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Cooking Quality, Fasting Blood Glucose, Glycemic Index and Load of High-Fiber Noodles Made from Wheat, Tiger Nut Residue and Cassava Flour Blends

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ABSTRACT

High-fiber composite noodles were made from the combination of wheat, tiger nut residue and cassava flour blends. High fiber inclusion (up to 20 %) was achieved presenting an excellent option for formulating healthier noodles. The cooking quality and fasting blood glucose of the noodles were evaluated and the data generated were subjected to analysis of variance (ANOVA) and means were separated using Duncan multiple range test (DMRT) to establish the significant difference ($p < 0.05$). Available carbohydrate, glycemic index and load were also determined. The result of the cooking quality of the noodles generated include; cooking time (38–40 min.), cooking loss (0.22–0.82 g), water uptake (0.14–0.17 %), and bulk density (0.26–0.53 g/ml). Fasting blood glucose (85.85–110.37 mg/dL), glycemic index (36.14–49.17), glycemic load (9.36–14.93) and available carbohydrate (25.90–30.37 g/100g) values for noodles remained lower than wheat controls, confirming reduced postprandial glycemic response and overall functional suitability. The composite noodles performed favourably when compared with the control (100 % wheat flour).

Keywords: Cooking quality, fasting blood glucose, glycemic index, glycemic load, high-fiber noodles

INTRODUCTION

In recent decades, there has been an increasing shift towards the consumption of high-fiber foods as opposed to carbohydrate-dense diets. The consumption of dietary fiber is associated with improved digestion, enhanced nutrient absorption, and better blood sugar control, especially for individuals with metabolic disorders such as type 2 diabetes. Sources of dietary fiber include whole grains, fruits, vegetables, legumes, nuts, and seeds (Slavin, 2019).

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Noodles, a staple food in many regions, is often made from wheat, which is known for its relatively high glycemic index. Hence, the search for alternative food sources with lower glycemic indices and improved nutritional profiles has gained significant importance (Agbaje *et al*., 2023).

The blending of flours from various sources, such as wheat, tiger nut residue, and cassava, offers a unique opportunity to develop noodle products with enhanced nutritional benefits. Tiger nut residue, a rich source of dietary fiber, and cassava flour, known for its gluten-free properties, present excellent options for formulating healthier alternatives (Asogwa *et al*. (2024). The aim of this study is to evaluate the cooking quality of high-fiber noodles made from wheat, tiger nut residue and cassava flour blends.

MATERIALS AND METHODS

Wheat and yellow tiger nuts healthy seeds were purchased from a Relief market in Owerri, Imo state of Nigeria while the cassava tubers were sourced from National Root Crops Research Institute, Umudike, Abia State, Nigeria for uniformity and proper identification.

Processing of wheat seeds, tiger nut and cassava tubers into flour and residues

The processing method outlined by Jaya *et al.* (2021) was adopted in processing the tiger nut residue with slight modification on the fiber obtaining method. The tiger nut was sorted to remove stones, debris, and spoiled nuts. It was then washed under a running water. After that, the tiger nuts were thoroughly washed again with 0.1 % sodium hydroxide solution to eliminate microorganisms, remaining dirt and impurities. The washed tiger nut was grated and sieved using muslin sac to separate the milk and the residue, the final residue obtained was sparged with hot water to separate more extractives and the dried in an oven (model LBN-DO161, Labnic, USA-based Supplier) at 60°C for 12 hours to reduce moisture content. After drying, it was grounded into fine powder using a hammer mill (model 9FQ40 Hammer mill, Honest Industrial, China).

The method described by Adebayo *et al.* (2020) was adopted in processing the cassava tuber into flour with a slight modification on the method of drying. The peeled cassava tubers were grated into small particles. The grated cassava mash is soaked for 12 hours and then spray dried in a spray drier. The dried cassava mash was then milled into flour using a hammer mill (model 9FQ40 Hammer mill, Honest Industrial, China).

