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Research

Evaluation and acceptability of crackers made from a blend of fonio (*Digitaria exilis*), and conophor nuts (*Tetracarpidium conophorum*) flours for diabetes mellitus patients

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Abstract

Diabetes mellitus (DM) is a complex disease recognised as one of the leading causes of death and disability worldwide. DM progression is heavily influenced by food consumption patterns, making it concerning for people with diabetes to snack between meals due to fears of a potential rise in blood glucose levels. In Africa, low-cost indigenous snack foods with low glycemic indices need to be developed and more widely available as an option for healthy snacks. Fonio, an African cereal, is attracting research attention due to its low gluten content, low glycemic index and high levels of phytochemicals. Mixing it with nuts would further reduce its glycemic index. The present study, conducted in Nigera, assesses the proximate and organoleptic properties of crackers produced from blends of fonio flour (FF) and conophor nut flour (CNF). Three formulations were prepared by blending FF and CNF at ratios of 95:5 (Sample SA), 90:10 (Sample SB), and 85:15 (Sample SC). A standardised method was employed in producing the crackers; they were analysed following AOAC standards for proximate analysis, and their sensory attributes were evaluated using a 9- point hedonic scale. Fifty-six panellists were recruited to assess the organoleptic properties of the crackers. The data were analysed using the Statistical Package for Social Sciences (SPSS) version 23.0. Analysis of Variance (ANOVA) was conducted, and the results were presented as mean ± SD. Duncan Multiple Range Test (DMRT) was utilised to determine significant differences at $p< 0.05$. Among the different crackers formulations, the percentage of carbohydrate ranged from 60.17% to 62.28%, while protein and fat contents ranged from 11.86% to 14.31%, and 10.31% to 16.47%, respectively. Sensory evaluation results indicated that the crackers containing 90% fonio flour and 10% conophor nut flour (Sample SB) achieved the highest mean score and were the most preferred sample, while those with 85% fonio flour and 15% conophor nut flour (Sample SC) were the least appealing based on sensory attributes. All the cracker blends produced may be suitable for diabetic patients; however, blends of Sample B are most appealing and preferred.

INTRODUCTION

Diabetes mellitus (DM) is a chronic metabolic disorder marked by persistent high blood glucose levels, leading to symptoms like polyuria, polydipsia, and polyphagia (Gaddam et al. 2019). It is primarily classified into Type I DM, where the body fails to produce sufficient insulin, requiring external insulin administration, and Type II DM (T2DM), characterised by impaired carbohydrate, fat, and protein metabolism due to reduced insulin sensitivity and declining pancreatic beta-cell function (Alfaqih et al. 2022).

Globally, diabetes prevalence has surged, with WHO noting an increase from 108 million cases in 1980 to 425 million in 2017 (WHO, 2022). The International Diabetes

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Federation (IDF) reported 537 million people with diabetes in 2019, projecting a rise to 643 million by 2030 and 783 million by 2045 (IDF, 2021). In Sub-Saharan Africa, Nigeria has the highest diabetes burden, with 3.9 million adults (4.99% prevalence) aged 20-79 affected in 2021. Additionally, 52 million adults globally have Impaired Glucose Tolerance (IGT), a precursor to T2DM, with numbers expected to reach 117 million by 2045 (IDF, 2021).

Nutrition education significantly enhances individuals' understanding of nutritional principles (Han et al. 2019), yet implementing suitable dietary practices remains a considerable challenge in managing T2DM (Forouhi et al. 2018). The success of such nutritional interventions largely depends on behavioural changes that support adherence to established dietary guidelines (Siopis et al. 2021). Effective nutrition education is strongly associated with choosing and maintaining recommended diets, which has been shown to improve eating habits and clinical outcomes (Muchiri et al. 2016). Additionally, affordable and healthy snack options must be available for these messages to be truly effective. In many parts of Africa, this continues to be a significant challenge.

