -12%) for storage stability for flours, suggesting its benefit in terms of prolonging shelf – life and retaining the quality of the flour.[44,45,16] . The ash content is a quantity of the whole aggregate of minerals existent in a food and reveal the inorganic remains left when water and organic substance have been detached via heating using dissolving agents, which provides a quantity of the overall aggregate of minerals within a food. The ash content of the processed flours ranged from 4.07 - 6.60% which was higher than the typical analytical figures for grains (2%).[44].

Dietary fibre is imperative for our digestive health and steady bowel movements, fibre likewise aids to feel fuller for long, improve cholesterol and blood sugar levels and support in deterrence of ailments such as, heart diseases, bowel cancer and diabetes.[46]. The processed grain flours fibre content varied from 1.59 – 2.96% which was higher than the typical analytical figures for grains[44] suggesting that the processed grains flours may help to improve the cholesterol and sugar levels of people suffering from diabetes and heart diseases.

Sugar, starch, Amylose and glycaemic index of the processed Fonio millet flours

Sugar, starch and amylose of the processed Fonio millet flours are as shown in Table 3a while the glycaemic index is in Table 3b. The fermented sample had the highest sugar content (19.40%) while the raw sample had the lowest sugar content (16.61%). The roasted sample had the highest starch content (74.14%) and the raw sample had the lowest starch content (64.46%). The raw sample had the highest amylose content (26.98 %) while the roasted sample had the lowest amylose content (25.89%). For the glycaemic index, the raw sample had the highest glycaemic index (21.10%) while the fermented had the least glycaemic index (20.46%).

Starch consists of amylose and amylopectin fractions (Amylopectin = 100 - %Amylose), both fractions have different structure. This could affect their rate of digestion and may have a great influence on the glycaemic index of food containing starch.

Due to straight chains of glucose units in amylose structure and the hydrolysis of glucose one at a time at its open ends during digestion, resulting in slow digestion rate, products with high amylose remained establish to give low glucose in the blood and insulin responses once likened to like products high in amylopectin which results from its branched structure allowing more glucose units to be hydrolysed at a time thus increasing the rate of digestion. From the amylose contents in Table 3a, amylopectin contents are more than amylose in the processed flour samples did not show hyperglycaemic response. This could be ascribed to the presence of additional substances like fibre and phenolic components, which have been confirmed to lower blood glucose in previous studies.[47, 48]

The Table 3b revealed that the processed flours have low GI. This makes the processed Fonio millet flours a good food selection for people with diabetes. The low GI of the processed samples could be an effect of the presence of polyphenols and fibre which reduces the activity of enzymes on starch.[49]

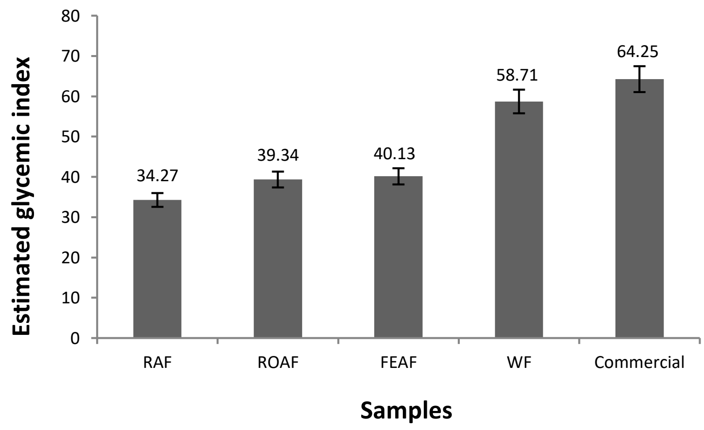

Figure 3: Estimated Glycaemic Index of formulated Fonio Millet Flour Biscuits and Commercial Biscuit
Values represent mean ± standard deviation (n = 3).
RAF (Raw Fonio Millet Flour Biscuit); ROAF (Roasted Fonio Millet Flour Biscuit); FEAF (Fermented Fonio Millet Flour Biscuit); WF (Wheat Flour Biscuit); Commercial Biscuit.