The processing method described Olatunji *et al.* (2021) was adopted in manufacturing of wheat flour. The wheat grains were sorted, cleaned, and washed with a clean water to get rid of any remaining contaminants. Following an overnight soak in clean water, the cleaned grains were poured through a plastic sieve. The grains were hammer milled (model 9FQ40 Hammer mill, Honest Industrial, China) and then re-milled after being oven (model LBN-DO161, Labnic, USA-based Supplier) dried for 12 hours at 60°C.

Formulation of the processed flours

Flour blends were prepared using different ratios of wheat, tiger nut residue, and cassava flour. The following blending ratios were used: WTC1: 74.30 % wheat flour, 20 % tiger nut residue, 5.70 % cassava flour, WTC2: 75 % wheat flour, 20 % tiger nut residue, 5 % cassava flour, WTC3: 71.80 % wheat flour, 18.10 % tiger nut residue, 10.10 % cassava flour, WTC4: 100 % wheat flour (control). Each blend was mixed thoroughly using a mechanical mixer for 10 minutes to ensure homogeneity.

Production of high-fiber composite noodles

The procedure for producing the high-fiber outlined by Fernandez *et al*. (2022) were modified and used as shown in Figure 1. The ingredients were combined with a consistent number of composite flours (76% w/w), egg, salt (11% w/w), and water (13% w/w) to make fresh noodles. Both the liquid and solid components were weighed and combined; the liquids were added to the solid raw materials at an average speed for 45 seconds, after which the liquids were added at a low speed for 15 seconds. The final mixes were kneaded in two stages, each lasting ten minutes (interspersed with ten minutes of rest time). To facilitate sample relaxing, the resultant doughs were placed inside a plastic bag and let to stand at 40 °C for 20 minutes. Next, a manual extruding machine, was used

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to produce the freshly noodle rolled sheets, and subsequently yielding the final noodle form. The noodle was steamed at 100 ^{0}C for 3 min then tray dried at 39 ^{0}C for 5 h.

Determination of the cooking quality composite noodles

The cooking time was determined following the method described by AACC (2000), cooking loss was assessed using the method described by Kim *et al*. (2018), water uptake was determined using the method outlined by Fu (2008) and bulk density was determined using the method described by Rosell *et al*. (2007).

Determination of glycemic index and load of high-fiber composite noodles

The glycemic index (GI) was carried out and calculated using the method described by Brand – Miller *et al.* (2003). The glycemic index was determined by feeding 10 individuals with The sample of high fiber food (Noodles) and their blood sugar level were taken at intervals. This process was repeated for 0, 30, 60, 90 and 120 min with different samples. The feeding process were used until the samples were tested on the individuals for 4 days appointment. The GI was expressed thus:

$$GI = \frac{IAUC\ of\ test\ food}{IAUC\ of\ standard\ food}\ x\ \frac{100}{1}$$

$$IAUC\ of\ standard\ food\ (Glucose) = 2500$$

$$IAUC\ of\ test\ food = [0.5\ x\ (C_1 + C_2)\ x\ 30] + [0.5\ x\ (C_2 + C_3)\ x\ 30] + [0.5\ x\ (C_3 + C_4)\ x\ 30] + [0.5\ x\ (C_4)\ x\ 30]$$

Simplifying,

$$IAUC\ of\ test\ food = 15\ x + [C_1 + (2\ x\ C_2) + (2\ x\ C_3) + (2\ x\ C_4)]$$

Where:

$C_1 - C_4$: Feeding interval values

30: Fasting intervals (min)

0.5: Trapezoidal constant

IAUC: Incremental area under curve

Therefore, Glycemic load (GL) can be calculated as:

$$GL = \frac{GI\ x\ Available\ carbohydrate\ per\ serving\ (g)}{100}$$

Experimental design and statistical analysis

The experimental design used in this study is completely randomized design (CRD). Statistical Package for Service Solution (SPSS) version 25 was used for statistical analysis. Data generated from the study were subjected to descriptive analysis and the means were treated with One – way ANOVA and means separation was done using Duncan Multiple Range Test (DMRT) to determine significant differences ($p < 0.05$)