Among indigenous sources of carbohydrate-rich foods that many people prefer, Fonio (*Digitaria exilis*) has a large diversity of local varieties (landraces) in Nigeria. Fonio is considered to be one of the tastiest and most nutritious cereals in Africa. It contains a very low level of gluten, and. while it does not have a high protein content, all twenty amino acids are present (Diop et al. 2018). Fonio varieties are attracting research attention due to their low gluten content, low glycemic index and high levels of phytochemicals, encouraging their use in functional food formulations (Adams and Yakubu, 2020).

The conophor plant (*Tetracarpidium conophorum*), commonly referred to as the African walnut, is called ‘ukpa’ among the Igbo and ‘awusa’ or ‘asala’ within the Yoruba-speaking communities of Nigeria (Adegbanke et al. 2024). The nuts have a high nutrient content (Enujiugha and Ayodele-Oni, 2003) and are either cooked or toasted and consumed as snacks or in conjunction with boiled corn (Enujiugha, 2003).

Cracker biscuits, commonly known as crackers, are a type of baked snack food that is usually thin, crispy, and crunchy, and is made from a mixture of flour, water, and other ingredients, such as salt, yeast, sugar, and fat. They come in a variety of shapes and sizes, and can be plain or flavoured with herbs, spices, or cheese (Manley, 2011). Cracker biscuit consumption is influenced by factors such as availability, cost, taste preferences, and cultural norms; however, due to their convenience, long shelf life, and versatility, crackers remain a popular snack food around the world (Chavan et al. 2016).

Crackers made from the combination of fonio (*Digitaria exilis*) and conophor nuts (*Tetricarpidium conophorum*) flour without additives of any sort could be used as a dietary intervention for diabetes mellitus management because both crops have low glycemic indices and are high in fibre content, which can slow down sugar digestion (Spritzler, 2019). Lower-carbohydrate and higher-fibre snacks have been found to consistently demonstrate more favourable effects on blood sugar and insulin levels than high-carbohydrate snacks in people with or without diabetes (Spritzler, 2019). However, few such products are widely available in Nigeria, and most are imported, making them subject to interruptions in availability and unexpected price increases, such as those caused by tariffs. The present study was carried out to formulate, produce, and evaluate crackers of different blends of indigenous fonio flour and conophor nuts flour at ratios of 95:5 (Sample SA), 90:10 (Sample SB) and 85:15 (Sample SC).

METHODS

MATERIALS

Conophor nuts (*Tetricarpidium conophorum*) and fonio (*Digitaria exilis*) were purchased from a local market, Oyingbo, in Lagos State. Common salt, eggs, margarine and ginger powder were also purchased from the same market.

PROCESSING OF CONOPHOR NUT FLOUR

A refined methodology, as delineated by Olanipekun et al. (2018), was employed for the processing of conophor nuts into flour. The conophor nuts underwent a comprehensive washing procedure to eliminate all residual contaminants. They were cooked in a stainless-steel pot for two hours to facilitate the detachment of the shells. The de-shelled nuts were then cut into small fragments and blanched for five minutes before draining. They were then dried in a cabinet dryer at a temperature of 60 ˚C for five hours and subsequently milled and filtered to yield the conophor nut flour.

PROCESSING OF FONIO FLOUR

A modified technique delineated by Ayo et al. (2018) was employed for the processing of fonio. The fonio grains underwent a meticulous cleaning process through the manual removal of chaff and dust. Subsequently, the cleaned and stone-free grains were subjected to an oven-drying process at 45°C for three hours, after which they were processed using a milling apparatus. The resultant flour was sieved through a mesh with a 0.3 µm aperture, thereafter packaged in zip-locked containers, and stored under ambient temperature conditions.

FORMULATION OF FLOUR BLENDS

To investigate the effects of different proportions, samples were formulated with varying concentrations of fonio and conophor nut flours. Specifically, Sample SA contained a 95:5 ratio of fonio to conophor nut, Sample SB had a 90:10 ratio, and Sample SC had an 85:15 ratio. For comparison, 100% wheat served as the control.

