Natural Resources for Human Health

visagaa publishing house

Original Research

View Article Online

Check for updates

Received 26 October 2021
Revised 22 November 2021
Accepted 29 November 2021
Available online 06 January 2022

Edited by Haipeng Lv

KEYWORDS:
Meals
coconut residue
sensory attributes
tapioca granules
grits

Natr Resour Human Health 2022; 2 (2): 200-207
https://doi.org/10.53365/nrfhh/144352
eISSN: 2583-1194

Fortification of cassava starch with coconut residue: effects on flours' functional properties and products' (Tapioca meals) nutritional and sensory qualities

Olalekan Jimi Adebowale [1,*], Oluwasegun Oluwagbenga Ajibode [2]

[1]Department of Food Technology, P.M.B. 50, Ilaro, Ogun State - 11101, Nigeria.
[2]Food Processing/Engineering Workshop, The Federal Polytechnic, P.M.B. 50, Ilaro, Ogun State - 11101, Nigeria.

ABSTRACT: Consumers are show interest in plant-based by-products due to their potential health-promoting properties. Coconut residue is food waste from coconut milk that is potentially rich in bioactive compounds, protein and dietary fibre. The effects of substituting cassava starch with coconut residue on the functional properties (bulk density, water absorption and swelling indexes), proximate composition, the energy value of flour, and sensory characteristics of tapioca grit's meal were studied. Cassava starch was mixed with coconut residue powder in five formulations that had 0, 10, 20, 30, and 40% of coconut residue powder, before being made into tapioca grits. The results showed that the bulk density, water absorption and swelling indexes decreased, whilst protein increased with the increasing addition of coconut residue. The colour of tapioca meals did not have any pronounced change in colour due to added coconut residue. Sensory results showed that tapioca samples fortified with 30% coconut residue was the most preferred with ranking in terms of aroma (8.7), overall acceptability (8.7) and willingness to buy (8.6) compared to other samples. Fortifying cassava starch with food waste like coconut residue improved the protein and fibre contents, and enhanced value addition and food product (tapioca meal) sensory quality.

1. INTRODUCTION

The sustainability and valorization of plant by-products such as coconut residue are of great concern to the stakeholders in the value chain, in respect of its waste-the residue (Bello et al., 2021) . However, food loss and waste or by-products have a great impact on the world's food supply (Amin et al., 2021) . Different agencies and researchers have developed and implemented several initiatives to ameliorate its food waste-the residue. The United States Environmental Protection Agency identified a food waste hierarchy that prioritises feeding hungry people, feeding animals and industrial uses (Lavenburg et al., 2021). For instance, coconut residue recovered during the coconut oil and/or coconut milk extraction process is a source of valuable nutrients such as proteins, fibre, magnesium, potassium, phosphorus, iron and zinc, and vitamins (Alebiosu et al., 2020). Some of these nutrients are principally lacking in most leading staple plant-based diets such as tapioca prepared from cassava starch. Also, coconut residue was reportedly to have health-promoting potentials that could be exploited in the formulation of functional foods because of its diverse nutrients and bioactive compounds (Adeloye et al., 2020; Bello et al., 2021). Therefore, to improve the nutritional composition of a starch-based food product like cassava starch-tapioca, coconut residue could be incorporated because it is rich in proteins and several micronutrients that are deficient in tapioca (100% cassava starch).

Consumption of tapioca meal has spread beyond the shores of Nigeria to West African sub-regions including the Benin Republic, Togo and Ghana. Tapioca grits can be prepared by the roasting of dried cassava starch leading to its incomplete hydrolysis and gelatinization (Samuel et al., 2012). Tapioca meal can be prepared after conditioning the grits for nearly 6 hours, to soften the grits before cooking to form a gel-like viscous mass. Prolong consumption of starchy food products has been of great concern by virtue that, it can lead to 'hidden hunger (dietary micronutrient deficiency) and protein-energy malnutrition (Buzigi et al., 2020). The sub-Saharan Africa region is persistently facing the challenges of food insecurity and malnutrition (Delight et al., 2021), notably as under-nutrition and hunger affect the health status of the inhabitants. The COVID-19 pandemic attributed to severe acute respiratory syndrome coronavirus (SARS-CoV-2) (Buys et al., 2020) , further aggravated undernutrition and hunger, mostly in lower-

* Corresponding author.
E-mail address: olalekan.adebowale@federalpolyilaro.edu.ng (Olalekan Jimi Adebowale)

natural resources for human health
HUMAN HEALTH

income earners (Bamidele & Fasogbon, 2020) . Therefore, fortifying cassava starch with coconut residue (a food waste) could improve the protein content and enhance the value addition of coconut residue in tapioca meals.