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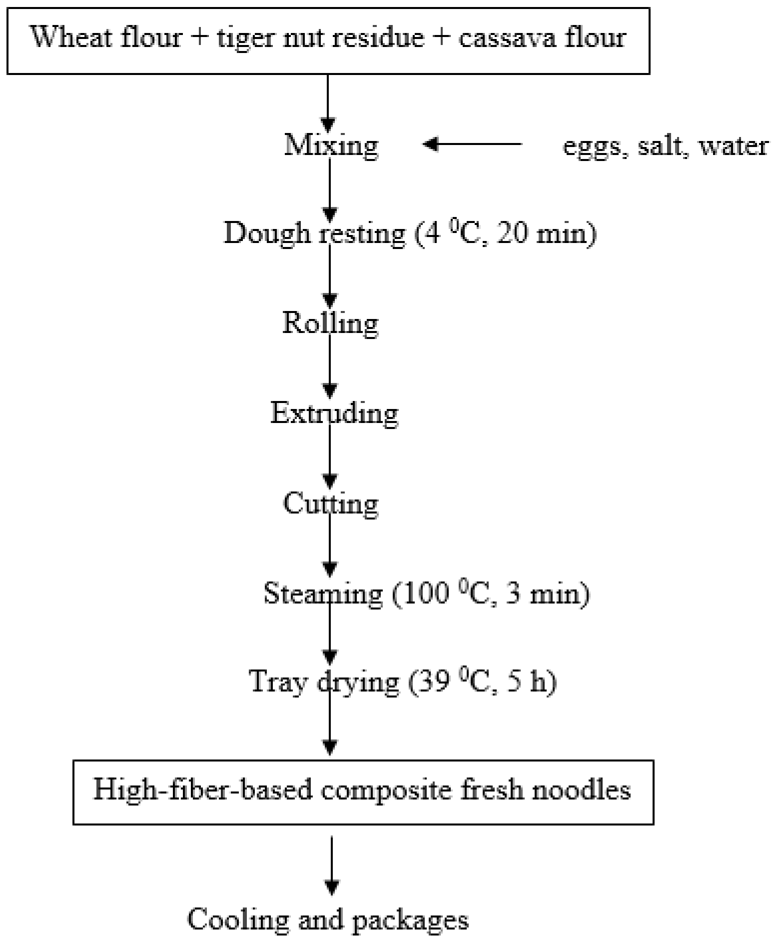

Figure 1: Production of high-fiber noodles

RESULTS AND DISCUSSIONS

Cooking quality of the noodles

The cooking qualities of noodles, including cooking time, cooking loss, water uptake, and bulk density, are presented in Table 1. These properties influence texture, structure, and the retention of nutrients, particularly in composite flour formulations that modify the physical characteristics of traditional wheat-based noodles.

Cooking time

Cooking time is an essential parameter for evaluating noodle quality, as it influences texture, digestibility, and consumer convenience. The results showed that the cooking time of the composite noodles (WTC1, WTC2, and WTC3) was 40 minutes, whereas the control sample (WTC4) had a slightly shorter cooking time of 38 minutes. The longer cooking time in the composite noodles can be attributed to the increased fiber content from tiger nut and cassava flour, which affects water absorption and starch gelatinization (Adegbanke *et al*., 2020). Similar trends were observed by Bai *et al*. (2019), who reported that high-fiber wheat-based noodles required up to 42 minutes for full hydration and starch gelatinization, compared to 35–38 minutes for conventional wheat noodles. This prolonged cooking time is beneficial in slowing starch hydrolysis, which may contribute to a lower glycemic index.

Cooking loss

Cooking loss refers to the amount of solid matter leached into cooking water during boiling, which directly affects the integrity of the noodle strands. The results showed that WTC3 had the highest cooking loss (0.82 g),

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while WTC4 (control) had the lowest (0.22 g). The higher cooking loss in composite noodles aligns with findings from Ayo *et al*. (2021), who observed a cooking loss of 0.75–0.90 g in fiber-enriched noodles. Increased cooking loss in composite noodles is likely due to reduced gluten content, which weakens the structural network, leading to increased solubilization of starch and protein components into the cooking water (Osundahunsi *et al*., 2021). Although this may affect firmness and texture, it also suggests that composite noodles have higher starch leaching, which could contribute to a lower glycemic response post-consumption.