The oven was preheated to 360°F (180°C). The flour blend was weighed into a mixing bowl, and the egg, salt, ginger powder, and water were added in amounts listed in Table 2. The mixture was then stirred with a wooden spoon until it formed a stiff dough. The dough was divided into two portions and placed directly on the parchment paper. They were rolled out into two rectangles, about 0 and 1 inches (2-3 mm) thick. A pizza cutter was used to cut them into round shapes. The samples were baked for about 10 minutes. The oven was monitored to prevent burning. The samples were stored in separate jars.

Table 1. Formulation of flour blends % composition

Samples	Fonio	Conophor nut
SA	95	5
SB	90	10
SC	85	15

PRODUCTION OF CRACKERS

Table 2. List of ingredients for cracker production

S/N	Ingredients	Quantity
1	Flour	300g
2	Egg	1medium
3	Salt	2tbsps
4	Water	1tsp
5	Ginger powder	1tsp
6	Margarine	105g

CHEMICAL COMPOSITION

Moisture, ash, protein, fat, fibre and carbohydrate content were determined using AOAC (2019) standard methods. Protein was determined by the Kjeldahl method, fat by Soxhlet extraction, and fibre by acid-base digestion. The percentage of available carbohydrates was calculated by subtracting the total contents of moisture, total ash, crude protein, crude fat, and crude fibre from 100%.

SENSORY EVALUATION

The sensory characteristics of the three varieties of formulated crackers were evaluated utilising a 9-point Hedonic scale (1 = extremely dislike, 2 = very much dislike, 3 = moderately dislike, 4 = lightly dislike, 5 = neither like nor dislike, 6 = slightly like, 7 = moderately like, 8 = very much like, 9 = extremely like). A cohort of fifty-six panellists who expressed a strong liking for crackers was chosen from a total of two hundred and forty (240) diploma students enrolled in the department of Nutrition and Dietetics. The panellists convened to assess the coded samples of crackers concerning colour, crispness, taste, texture, and overall acceptability. The crackers were presented to the panellists in sterile, odourless, and tasteless containers. Additionally, they were provided with water to cleanse their palates between evaluations.

STATISTICAL ANALYSIS

Data from the study were analyzed using the Statistical Package for the Social Sciences (SPSS) version 25.0, utilizing one-way ANOVA and Duncan's multiple range test (DMRT) to separate means at $P < 0.05$ (95% confidence interval). Results were provided as mean ± standard deviation.

RESULTS AND DISCUSSION

Table 3. Proximate composition of crackers produced from blended flour of fonio and conophor nuts

S/N	Nutrient Composition	Control	Sample SA	Sample SB	Sample SC
1	Moisture content	$7.05^{a} \pm 0.21$	$5.59^{c} \pm 0.12$	$6.11^{b} \pm 0.01$	$4.90^{d} \pm 0.14$
2	Protein	$14.09^{a} \pm 0.12$	$11.86^{c} \pm 0.06$	$12.87^{b} \pm 0.12$	$14.31^{a} \pm 0.06$
3	Fat	$10.88^{d} \pm 0.17$	$15.60^{b} \pm 0.24$	$14.79^{c} \pm 0.19$	$17.86^{a} \pm 0.91$
4	Ash	$3.27^{a} \pm 0.08$	$3.04^{ab} \pm 0.08$	$2.11^{b} \pm 0.15$	$2.25^{b} \pm 0.13$
5	Crude fibre	$2.43^{c} \pm 0.64$	$2.72^{a} \pm 0.07$	$2.51^{b} \pm 0.01$	$2.88^{a} \pm 0.02$
6	Carbohydrates	$62.28^{a} \pm 0.31$	$60.22^{b} \pm 0.08$	$60.17^{b} \pm 0.08$	$60.71^{b} \pm 0.16$

Note: Sample A: 95% fonio and 5% conophor nut; Sample B: 90% fonio and 10% conophor nut; Sample C: 85% fonio and 15% conophor nut; Control: 100% wheat flour. **NB:** Values are expressed as mean ± standard deviation of duplicate values. P-values <0.05

Table 3 presents the nutrient composition results of three different cracker samples compared with wheat flour. Moisture content decreased as the proportion of conophor nut flour increased; thus, the lowest moisture content was found in sample C, which comprised 85% fonio and 15% conophor nut flours.