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Table 2: Proximate Composition of Processed Fonio millet Flours

Parameters	Moisture Content (%)	Crude Protein (%)	Ash Content (%)	Fat Content (%)	Crude Fibre (%)	Carbohydrate (%)
Raw	6.74 ± 0.05[a]	13.41 ± 0.05[a]	6.60 ± 0.14[c]	3.00 ± 0.14[b]	2.15 ± 0.07[b]	68.10 ± 0.21[a]
Roasted	6.53 ± 0.11[a]	14.22 ± 0.19[b]	4.03 ± 0.11[a]	2.55 ± 0.07[a]	1.50 ± 0.14[a]	71.18 ± 0.40[b]
Fermented	6.94 ± 0.05[a]	13.39 ± 0.15[a]	5.40 ± 0.14[b]	2.50 ± 0.14[a]	2.96 ± 0.08[c]	68.81 ± 0.01[a]

Values represent mean ± standard deviation (n = 3). Values with the same superscripts along the same column are not significantly different ($p > 0.05$).

Table 3a: Sugar, Starch and Amylose Contents of the Processed Fonio Millet Flours

Samples	Sugar (%)	Starch (%)	Sugar/Starch	Amylose (%)
Raw	16.61 ± 0.08[a]	64.46 ± 0.26[a]	0.25	26.93 ± 0.28[b]
Roasted	16.91 ± 0.11[a]	74.18 ± 2.22[c]	0.22	25.89 ± 0.81[a]
Fermented	19.40 ± 0.44[b]	68.64 ± 0.05[b]	0.28	26.58 ± 1.39[b]

Values represent mean ± standard deviation (n = 3). Values with the same superscript along the same column are not significantly different ($p > 0.05$).

Table 3b: Estimated Glycaemic Index of the Processed Fonio Millet Flours

Samples	Estimated Glycaemic Index
Raw	21.10 ± 0.18[b]
Roasted	20.65 ± 0.13[a]
Fermented	20 .46 ± 0.16[a]

Values represent mean ± standard deviation (n = 3). Values with the same superscript along the same column are not significantly different ($p > 0.05$).

Previous study also suggests that the low GI of the samples can improve glycaemic switch in people with weakened glucose tolerance and type 2 diabetes by dropping fasting blood glucose and glycated proteins, thereby enhancing insulin sensitivity.[50].

Sensory evaluation of the biscuits

Sensory evaluation determines food acceptability, and this guarantees whether consumers will continue to demand such products.[51]. It covers established techniques that can give analytical facts on the sensory attributes of food as presented in Table 4. The result non-food products to define the procedural description of the product and the hedonistic understanding of that product as defined by the user or customer.[52]. The basic sensory evaluation of food products comprises the appraisal of odour, flavour, texture, taste and appearance.[53]. The sensory evaluation result of the biscuits shows no significant ($p > 0.05$) difference amid the biscuits produced from Fonio millet flour in relations of texture, taste, and aroma. The wheat and commercial biscuits were significantly higher ($p < 0 .05$) in taste, aroma, and texture. The colour of the raw Fonio millet flour biscuit, the fermented Fonio millet flour biscuit, wheat flour biscuits and commercial biscuits was well accepted compared to that of the roasted Fonio millet flour biscuit. Among the produced Fonio millet biscuits, the fermented Fonio millet flour biscuit (4.79 ± 1.27) was generally accepted when compared to the raw (4.38 ± 1.07) and roasted (4.47 ± 1.21) Fonio millet flour biscuits. It shows that the fermented Fonio millet flour biscuit was preferred when compared to other Fonio millet flour biscuits produced. Indicating that fermented Fonio millet flour could be used in place of wheat flour for biscuit production. The result also revealed that the commercial biscuit was most generally accepted by the panelists, followed by the fermented Fonio millet flour. This adequacy could be based on the general standard that publics have become accustomed with the quality of some commercially available biscuits.