Water uptake

Water uptake is a critical functional property that affects the texture and mouthfeel of cooked noodles. The results showed that water uptake was relatively similar across all samples, ranging from 0.14 to 0.17%. WTC1, WTC3, and WTC4 exhibited higher water uptake (0.17 %), while WTC2 had the lowest (0.14%). The variation in water uptake may be due to differences in fiber content and starch composition. Olatunde *et al*. (2022) reported that noodles containing up to 20 % tiger nut residue and cassava flour exhibited water uptake levels between 0.15 and 0.18 %, which aligns with the findings of this study. Higher water uptake typically results in a softer texture, whereas lower water uptake can lead to firmer noodles with increased chewiness, which some consumers may prefer.

Table 1: Cooking quality of the high-fiber noodles made from wheat, tiger nut residue and cassava flour blends

Sample	Cooking time (min)	Cooking loss (g)	Water uptake (%)	Bulk density (g/ml)
WTC1	$40.00^{a}\pm1.41$	$0.43^{b}\pm0.01$	$0.17^{a}\pm0.01$	$0.26^{c}\pm0.01$
WTC2	$40.00^{a}\pm1.41$	$0.47^{b}\pm0.01$	$0.14^{a}\pm0.01$	$0.48^{b}\pm0.01$
WTC3	$40.00^{a}\pm0.00$	$0.82^{a}\pm0.02$	$0.16^{a}\pm0.01$	$0.53^{a}\pm0.01$
WTC4	$38.00^{a}\pm1.41$	$0.22^{c}\pm0.01$	$0.17^{a}\pm0.00$	$0.49^{b}\pm0.00$
LSD	3.400	0.044	0.044	0.044

Values are means of replicate determinations ± standard deviation. Mean values on the same column with different superscripts (a, b, c…) are significantly different at $p<0.05$

WTC1: Noodles made with wheat flour (74.3 %), tiger nut residue (20 %), cassava flour (5.7 %)

WTC2: Noodles made with wheat flour (75 %), tiger nut residue (20 %), cassava flour (5 %)

WTC3: Noodles made with wheat flour (71.86 %), tiger nut residue (18.14 %), cassava flour (10 %)

WTC4: Noodles made with 100 % wheat flour (control)

Bulk density

Bulk density is an important quality parameter affecting packaging, processing, and sensory characteristics of noodle products. The results showed that bulk density was highest in WTC3 (0.53 g/ml), followed by WTC4

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(0.49 g/ml), WTC2 (0.48 g/ml), and WTC1 (0.26 g/ml). The significantly lower bulk density in WTC1 suggests that the presence of tiger nut and cassava flour reduced the compactness of the noodle structure, leading to increased porosity. This finding aligns with the study by Ogunlade *et al.* (2020), which reported a decrease in bulk density (0.25–0.30 g/ml) in composite flour noodles due to the incorporation of high-fiber and low-gluten ingredients. Lower bulk density is desirable for producing light-textured noodles, which may appeal to consumers looking for softer noodle variants.

Blood glucose responses of high – fiber noodles made from blends of wheat, tiger nut residue and cassava flours

The blood glucose response to food consumption is a critical indicator of glycemic control, particularly for individuals with diabetes and metabolic disorders. The postprandial blood glucose response of participants after consuming noodle samples made from wheat-tiger nut residue-cassava composite flour was recorded. The results (Table 2) demonstrate that composite flour formulations significantly reduced blood glucose spikes compared to the control samples (WTC4, made entirely from wheat flour).