Studies have shown that fortification of tapioca grits with under-utilised food crops can encourage its consumption (Adeboye et al., 2019), improve nutritional value (Adebowale & Komolafe, 2018), provide health benefits (Adeloye et al., 2020) and sensory quality of the meals (Adeboye et al., 2019; Samuel et al., 2012). Samuel et al. (2012) evaluated the improvement of tapioca by supplementation with full-fat soybean flour. The authors found that the tapioca sample with 15% level full-fat soy flour does not differ from the control sample in terms of the functional properties. Adeboye et al. (2019) evaluated the effect of almond seed flour inclusion in tapioca and found that at 10% level almond flour inclusion, tapioca had improved protein content and higher overall product acceptability. Recently, Bello et al. (2021) optimised cassava-mungbean with coconut pomace for cookies production and found that, a higher percentage of coconut pomace flour-enhanced ash, crude fibre, carbohydrate and total dietary fibre contents of cookies. To the best of our knowledge, information on the fortification of cassava starch tapioca with coconut residue is scanty.

The present study investigates the effect of replacement of cassava starch with coconut residue of the flour functional properties, proximate composition and products; sensory quality to improve protein and crude fibre contents, enhance value addition of coconut residue in tapioca meal.

2. MATERIALS AND METHODS

2.1. Materials

Matured and freshly harvested cassava roots (*Manihot esculenta* Crantz) locally known as oko iyawo and coconut (*Cocos nucifera*) were purchased from a retail market in Ilaro, Nigeria. All chemicals were of analytical grades.

2.2. Methods

2.2.1 Starch extraction from cassava roots

Cassava roots were sorted, cleaned, and then processed into pulps. Collected pulps were thoroughly mixed with sufficient water, to extract the starch through a muslin cloth as filtrate. The filtrate settled after 4 hours and the starch sediment was then dried in a single-stage process using the cabinet dryer at 60 ºC for 6 hours. Dried starch granules were milled with a laboratory mill fitted with 500 μm sieve size, packaged in zip lock bags and kept at -20 ºC until required.

2.2.2 Preparation of coconut residue

Pre-processing operations of deshelling and coconut water were carried out on coconut. The dark covering on the endocarp was scraped and the resulting white kernels were blended to a smooth paste. Hot water (80 ºC) was added to the paste and mixed thoroughly to remove oil-in-water emulsion (supernatant). The supernatant was collected (to reduce the fat content) and the sediment (residue) was dried (80-90 ºC for 5 minutes) in a single-stage process using the cabinet dryer. The dried mas (coconut residue) was milled (500 μm sieve size), packaged in zip lock bags and stored at - 20 ºC for further use.

2.2.3 Preparation of tapioca samples from cassava starch-coconut residue blends

Blend formulations were based on a mixture design, to achieve five samples combinations, by replacing cassava starch with coconut residue from 10% to 40%. Cassava starch (100% or without coconut residue) was used as a control (Table 1). The blends were separately conditioned to 20% moisture and roasted (120±10 °C) in a stainless pan and stirred constantly for 20 minutes. The resulting tapioca granules (Figure 1) were spread to cool (27 ± 2 ºC) on a stainless tray, and packaged in zip lock bags for storage (-20 ºC) until needed for further analyses.

Table 1
Formulations based on cassava starch and coconut residue powder combinations for the production of tapioca granules.

Sample blends	Cassava starch (%)	Coconut residue (%)
100%CS	100	0
90%CS+10%CR	90	10
80%CS+20%CR	80	20
70%CS+30%CR	70	30
60%CS+40%CR	60	40

CS = Cassava Starch, CR= Coconut Residue

Figure 1. Tapioca grit samples with and without different levels of coconut residue.

2.3. Analyses

All parameters were determined in triplicates for tapioca grit samples (Figure 1) and once for product sensory evaluation test.

2.3.1 Flour functional properties determination

Bulk density: About 50 grams sample was weighed into a graduated measuring cylinder (100 ml capacity), and tapped gently on the laboratory flat desk for about 5 minutes until the contents were tightly packed (Gbadamosi & Oladeji, 2013). Bulk density was calculated as the ratio of weight (g) and volume (ml) occupied by the sample. Bulk density was calculated as:

$$\text{Bulk density (g/ml)} = \frac{weight\ of\ the\ sample}{volume\ occupied\ by\ the\ sample\ after\ tapping}$$

Water absorption index: Exactly 2.5 g of tapioca flour sample was dispersed into a 50-ml centrifuge tube containing 30 ml of distilled. The mixture was incubated in a shaking water bath (OLS26 Aqua Pro, Grant Instrument Ltd., Wehingen, Germany) with a temperature set at 30 °C for 30 minutes and vortex at 5 min intervals. The mixture was cold (10 °C) centrifuged (Z366K, Hermle Labortechnik GmbH, Wehingen, Germany) at 4500 rpm for 15 minutes to obtain a gel. The supernatant was decanted carefully into a moisture tin of known weight and dried at 100 °C for 8 hours. (Singh & Singh, 2002). The water absorption index was calculated as follows:

$$\text{Water absorption index} = \frac{weight\ of\ gel\ obatined}{weight\ of\ tapioca\ flour\ sample}$$

Swelling index: Into a dry graduated (100 ml capacity) measuring cylinder glass, exactly 10 g of tapioca sample was weighed and tapped gently. The volume occupied by the sample was noted. 50 ml distilled water was added, the mixture was allowed to stand for 4 hours. The swelling index was calculated as the ratio of the original volume to the final volume (Karim et al., 2016). The swelling index was calculated as shown:

$$\text{Swelling index} = \frac{initial\ volume\ of\ sample\ after\ tapping}{final\ volume\ occupied\ by\ sample\ mixed\ with\ 50\ ml}$$