Biscuits Proximate Composition

The biscuits proximate composition stated in percentage is shown in Table 5. As revealed WF biscuit (7.73 ±0.02%) had the highest moisture content, whereas commercial biscuit (6.04 ±0.07%) had the least moisture content. The moisture content of the Fonio millet biscuits showed no significant difference ($p < 0.05$) in biscuits produced. The biscuits moisture content falls within the satisfactory range of 10%. This discovery agrees with the reports of Omobuwajo, [17] Agu *et al*., [18] and Gbenga - Fabusiwa *et al*.[40]. The insignificant moisture content of the biscuit is beneficial in protecting the biscuit from growing mould and extending the shelf life.[54]. Ash is a non-organic composite having the mineral elements of food. This helps the breakdown of additional compounds like proteins, fats, and carbohydrates.[55]. No significant difference ($p > 0.05$) (Table 5) in the assessment of the produced biscuits as likened to the commercial biscuit (2.07 ± 0.10%), though the FEAF biscuit had the highest ash content (2.22 ± 0.17%) while the WF biscuit had the least (1.52 ± 0.17%). The biscuits fat content ranged from 5.92 ± 0.10% for the RAF biscuit to 9.67 ± 0.17% for the commercial biscuit. The result revealed low fat content in the Fonio millet flour produced biscuits when compared to commercial biscuits. This implies that the Fonio millet flour-produced biscuits will be less prone to rancidity. The biscuits fibre content increased significantly ($p < 0.05$) and ranged from 0.56 ± 0.08% (WF biscuit) to 2.95 ± 0.21% (commercial biscuit). Crude fibre could promote healthy conditions as a consequence of its capability to bind fat in the digestive system of humans, thus deterring several deteriorating pathologies that place threats to healthiness, like obesity, diabetes, and other cardiovascular diseases.[56]. The Fonio millet flour biscuits produced had an extraordinary fibre content and could be beneficial in the diets of diabetics and others suffering from a variety of cardiovascular diseases. The protein increased significantly ($p < 0.05$) among the biscuits, ranging from the 6.25 ± 0.98% (FEAF biscuit) to the 10.57 ± 0.53% (WF biscuit). The produced Fonio millet flour biscuits had higher protein content when compared with commercial biscuits, suggesting that they could have a better influence on obese and diabetic persons who require extra crude protein in their diet. The biscuits total carbohydrate content ranged from 72.88 ± 0.01% (WF biscuit) to 77.24 ± 0.40% (RAF biscuit).

Soluble sugar and Starch contents of the biscuits

The effect of the biscuit sugar content is revealed in Table 6. The biscuits sugar content was generally low; the sugar content ranged from 16.81± 0.00% (FEAF) to 32.90 ± 0.01% (commercial biscuit). The sugar content of RAF, ROAF, and FEAF formulated biscuits had no significant difference ($p > 0.05$), however the sugar content of WF was meaningfully higher than that of the formulated biscuits. The formulated biscuits possessing low sugar suggests that Fonio millet flour can be used in place of WF in biscuit production, which will provide a suitable meal and confectioneries for individuals distressed from malnourishment and fatness, similar result have been obtained by Omah and Okafor.[15]. As shown in Table 6, the starch content varied from 31.12 ± 0.01% (FEAF) to 36.78 ± 0.01% (commercial biscuit). There was no significant difference ($p > 0.05$) in the starch content of ROAF and FEAF. The sugar/starch ratio of commercial and WF biscuits was significantly different ($p < 0.05$) than the produced Fonio millet flour biscuits as shown in Table 6. This implies that the produced Fonio millet flour biscuits (RAF, ROAF, and FEAF) will be a favourite and provide extra health aids to clients with health conditions, such as people with diabetes, which needs daily diets with low sugar.

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Table 4: Sensory qualities of the formulated Fonio Millet biscuit

Samples	Aroma	Texture	Taste	Colour	General Acceptability
Commercial	5.67 ± 1.00[c]	5.94 ± 0.64[c]	6.32 ± 0.58[b]	5.82 ± 0.71[c]	6.17 ± 0.45[c]
RAF	4.32 ± 1.42[a]	4.14 ± 1.18[a]	4.11 ± 1.12[a]	4.61 ± 1.30[b]	4.38 ± 1.07[a]
ROAF	4.08 ± 1.31[a]	4.08 ± 1.31[a]	4.44 ± 1.28[a]	4.17 ± 1.19[a]	4.47 ± 1.21[b]
FEAF	4.35 ± 1.22[a]	4.38 ± 1.12[b]	4.55 ± 1.25[a]	4.41 ± 1.10[b]	4.79 ± 1.27[b]
WF	4.52 ± 1.18[b]	4.94 ± 1.15[b]	5.14 ± 1.20[b]	4.79 ± 1.45[b]	4.97 ± 1.56[b]