These findings are within the same range as those found by Okoye et al. (2019), who studied the quality of crackers made from flour blends of wheat, maize, African yam bean seed, and cassava cortex, observing moisture contents ranging from 4.85% to 7.45%. Similarly, Ayo et al. (2018) found in their study on the quality assessment of Acha-Mushroom flour and biscuits that the moisture content ranged from 6.66% to 7.77%. These are all lower than the 8.12% to 10.68% values reported by Olanipekun et al. (2018) for biscuits produced from wheat and African walnut flour. Generally, a lower moisture content enhances the shelf life of a product, as low moisture is associated with longer storage periods for many food items, including dried foods (Lee & Robertson, 2022).

We found that the sample with the highest nut content, SC (85:15), had the highest crude fibre content (2.88%). Diabetics are prone to constipation due to gastrointestinal dysfunction and require high-fibre diets (Marathe, 2024). There were also significant ($p < 0.05$) differences in protein content among the samples. The highest protein level (14.31%) was found in sample SC, which contained 85% fonio and 15% conophor nut. This suggests that the amount of conophor nut is a key factor in determining the protein content. According to Ubbor and Akobundu (2019), the protein content of carbohydrate-based composite flour can be elevated through the incorporation of legume flours since they are usually carbohydrate-dense and very low in protein. These results (11.86% to 14.31%) are similar to the results reported by Owusu et al. (2011) for crackers made from cassava and sweet potato flours (3.29% to 15.69 %). These results and those reported by Olagunju et al. (2018) for crackers from blends of acha and blanched pigeon pea (10.47%-19.18%) show variations. Results from Olanipekun et al. (2018) for the evaluation of biscuits produced from the composition of wheat and African walnut flour (10.34%-18.44%) also show disparities.

The fat content (10.88%) in the control sample (100% of Wheat flour) was lower than the fat content in the three samples (14.79% - 17.86%) due to the undefatted conophor nut used in the production of the composite flour. The values

in our samples are comparable to those reported by Owusu et al. (2011) for crackers made from cassava and sweet potato flours (10.31% –16.47 %), those obtained by Ayo et al. (2018) for quality characterisation of Acha-Mushroom flour and biscuit (17.22%-17.75%) and those reported by Barber and Obinna-Echem (2016) for Wheat-African walnut cookies (14.4%-21.3%).

The values for the ash content of the samples ranged from the lowest value (2.11%) in sample SB (90% fonio and 10% conophor nut) to the highest value (3.04%) in sample SA. There was no significant difference ($p < 0.05$) in the ash contents of samples SB (2.11%) and SC (2.25%), respectively. The ash content observed in this study is higher than the values (0.55% to 2.80%) reported by Owusu et al. (2011) for crackers made from cassava and sweet potato flours but lower than the values (2.83%-4.86%) reported by Azeez et al. (2021) for quality evaluation of bread produced from the blends of cassava, Acha and Pigeon pea flour or for the 1.5%-1.7% reported by Barber and Obinna-Echem (2016) for Wheat-African walnut cookies.

Similarly, the crude fibre content was different among samples but not clearly linked to the content of nuts. These levels were lower than the values (14.1% to 17.1%) reported by Osundahunsi et al. (2012) who did a study on cassava fibre as an ingredient in cracker-like products but compared well with the results (2.18% to 2.41%) reported by Okpala and Okoli (2011) for cookies produced from pigeon pea, cocoyam, and sorghum flour blends. The values obtained from this study are higher than those (0.93%-1.28%) reported by Azeez et al. (2021) for quality evaluation of bread produced from the blend of cassava, acha and pigeon pea flour and higher than those (3.1%-4.6%) reported by Barber and Obinna-Echem (2016) for Wheat-African walnut cookies. According to Wardlaw et al. (2006), fibre-rich foods are important because they help with several bodily functions. They promote regular bowel movements by expanding the colon walls, can relieve constipation, help to lower cholesterol, and reduce the risk of various cancers.