2.3.2 Chemical analyses

Proximate analysis (moisture, crude protein, crude fat, crude fibre, and ash contents) was conducted using official methods (AOAC, 2012) on the samples in Figure 1**.**

2.3.2.1 Moisture content determination The moisture content was determined by the gravimetric or drying method. The principle is based on the weight loss of water after heating under controlled conditions in an oven set at 105 ºC. A cleaned and dried petri dish was weighed, and its weight was recorded as (w1). Exactly 5 grams of the sample was weighed into the Petri dish and recorded as (w2) and then transferred into the thermosetting-oven set at 105 ºC for 3 hours. It was later transferred into the desiccator for effective cooling and then reweighed. This process was performed repeatedly until a constant weight (w3) was obtained. The weight loss (w2 - w3) during drying to the samples ($w_2 - w_1$) weight, in percentage was taken to be the percentage of moisture content and was calculated as:

$$\text{Moisture (\%)} = \frac{weight\ loss}{weight\ of\ sample}\ x\ 100$$

2.3.2.2 Crude Protein determination The crude protein content of the samples was determined using the Kjeldahl method. Exactly 1 gram of the sample was weighed into a Kjeldahl flask, 10 ml of H2SO4 with Kjeldahl catalyst was added. Then, the flask containing the mixture was heated on a heating mantle while the flask was rotated at 2 minutes intervals until the digestion was achieved (without frosting), in the fume cupboard. The heated mixture was allowed to cool for 40 minutes and the digested sample was made up to 50 ml solution (v1). Later, 25 ml of the resulting solution was pipetted into a clean conical flask and neutralized with 50 ml of 40 % NaOH(aq). Then titration was performed using 2% boric acid to determine the amount of NH3(aq). The percentage of nitrogen was estimated using:

$$\text{\% Nitrogen} = \frac{(T-B)titre\ value\ x\ 14\ x\ 0.01\ x\ V1}{weight\ \ of\ sample\ \ x\ V2}\ x\ 100$$

% Protein = % Nitrogen × 6.25. Where T is the titre value, B is the blank, V1 and V2 are the total volumes of digested sample and the volume of digested sample used for titration respectively.

2.3.2.3 Crude fat determination Exactly 1 gram of each sample was weighed into a fat-free extraction thimble and then blocked lightly with cotton wool. The thimble was placed in the extractor and fitted up with a reflux condenser. A-250 ml Soxhlet flask which had been dried in the oven, cooled in the desiccator was weighed. The Soxhlet flask was filled to three-quarters of its volume with n-hexane (boiling point of 40°C - 60°C). The flask, extractor with condenser set was placed on the heater for 6 hours with constant running water from the tap for condensation of the ether vapour. The thimble with the sample was dried, extractor and condenser replaced and distillation continued until the flask was dried. The flask with the oil was detached, its exterior was cleaned and dried at 50 ºC to a constant weight in the oven. Crude fat/oil content was calculated as follows:

$$\text{Crude fat} = \frac{Weight\ of\ extracted\ oil\ from\ sample}{weight\ of\ original\ sample} \times 100$$

2.3.2.4 Crude fibre determination About 3 grams (W1) of the defatted sample was weighed into a 500 cm3 conical flask placed on a heating mantle, and 200 cm^3 of 1.25% of H_2SO4(aq) was then added. The set-up was heated to boil for 2 minutes and thereafter allowed to boil gently for 30 minutes, to hydrolyse the carbohydrates and protein. The mixture was filtered through Whatman filter paper No. 4 and rinsed well with hot distilled water until the clear filtrate was obtained. The sample was scrapped with a spatula, back into a flask containing 200 cm3 of 1.25% NaOH(aq) and it was heated gently for half another 30 minutes. Thereafter, it was filtered through a filter paper and rinsed well with hot distilled water 4 times and once with 10% HCl to neutralize the residual NaOH in the sample. It was then rinsed with hot distilled water four times and twice with absolute ethanol. The residue was scrapped into a crucible and dried in a drying oven set at 105 ºC. The sample was reweighed (W2). The percentage of crude fibre was calculated as follows:

$$\text{\% Crude Fibre} = \frac{weight\ of\ dried\ sample\ after\ treatment\ (W2)}{weight\ of\ sample\ defatted\ and\ treated\ sample\ (W1)}$$
x 100

2.3.2.5 Ash content determination Exactly 3 grams of the sample powder was put into different 3 marked crucibles of known weight. The samples were placed in an oven at 600 ºC for 24 hours. The crucibles plus the content were reweighed after cooling. The percentage of ash content was calculated:

$$\text{\%Ash content} = \frac{(weight\ of\ crucible+sample\ after\ ashing)-(Weight\ of\ empty}{weight\ of\ sample\ powder}$$

2.3.2.6 Carbohydrate content and energy value determinations Carbohydrate was calculated as the difference between the sum of the predominant food constituents in percentages (ash, crude protein, fat, crude fibre, moisture) and one hundred. That is: [100 – (Σ moisture, ash, fat, protein and fibre contents)]. Energy value (kcal) was calculated as: [(Σ lipid (8.37kcal/g), protein (3.87 kcal/g) and carbohydrate (4.11 kcal/g) contents)] (FAO, 2003) .