Values are Mean ± standard deviation (SD). Values with the same superscripts in the same column are not significantly different ($p > 0.05$).
KEY: Commercial biscuit; RAF (Raw Fonio millet flour biscuit); ROAF (Roasted Fonio millet flour biscuit); FEAF (Fermented Fonio millet flour biscuit); WF (Wheat flour biscuit)

Table 5: Proximate Composition of the formulated Fonio Millet biscuits

Parameter	%Moisture	% Ash	% Fat	%Crude fibre	%Protein	%Carbohydrate
Commercial	6.04 ± 0.07[a]	2.07 ± 0.10[a]	9.67 ± 0.17[c]	2.95 ± 0.21[c]	5.25 ± 0.98[a]	74.00 ± 1.20[a]
RAF	6.88 ± 0.09[a]	1.75 ± 0.07[a]	5.92 ± 0.10[a]	1.37 ± 0.10[b]	6.82 ± 0.24[b]	77.24 ± 0.01[b]
ROAF	7.04 ± 0.08[a]	1.67 ± 0.10[a]	6.57 ± 0.03[a]	0.81 ± 0.01[a]	8.05 ± 0.00[c]	75.85 ± 0.07[b]
FEAF	6.72 ± 0.02[a]	2.22 ± 0.17[a]	7.02 ± 0.10[b]	1.45 ± 0.21[b]	6.25 ± 0.56[b]	76.33 ± 0.25[b]
WF	7.73 ± 0.02[b]	1.52 ± 0.17[a]	6.72 ± 0.17[a]	0.56 ± 0.08[a]	10.57 ± 0.53[d]	72.88 ± 0.40[a]

CHO content = 100% − (Moisture + Ash +Fat + Fibre + Crude protein) %. Values are Mean plus or minus standard deviation (SD) with the same superscripts in the same column are not significantly different ($p > 0.05$).
Key: Commercial biscuit; RAF (Raw Fonio millet flour biscuit); ROAF (Roasted Fonio millet flour biscuit); FEAF (Fermented Fonio millet flour biscuit); WF (Wheat flour biscuit)

Table 6: Sugar, starch, and sugar/starch ratio of the formulated Fonio Millet biscuits

Samples	Sugar (%)	Starch (%)	Sugar/Starch
Commercial	32.09 ± 0.01[c]	36.78 ± 0.01[d]	0.87
RAF	17.71 ± 0.02[a]	35.91 ± 0.03[c]	0.49
ROAF	17.99 ± 0.02[a]	32.44 ± 0.33[a]	0.55
FEAF	16.81 ± 0.00[a]	31.21 ± 0.01[a]	0.54
WF	21.86 ± 0.01[b]	33.41 ± 0.02[b]	0.65

Values represent mean ± standard deviation (n = 3).
Values with the same superscript along the same column are not significantly different ($p > 0.05$). KEY: Commercial biscuit; RAF (Raw Fonio millet flour biscuit); ROAF (Roasted Fonio millet flour biscuit); FEAF (Fermented Fonio millet flour biscuit); WF (Wheat flour biscuit).

Amylose, amylopectin, and amylose/amylopectin ratio of the biscuits starch contents