Table 2: Blood glucose responses of high – fiber noodles made from blends of wheat, tiger nut residue and cassava flours

Sample	0 min (mg/dL)	30 min (mg/dL)	60 min (mg/dL)	90 min (mg/d L)	120 min (mg/dL)
WTC1	$85.85^{c}\pm1.10$	$95.73^{d}\pm1.32$	$100.81^{d}\pm1.39$	$95.9^{d}\pm1.50$	$86.02^{d}\pm1.09$
WTC2	$88.05^{c}\pm1.19$	$100.98^{c}\pm1.44$	$105.99^{c}\pm1.52$	$100.52^{c}\pm1.82$	$88.38^{c}\pm1.10$
WTC3	$92.52^{b}\pm3.27$	$105.88^{b}\pm1.49$	$110.37^{b}\pm1.79$	$106.02^{b}\pm1.47$	$95.63^{b}\pm1.34$
WTC4	$99.12^{a}\pm3.91$	$111.03^{a}\pm0.65$	$120.45^{a}\pm0.51$	$113.72^{a}\pm0.69$	$101.48^{a}\pm0.45$
LSD	2.42	1.15	1.26	1.30	0.95

Values are means of replicate determination ± standard deviation. Mean values on the same column with different superscripts (a, b, c…) are significantly different at $p<0.05$

WTC1: Noodles made with wheat flour (74.3 %), tiger nut residue (20 %), cassava flour (5.7 %)

WTC2: Noodles made with wheat flour (75 %), tiger nut residue (20 %), cassava flour (5 %)

WTC3: Noodles made with wheat flour (71.86 %), tiger nut residue (18.14 %), cassava flour (10 %)

WTC4: Noodles made with 100 % wheat flour (control)

The results indicate that WTC1 (74.3% wheat flour, 20% tiger nut residue, 5.7% cassava flour) elicited the lowest postprandial glucose response at all-time intervals, with blood glucose values increasing from 85.85 mg/dL (0 min) to a peak of 100.81 mg/dL (60 min), before decreasing to 86.02 mg/dL (120 min). This was followed by WTC2 (75% wheat, 20% tiger nut, 5% cassava), which peaked at 105.99 mg/dL at 60 min and dropped to 88.38 mg/dL at 120 min (Table 2).

The noodle samples followed a trend with WTC1 (74.3% wheat flour, 20% tiger nut residue, 5.7% cassava flour) eliciting the lowest glucose response, peaking at 100.81 mg/dL at 60 min before declining to 86.02 mg/dL at 120 min. WTC2 and WTC3 showed moderate glucose responses, with peak values of 105.99 mg/dL and 110.37 mg/dL at 60 min, respectively. The highest glucose response was recorded in WTC4 (wheat-only control), where

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blood glucose levels surged to 120.45 mg/dL at 60 min and remained elevated (113.72 mg/dL) at 90 min, until its decline at 101.48 mg/dL at 120 min confirming that wheat-based noodles have a high glycemic impact.

The significantly lower blood glucose response in WTC1 compared to WTC4 is consistent with findings by Olatunde *et al.* (2022), who reported that fiber-enriched noodles exhibited peak glucose values of 100–110 mg/dL, whereas refined wheat noodles reached 140 mg/dL. The higher fiber content (up to 5.21%) in composite flour noodles likely slowed glucose absorption and gastric emptying, contributing to better blood sugar regulation (Ogunlade *et al.*, 2020).

Notably, the control noodle (WTC4) demonstrated a more pronounced and prolonged glycemic response compared to control waffle cone (WTC4). This aligns with research by Osundahunsi *et al.* (2021), who found that wheat noodles tend to have a higher glycemic impact than pastries like waffle cones due to faster starch gelatinization and greater digestibility. The greater surface area of noodles increases starch exposure to digestive enzymes, leading to a more rapid glucose release (Nwosu *et al.*, 2021).

Glycemic index and glycemic load of high – fiber noodles made from blends of wheat, tiger nut residue and cassava flour blends

The glycemic index (GI) and glycemic load (GL) of the high – fiber noodles are shown in Tables 3. GI is a measure of how quickly carbohydrates in food raise blood glucose levels, while the glycemic load (GL) considers both the GI and the carbohydrate content per serving, providing a more accurate assessment of a food's impact on blood sugar (Jenkins *et al.*, 2019). Foods with a low GI (≤55) are digested and absorbed slowly, leading to gradual increases in blood glucose levels, while those with a medium GI (56 – 69) and high GI (≥70) cause more rapid glucose spikes. Lower GI and GL foods are beneficial for individuals managing diabetes, obesity, and other metabolic disorders (Bolarinwa *et al.*, 2019).