2.3.3 Sensory evaluation tapioca meals

Panellists (n=65) comprising of 45 females and 20 males, aged between 18 and 35 years were used to evaluate the sensory attributes of tapioca meals. The panels were trained for 2 hours in 2 sessions within a week on sensory evaluation of food and interpretation of a 9-point hedonic scale. Tapioca grits were soaked in portable water for 4 hours at a 1:5 (grits: water) ratio to hydrate and soften the grits before cooking. The pre-soaked grits were poured in boiling water (100 ml), cooked (10 min) while stirring consistently. Meal (~40 g) i.e., cooked tapioca meal (porridge or gel-like form), was served to the panellists at 50±2 °C in glass ramekins which was covered with aluminium foil and blind-folded using 3-digit codes. Sample meal (randomised order within the session) was presented to the panellists, 1 hr session/week in the sensory booths. Meals (5, one at a time) were served (at 5 minutes intervals between the samples) with 4 g of sugar and 10 ml of liquid milk. An evaluation was conducted twice for colour, aroma, taste, smoothness, aftertaste, overall acceptability. Meals were evaluated on a 9-point hedonic scale of preference (1= dislike extremely to 9 = like extremely). Drinking water was provided to cleanse the palates between each evaluation. Attributes evaluated were colour, taste, aroma, smoothness (mouthfeel), aftertaste and overall acceptability of the samples (Figure 2). The aroma was evaluated by taking short sniffs instantly after uncovering the ramekins. By chewing a teaspoonful of sample in the mouth, smoothness was evaluated. Then after swallowing the sample, the aftertaste was evaluated.

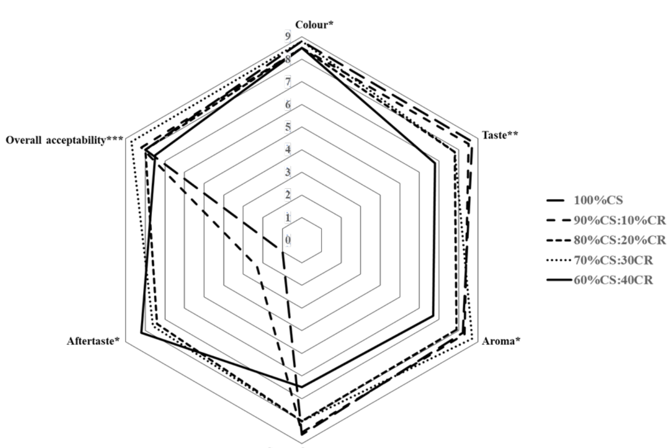

Figure 2. Sensory attributes profiles of tapioca meals prepared from different proportions of casava starch and coconut residue

2.4. Statistical analysis

The homogeneity of variance normality of the data obtained from this experiment was checked using Levene's (p = 0.00) and kurtosis's (0.00) tests respectively. Indicating that the variances are not homogeneous and that data are normally distributed. Statistical analysis on bulk density, water absorption index, swelling index, and proximate composition of samples was reported as means ± standard deviation of replicates (n=3). The differences between mean values were evaluated by a one-way analysis of variance. Multiple pairwise comparisons were established using the LSD (Least Significant Difference) test at a significance level of $p<0.05$. XLSTAT® software package (Addinsoft™, New York) was used for the analyses.

3. RESULTS

The results of the functional properties of cassava starch-defatted coconut residue blends are presented (Table 2).

Table 2
Effect of cassava starch-coconut residue blends on the functional properties of tapioca granules.

Sample blends	Functional properties		
	Bulk density (g/ml)	Water absorption index (%)	Swelling index
100%CS	0.62 ± 0.02^{a}	193.3 ± 2.2^{a}	2.13 ± 0.1^{a}
90%CS+10%CR	0.60 ± 0.03^{a}	166.7 ± 1.4^{b}	1.83 ± 0.1^{b}
80%CS+20%CR	0.59 ± 0.02^{ab}	151.7 ± 1.2^{c}	1.63 ± 0.1^{c}
70%CS+30CR	0.58 ± 0.01^{b}	138.3 ± 1.1^{d}	1.53 ± 0.2^{d}
60%CS+40CR	0.57 ± 0.01^{b}	129.5 ± 1.4^{e}	1.20 ± 0.1^{e}
LSD p0.05	0.065	<0.0012	<0.0054

Values are means ± standard deviation of replicate (n = 3) determination. Means within the same column with same superscript are not significantly (p>0.05) different from one another using the Fischer-Snedecor's test to verify the equality of the variance.
CS = Cassava Starch, CR = Coconut Residue
100%CS = 100-part of cassava starch without coconut residue, 90%CS+10%CR = 90-part of cassava starch with 10-part coconut residue blends, 80%CS+20%CR = 80-part of cassava starch with 20-part coconut residue blends, 70%CS+30%CR = 70-part of cassava starch with 30-part coconut residue blends, 60%CS+40%CR = 60-part of cassava starch with 40-part coconut residue blends; for the production of tapioca grit products