The carbohydrate content of the samples ranged from 60.17% to 62.28%. These values are similar to results (54.59%-65.42%) obtained in the development of value-added nutritious crackers with high antidiabetic properties from blends of acha and blanched pigeon pea (Olagunju et al. 2018).

Results of the sensory attributes are presented in Table 4. The control sample, made from 100% wheat flour, was the most preferred overall. Panellists found its colour, taste, crunchiness, and texture to be the most familiar and similar to crackers already available on the market. This familiarity likely contributed to its general acceptance and high scores.

Table 4. Sensory attributes of crackers produced from a blend of fonio and conophor nuts

Sensory Attribute	Control	Sample A	Sample B	Sample C
Colour	6.90 ± 1.37	6.4 5± 1.50	6.54 ± 1.73	6.50±1.39
Taste	7.35 ± 0.99	5.15 ± 1.95	6.80 ± 1.24	6.65±1.87
Crunchiness	7.65 ± 1.27	6.40 ± 1.27	7.21 ± 1.32	6.85±1.59
Texture	7.45 ± 1.15	6.60 ± 1.19	6.9 5± 1.19	6.65±1.49
General Acceptability	7.90 ± 0.85	6.15 ± 1.18	7.40 ± 1.23	7.05±1.09

Note: Control: wheat flour; Sample SA: 95: 5 ; Sample SB: 90: 10; Sample SC: 85: 15 percent of fonio and conophor nut.

Of the samples, B and C received the highest scores for colour. In general, an increase in conophor nuts to 15% negatively impacted the crackers' sensory qualities. This suggests that more than 10% of conophor nuts altered the overall taste, crunchiness, and texture, making the product less desirable.

CONCLUSION

In conclusion, the crackers produced in this study varied in their nutritional value, with sample SC produced from 85% fonio and 15% conophor nuts flour blend having the highest protein and fat contents with the values of 14.31%, and 17.86% respectively and no significant ($p<0.05$) difference was found in the carbohydrate content of the crackers produced in the study. Sample SB crackers were most preferred by the panellists based on their sensory attributes.

RECOMMENDATIONS

Based on the findings of the study, the following were recommended:

1. Crackers made from 90% fonio and 10% conophor nuts could be a healthy snack option for diabetic patients due to the low glycemic index of fonio and conophor nuts
2. The flour blend produced in this study could be recommended to the food industry to use as complementation or substitution to produce baked products.
3. The consumption of crackers made in this study could be encouraged as a snack for households and the general public due to their nutritional quality.
4. Further research is needed to investigate the shelf life and glycemic index of these types of crackers before they can be confidently recommended as part of diabetes mellitus management.
5. Further research is needed to conduct among diabetic patients to see the effects in reducing high blood sugar

AUTHOR CONTRIBUTIONS

IA and JS-M participated in the conceptualisation and design of the study. AOB, MUI and CRE participated in food processing, formulation and analysis. OO analysed laboratory data. OO participated in project administration and supervision. IA, TBA and JS-M participated in reviewing and editing the final draft of the manuscript. All authors have read and approved the final version of the paper and its submission.

CONFLICT OF INTEREST

The authors declare that they have no other potential conflicts of interest.

DECLARATION OF GENERATIVE AI AND AI-ASSISTED TECHNOLOGIES IN SCIENTIFIC WRITING

No generative AI or AI-assisted technologies were used in the writing, editing, data analysis, or production of this manuscript, unless explicitly acknowledged. The authors declare that the original work was designed by them. Grammarly and Gemini were used to refine language in some areas, and the authors remain fully responsible for the manuscript's content and integrity.

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