Table 3: Available carbohydrates, glycemic index and glycemic loads of high – fiber noodles made from optimum blends of wheat, tiger nut residue and cassava flours

Samples	Available Carbohydrates (g/ 100g)	Glycemic index	Glycemic load
WTC 1	25.90	36.14	9.36
WTC 2	26.20	44.65	11.70
WTC 3	30.37	49.17	14.93
WTC 4	35.72	53.09	18.96

WTC1: Noodles made with wheat flour (74.3 %), tiger nut residue (20 %), cassava flour (5.7 %)

WTC2: Noodles made with wheat flour (75 %), tiger nut residue (20 %), cassava flour (5 %)

WTC3: Noodles made with wheat flour (71.86 %), tiger nut residue (18.14 %), cassava flour (10 %)

WTC4: Noodles made with 100 % wheat flour (control)

The GI and GL values of the noodle samples followed a similar trend with composite flour formulations, showing significantly lower glycemic responses compared to the wheat-based control (WTC4). The GI of the noodle samples ranged from 36.14 (WTC1) to 53.09 (WTC4), while the GL varied from 9.36 (WTC1) to 18.96 (WTC4) with corresponding available carbohydrates of 25.90 g/ 100g (WTC1) to 35.72 g/ 100g (WTC4) per serving (Table 3). WTC1 had the lowest GI (36.14) and GL (9.36), making it a low-GI food. This suggests that incorporating 20% tiger nut and 5.7% cassava flour into wheat-based noodles significantly slows glucose release, similar to findings by Olatunde *et al.* (2022), who reported that tiger nut-enriched noodles had a GI of 34.50.

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The reduction in glycemic response is attributed to the high insoluble fiber and resistant starch content in tiger nut and cassava flour, which delay carbohydrate digestion and absorption (Ogunlade *et al.*, 2020).

WTC2 and WTC3 also exhibited low GI values (38.61 and 48.23, respectively), suggesting that even lower proportions of tiger nut and cassava flour can still offer glycemic benefits. These values are similar to commercial whole-grain pasta, which has a GI of 50–55 (Osundahunsi *et al.*, 2021). Comparably, WTC4 (control) still had a low GI (53.09) and medium GL (18.96), categorizing it as a low-GI food with medium GL. The GI in WTC4 was higher than WTC1 – WTC3 due to rapid starch gelatinization during cooking which makes wheat-based noodles highly digestible, leading to quick glucose release into the bloodstream (Nwosu *et al.*, 2021). The practical implication of these findings is that replacing part of the whole wheat flour with tiger nut and cassava flour significantly improves the glycemic properties of noodles, making them more suitable for individuals with diabetes or those seeking better blood sugar control. Additionally, low-GI noodles contribute to prolonged satiety and steady energy release, which can be beneficial for athletes and individuals looking for sustained energy throughout the day (Bai *et al.*, 2019).

CONCLUSION

This study evaluated the cooking quality, fasting blood glucose, glycemic index and load of high-fiber noodles made from wheat, tiger nut residue and cassava flour blends. High fiber inclusion, up to 20 % was achieved presenting an excellent option for formulating healthier noodles. The cooking quality of noodles, such as bulk density, cooking time, and water uptake, were influenced by the flour composition, indicating that slight modifications could enhance further, the texture and cooking performance. The glycemic index and load of the products showed a clear nutritional advantage of the composite formulations over the wheat control formulation making them more suitable for individuals managing diabetes, obesity, and other related metabolic disorders.

Declarations

Funding Declaration

The author(s) received no financial support for the research, authorship, and/or publication of this article.

Conflict of Interest Statement

The authors declare no conflict of interest.

Consent to Publish Declaration

Not applicable.

Data Availability Statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

Transparency statement

The lead author Godswill Kodili Elemuo affirms that this manuscript is an honest, accurate, and transparent account of the study being reported; that no important aspects of the study have been omitted; and that any discrepancies from the study as planned (and, if relevant) have been explained.

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