There were significant ($p<0.05$) differences in water absorption and swelling indexes for all the samples. These parameters, notably water absorption and swelling indexes decreased with an increasing amount of coconut residue in the blends. The bulk density of substituted samples was lower than that of control (100% cassava starch). Bulk densities were of samples were ranged between 0.57 g/ml and 0.62 g/ml. The highest values of bulk density were recorded in the control while the lowest value was in the sample with 40% coconut residue. The water absorption index of substituted samples decreased with an increasing level of coconut residue in the blends. Water absorption indexes of the samples were in the range of 129.5% to 193.3%. The control sample had the highest water absorption index value (193.3%), this value decreased steadily with progressive increase addition of coconut residue into cassava starch. The lowest value of the water absorption index was recorded in the sample with 40% coconut residue substitution for cassava starch. Similarly, swelling indexes of all samples decreased with increasing substitution of cassava starch with coconut residue, for the production of tapioca grits or granules. Values of swelling indexes recorded for the samples were ranged from 1.20 to 2.13, with the highest value being that of the control and lowest in sample substituted with 40% coconut residue.

Table 3 shows the results of proximate composition and energy value of tapioca samples prepared from cassava starch-coconut residue blends. Significant ($p < 0.05$) differences existed in the percentage moisture, ash, fibre, fat, carbohydrate contents and energy values among the blends. The ash, fibre, fat, carbohydrate contents and energy values increased as the percentage of coconut residue increased, while moisture and carbohydrate contents decreased with an increase in coconut residue fortification. The moisture content for the samples ranged between 9.4% and 9.5%, and the values were significant ($p<0.05$). The ash content for the samples ranged significantly ($p<0.01$) from 2.8% to 3.3% with fortified samples showing higher values compared to the control (tapioca from 100% cassava starch). The crude fibre contents of substituted samples were significantly ($p<0.001$) different from the control (without coconut residue). The fat contents of the substituted samples differed significantly ($p<0.001$) and ranged from 1.5% to 2.7%. The protein contents for the substituted samples also differed significantly ($p<0.001$) and the values ranged between 4.6% and 10.3%. Substituted samples had values of protein contents higher than that of the control. The carbohydrate content of substituted samples differed significantly ($p<0.05$). The values ranged from 70.6% to 80.3% lower than that of control (83.7%). The energy value contents increased with the increasing addition of defatted coconut to cassava starch. The energy value ranged from 349.7 to 365.6 kcal/100 g and showed that there was a significant ($p<0.05$) difference between the samples. The energy values increased with increasing levels of coconut residue addition into cassava starch.

The mean scores of sensory attributes of tapioca meals prepared from the blends of cassava starch and coconut residue are shown in Figure 2. Sensory attributes profile of tapioca meal prepared from different proportions of cassava starch and coconut residue showed that significant differences existed at $p < 0.01$ for taste and aroma, $p < 0.05$ for the aftertaste, and $p < 0.001$ for smoothness and overall acceptability. Sample blends containing 90% cassava starch with 10% coconut residue was not significant ($p > 0.05$) from the control (100% cassava starch) in terms of taste and smoothness (mouthfeel). Sample blends containing 70% cassava starch with 30% coconut residue was rated highest in terms of aroma (8.7), overall acceptability (8.7) and the most preferred by the panellists to buy (8.6). Whereas the panellists did not detect any aftertaste of coconut after swallowing the sample meal, the perceived aftertaste of coconut was more pronounced in sample 60% cassava starch with 40% coconut residue.

4. DISCUSSION

Bulk density is an indication of the amount of load the flour samples can carry if allowed to rest directly over one another. Bulk density is very important for food (dietary) bulk and packaging requirements (Gbadamosi & Oladeji, 2013). Higher bulk density is desirable for greater ease of dispensability of flours. In contrast, low bulk density would be an advantage in the formulation of infant food (Emelike et al., 2020). The low bulk density values recorded in this study could therefore be advantageous in the preparation of weaning food formulas. Lower bulk density possibly explains that free spaces could exist between the foods after packaging. Adeboye et al. (2019) reported that an increase in bulk density for cassava-almond flour blends could be ascribed to the smaller particle size of the composited samples relative to that of cassava starch. The authors also opined that the substitution led to a freer space in the composite system compared to the 100% cassava starch tapioca sample. Large free space in packaged foods could constitute a large oxygen reservoir which may trigger an oxidation reaction, an undesirable scenario in this case. Lower bulk density in substituted tapioca samples is therefore undesirable because it can result in greater oxygen transmission if the tapioca is packed as food in transit (Adeboye et al., 2019).