The amylose contents of the Fonio millet biscuits were higher when compared with the commercial and WF biscuits (Table 7) though, no significant difference ($p > 0.05$) amid the values of the Fonio millet flour biscuits. This is in line with the reports on pigeon peas by Kaun and Sundhi.[57]. The high value of amylose content in the Fonio millet biscuits suggests a higher level of resistant starch, [21] making them a more suitable diet for patients having diabetic challenges. The amylopectin result is revealed in Table 7. The result varied from (79.04 ± 0.64%) FEAF to WF (85.97 ± 0.23%). FEAF had the least amylopectin content, however WF had the most value. The standards of amylopectin extents of all the produced Fonio millet flour biscuits were in the usual reach of amylopectin noted in the works appraisal.[58]. Because of the low levels of amylopectin in the produced Fonio flour biscuits, the breakdown of starch to glucose may be slowed. It remains known that intestinal enzymes gradually abridgment amylose, while amylopectin stands quickly broken down owing to its branched structural organization. [59]. The value of amylose content was used to divide that of amylopectin to get the amylose amylopectin ratios of the produced Fonio millet flour biscuits as in Table 7. The result reveals that FEAF (0.27) had the maximum value of amylose-to-amylopectin ratio, whereas the commercial and WF biscuits had the least value (0.19). This is in line with the report by Dipnaik and Kokare [60] that attributed greater value of amylose: amylopectin fraction in nourishments to be suggestive of great well-being assistances.

Determination of the estimated glycaemic index

The glycaemic index (GI) is destined to denote the comparative quality of food comprising carbohydrate. Foods having carbohydrates which are simply broken down, engrossed, and taken up have great GI (GI ≥ 70 on the glucose scale), whereas small-GI foods (GI ≤ 55 on the glucose gage) have gradual edible carbohydrates which provokes a reduction in postmeal glucose response. Foods with average-GI foods have a GI amid 56 and 69.[29]. The biscuits estimated glycaemic index (eGI) values is presented in Figure 3. When related to WF and commercial biscuits, the eGI value of produced biscuits was significantly lower ($p < 0.05$). The eGI of the produced biscuits falls within the low GI foods (GI ≤ 55 on the glucose gage), meaning they devise the ability to digest slowly, which will result in a reduced postmeal glucose response. Eating of high GI diets results in extreme postmeal glucose elevations and can generate a great insulin response that is related to insulin resistance, hyperinsulinemia, and eventually, the inception of Type 2 diabetes mellitus.[61]. WHO suggested foods with low GI as an effective way of deterring and circumventing fears of non-contagious ailment in some countries. A diet with low GI can gradually release glucose that will effect an increase in appropriate postprandial (after diet) values of blood glucose [61] however, a diet with high GI effects an instant increase in levels of blood glucose .[62]. The low GI index observed in the produced biscuits suggests they could be a more suitable biscuit for diabetic patients.

Conclusion

The processed Fonio flours indicated low fat content but were rich in carbohydrate and protein. The findings of this research showed that the biscuits produced had appreciable nutrient composition and sensory qualities. The result also presented low amylose, sugar, and glycaemic index. This study revealed that processed Fonio millet whole grain flours produced could be a better recipe and an ample substitution of wheat flour in the making a good nutritional health-promoting and disease-preventing snack food for patients with diabetic challenges and other consumers. Results from this study may serve as foresight that Fonio millet whole grain flour can be used as a whole or total substitution of wheat flour in producing safe and nutritious foods. This will help to promote the use and cultivation of Fonio millet grain, which is one of the under-utilized grain crops in tropical Africa.

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Table 7: Amylose, amylopectin, and amylose/amylopectin ratio of the starch contents of the formulated Fonio millet biscuits

Samples	Amylose (%)	Amylopectin (%)	Amylose/Amylopectin
Commercial	16.12 ± 0.00[a]	83.88 ± 0.06[a]	0.19
RAF	20.68 ± 0.02[c]	79.32 ± 0.13[c]	0.26
ROAF	20.48 ± 0.01[c]	79.52 ± 7.47[d]	0.25
FEAF	20.96 ± 0.01[c]	79.04 ± 0.64[b]	0.27
WF	17.03 ± 0.02[b]	85.97 ± 0.23[a]	0.19

Values represent mean ± standard deviation (n = 3). Values with the same superscript along the same column are not significantly different ($p > 0.05$). KEY: Commercial biscuit; RAF (Raw Fonio millet flour biscuit); ROAF (Roasted Fonio millet flour biscuit); FEAF (Fermented Fonio millet flour biscuit); WF (Wheat flour biscuit).

Conflict of Interest

The authors declare no conflict of interest.

Authors' Declaration

The authors hereby declare that the work presented in this article is original and that any liability for claims relating to the content of this article will be borne by them.

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