Water absorption index is the ability of a matrix of macromolecules at low concentrations to imbibe quantifiable amounts of water (Amin et al., 2021). The water absorption index of substituted samples decreased with an increasing level of coconut residue in the blends. Water absorption index values in this study were higher than those reported for soy-tapioca and cassava-almond blends (Adeboye et al., 2019). Water absorption index is important in foods where water will be imbibed without the dissolution of protein, thus increasing their viscosity and body thickening (Amin et al., 2021). A direct relationship was reported to exist between increasing fibre size and the volume of trapped water (Gao et al., 2020). The decrease in the water absorption index of samples can be attributed to milling operation and thermal treatments given to coconut residue during preparation damaged the fibre chains and reduce their ability to trap water (Zhao et al., 2017). Specifically, mechanical treatments like dry milling can collapse the porous matrix formed by the carbohydrate chains that can trap water (Gao et al., 2020). Coconut residue was reportedly having a higher water absorption index than any other dietary fibre residues, including apple, potato and wheat bran fibres (Raghavendra et al., 2004)

The swelling index of the aqueous suspension of starch is a reflection of the strength of the hydrogen bonding between the granules. The decrease in swelling index of sample substituted with coconut residue could be attributed to the possible formation of amylose lipid complex between the starch components in cassava and residual lipid in coconut residue, this may have reduced water uptake and swelling of the meals during cooking operation (Wokadala et al., 2012). This can be that exposure of the hydrophobic site of denatured protein due to milling and heat treatments might have caused the proteins to repel water from starch granules thereby resulting in low water uptake by the samples (Ogundele et al., 2017). Another likely reason for a decrease in swelling index could be due to the damage done to the fibre matrix during milling or

Table 3
Proximate composition and energy content of fortified tapioca grit/granules from cassava starch with and without coconut residue blends.

Parameters	Tapioca grit products with and without coconut residue					LSD p0.05
	100%CS	90%CS:10%CR	80%CS:20%CR	70%CS:30CR	60%CS:40CR	
Moisture (%)	$10.5^{a}\pm0.1$	$9.5^{b}\pm0.2$	$9.4^{b}\pm0.09$	$9.4^{b}\pm0.1$	$9.5^{b}\pm0.1$	0.0231
Ash (%)	$2.8^{bc}\pm0.1$	$2.8^{b}\pm0.2$	$2.8^{b}\pm0.01$	$3.2^{a}\pm0.1$	$3.3^{a}\pm0.1$	<0.0140
Fibre (%)	$1.1^{d}\pm0.2$	$1.2^{c}\pm0.1$	$1.3^{b}\pm0.01$	$1.5^{b}\pm0.2$	$3.6^{a}\pm0.1$	<0.0012
Fat (%)	$1.4^{c}\pm0.1$	$1.5^{c}\pm0.1$	$1.8^{b}\pm0.02$	$2.6^{a}\pm0.2$	$2.7^{a}\pm0.2$	0.0017
Protein (%)	$0.6^{e}\pm0.1$	$4.8^{d}\pm0.1$	$6.3^{c}\pm0.04$	$8.7^{b}\pm0.1$	$10.3^{a}\pm0.2$	<0.0001
Carbohydrate (%)	$83.7^{a}\pm2.1$	$80.3^{b}\pm1.2$	$78.5^{c}\pm1.5$	$74.6^{d}\pm1.3$	$70.6^{e}\pm1.1$	<0.0164
Energy content (kcal/100 g)	$349.7^{d}\pm5.6$	$354.1^{bc}\pm4.2$	$355.6^{b}\pm6.1$	$357.5^{b}\pm5.3$	$365.6^{a}\pm6.1$	0.0133

Values are means ± standard deviation of replicate (n = 3) determination. Means within the same row with same superscript are not significantly (p>0.05) different from one another using the Fischer-Snedecor's test to verify the equality of the variance.
CS = Cassava Starch, CR = Coconut Residue
100%CS = 100-part of cassava starch without coconut residue, 90%CS+10%CR = 90-part of cassava starch with 10-part coconut residue blends, 80%CS+20%CR = 80-part of cassava starch with 20-part coconut residue blends, 70%CS+30%CR = 70-part of cassava starch with 30-part coconut residue blends, 60%CS+40%CR = 60-part of cassava starch with 40-part coconut residue blends; for the production of tapioca grit products

grinding operation while preparing the samples (section 2.3.2 above). The swelling index of the samples reflects the extent of associative forces within the tapioca; therefore, the lower swelling index of substituted tapioca samples was probably caused by damage to the granules during processing. The swelling index of fibres can have a notable effect on physiological activities (Amin et al., 2021). This is because, a fibre with an increased swelling index could enhance gastrointestinal motility and defecation, thereby helping to prevent stomach constipation (Amin et al., 2021).

Moisture is a measure of the water content in food that could be used as an index of flour storage stability (Bamidele & Fasogbon, 2020). The moisture contents of all the tapioca grit samples were below the 10% recommended standard (SON, 1988) . Generally, the samples with lower moisture content (probably <10%) can be stored longer, which implied that they could have an extended shelf life (Emelike et al., 2020). This is because samples could be less susceptible to mould infestation unlike the unprocessed raw materials (cassava and coconut endosperm). With higher moisture content, activities of micro-organisms like contamination and chemical reaction like oxidation are promoted which often lead to a reduction in food quality and stability (Bello et al., 2021).

Ash content is an indication of mineral elements in food samples remaining after incineration which destroys combustible organic matter (Emelike et al., 2020). Higher ash content in samples with coconut residue probably indicates the presence of inorganic elements that are present in a food as minerals. Higher ash content recorded in the present study agrees with the reports on cookies from wheat-corn-almond with defatted coconut (Makinde & Adeyemi, 2018), tapioca from cassava starch-defatted almond (Adeboye et al., 2019), and cookies from cassava-mungbean with coconut pomace (Bello et al., 2021). The substituted samples in this study could be endowed with minerals.

Food material with more than 3 g dietary fibre/100 g is considered as a 'source of fibre' based on a nutritional claim elsewhere (Anonymous). Since sample blend containing 60% cassava starch with 40% coconut residue with the largest proportion of coconut residue had more than 3 g fibre/100 g (Table 3), then this sample can be tagged "source of dietary fibre" based on the above assumption. Coconut flour has been adjudged as extremely high in fibre with almost twice the amount found in wheat bran (Adeloye et al., 2020). The increase in the crude fibre content of fortified samples recorded in the current study agrees with the recent report by Bello et al. (2021) on the optimization of cookies from cassava-mungbean fortified with coconut pomace. Values of crude fibre obtained in the present study were within the range values (1.45%-3.05%) reported cookies incorporated with coconut pomace powder (Bello et al., 2021) and tapioca fortified (2.09%-2.66%) with defatted almond meal (Adeboye et al., 2019). The increasing crude fibre content reported in the present study with the increasing addition of coconut residue flour could also be considered as a nutritional advantage going by the potential effect of fibre in the digestion of food.

Dietary fat that provides essential fatty acids has been reported to enhance the taste and general acceptability of food products, slow gastric emptying and intestinal motility (Emelike et al., 2020). Cassava flour or starch is reportedly low in lipid content (≈0.60%), therefore the observed increase in fat content in the substituted samples could be attributed to the residual oil present in coconut residue (Adebowale & Komolafe, 2018). Coconut residue processed and used in the present study might contain some amounts of lipids that were not extracted during defatting operation (in section 2.3.2 above) but bound to coconut fibre within the cell wall constituents (Bello et al., 2021). This possibly contributed to the observed increase in fat content of samples containing coconut residue.

An increase in protein contents of substituted samples could be attributed to the progressive increase in the amount of coconut residue substituted for cassava starch. This could be because coconut residue is a better source of protein in the composite blends. The finding from the present study agrees with some previous reports, showing an improvement in the nutritional value of tapioca fortified with defatted or full-fat soybean flour (Adeboye et al., 2019), almond seed flour (Adeboye et al., 2019) and recently in cookies from cassava-mungbean with coconut pomace (Bello et al., 2021). The values recorded in the present study is however higher than those reported for tapioca fortified with defatted almond (Adeboye et al., 2019) and cookies from cassava-mungbean with coconut pomace (Bello et al., 2021). Thus, the present finding is re-affirming and strengthening the potential benefits of plant protein supplementation into starch-dense food materials. Therefore, the protein content and nutritional value of tapioca samples would be improved by the addition of coconut residue due to the complementation in cassava starch.

Naturally, coconut is low in digestible carbohydrates and with no gluten, and so could confer health benefits to the consumers (Trinidad et al., 2003). The reduction in carbohydrate content probably implies that the progressive addition of coconut residue to cassava starch for the production of tapioca grits dilutes the blend and consequently reduce the carbohydrate (starch) content. This is because cassava starch is principally rich in starch than any other component. Again, the present finding agrees with previous and recent reports that showed a reduction in carbohydrate content by substitution with coconut residue and /or coconut pomace (Bello et al., 2021; Kulasekar & Amritkumar, 2018). The energy value contents increased with increasing levels of coconut residue, indicating that coconut residue could have contributed more energy to the samples, possibly from the residual fat.

The addition of coconut residue to cassava starch does not have a noticeable impact or change on the colour of the resulting tapioca meals when compared with the control (100% cassava starch), as evaluated based on the panel's ratings and mean score (Figure 2). No significant difference was observed in some attributes like taste and smoothness between samples containing 90% cassava starch with 10% coconut residue and that of control, which could be that the quantity of coconut residue added was very low level, hence the intensity of the residue was not easily detected. Whereas the panellists could not detect any aftertaste of coconut after swallowing at a lower concentration (10-30%) in the sample meal, coconut aftertaste was easily detectable in sample 60% cassava starch with 40% coconut residue. The aftertaste of coconut perceived in the sample could be attributed to the higher concentration of coconut residue in the sample.

5. CONCLUSION

Fortifying cassava starch with coconut residue (a food waste) improves the nutritional value of tapioca grits in terms of protein and crude fibre contents; and food product (tapioca meal) sensory quality. Sensory panellists show a greater preference for tapioca meal sample containing 70% cassava starch and 30% coconut residue. With an increase in protein and crude fibre contents, a tapioca sample containing coconut residue at 30% has shown that the product has the potential to address protein deficiency and malnutrition. Therefore, food scientists and the stakeholders in the value chain should prioritize sustainability and the reduction of food waste from coconut milk processing. A way to achieve a reduction of its food waste could be through the development of functional food products by incorporating the food waste in convectional snack and bakery food products. This could be another strategy to fulfil the Sustainable Development Goal being orchestrated by FAO of the United Nations fortifying cassava starch with coconut residue (a food waste) could improve the protein content and enhance the value addition of coconut residue in tapioca meals.

CONFLICTS OF INTEREST

The authors declare no conflict of interest.

ORCID

Olalekan Jimi Adebowale 0000-0002-5207-1420

Oluwasegun Oluwagbenga Ajibode 0000-0002-7998-9418

AUTHOR CONTRIBUTIONS

Olalekan J. Adebowale: Investigation, Methodology, Data curation, Formal analysis, Writing – review & editing. Oluwasegun O. Ajibode: Methodology, Writing – original draft.

REFERENCES

Adebowale, O.J., Komolafe, O.M., 2018. Effect of supplementation with defatted coconut paste on proximate composition, physical and sensory qualities of a maize-based snack. Journal of Culinary Science and Technology. 16(1), 40–51. https://doi.org/10.1080/15428052.2017.1315322

Adeboye, A.S., Bamgbose, A., Adebo, O.A., Okafor, D.C., Azeez, T.B., 2019. Physicochemical, functional and sensory properties of tapioca with almond seed (Terminalia catappa) flour blends. African Journal of Food Scinece. 13(8), 182–190. https://doi.org/10.5897/AJFS2018.1739

Adeloye, J.B., Osho, H., Idris, L.O., 2020. Defatted coconut flour improved the bioactive components, dietary fibre, antioxidant and sensory properties of nixtamalized maize flour. Journal of Agriculture and Food Research. 2, 100042. https://doi.org/10.1016/j.jafr.2020.100042

Alebiosu, M.O., Akinbode, B.A., Oni, I.S., Oladele, J.O., 2020. Quality evaluation of cookies produced from wheat , sorghum and defatted coconut flour blends. Asian Food Science Journal. 17(3), 11–21. https://doi.org/10.9734/afsj/2020/v17i330192

Amin, S., Jung, S., Kang, I., Duval, A., 2021. Valorization of baby carrot processing waste. Journal of Culinary Science and Technology. https://doi.org/10.1080/15428052.2021.1879338

AOAC., 2012. Official Method of Analysis of the Association of Analysis Chemist, In: 19th (Eds.); and others, (Eds.). AOAC International, Washington DC.

Bamidele, O.P., Fasogbon, B.M., 2020. Nutritional and functional properties of maize- oyster mushroom (Zea mays-Pleurotus ostreatus) based composite flour and its storage stability. Open Agriculture. 5, 40–49. https://doi.org/10.1515/opag-2020-0007

Bello, F.A., Bassey, V.I., Edet, M.O., 2021. Optimization of cassava, mung bean and coconut pomace flour levels in the production of fibre-rich cookies using response surface methodology. Journal of Culinary Science and Technology. https://doi.org/10.1080/15428052.2020

.1871147
Buys, E.M., Katiyo, W., Olaonipekun, B.A., Agbemavor, S.W.K., Torgby-Tetteh, W., 2020. The Food processing industry and COVID-19. Part I. https://fbreporter.co.za/
Buzigi, E., Pillay, K., Siwela, M., 2020. Caregiver Perceptions and Acceptability of a Provitamin A Carotenoid, Iron and Zinc Rich Complementary Food Blend Prepared from Common Bean and Pumpkin in Rural Uganda. Nutrients. 12(4), 906. https://doi.org/10.3390/nu12040906
Delight, N., Ziphorah, N., Kolanisi, U., Siwela, M., 2021. Effect of Amaranthus leaf powder addition on the nutritional composition , physical quality and consumer acceptability of instant noodles. South African Journal of Botany, 1–7. https://doi.org/10.1016/j.sajb.2021.01.022
Emelike, N.J.T., Achinewhu, S.C., Ebere, C.O., 2020. Nutritional composition, functional and organoleptic properties of breakfast cereals formulated from acha, wheat, cashew kernel and prawn. European Journal of Agriculture and Food Sciences. 2(5), 1–6. https://doi.org/10.24018/ejfood.2020.2.5.112
FAO., 2003. Food energy-Method of analysis and conversion factors. Food and Nutrition paper 77.
Gao, W., Chen, F., Zhang, L., Meng, Q., 2020. Effects of superfine grinding on asparagus pomace. Part I: Changes on physicochemical and functional properties. Journal of Food Science. 85(6), 1827–1833. https://doi.org/10.1111/1750-3841.15168
Gbadamosi, S.O., Oladeji, B.S., 2013. Comparative studies of the functional and physicochemical properties of isolated cassava, cocoyam and breadfruit starches. International Food Research Journal. 20(5), 2273–2277.
Kulasekar, A., Amritkumar, P., 2018. Nutritive analysis of coconut residue-composite bread fermented with lactic acid bacilli (lab) and yeast and cr-gluten-free biscuits. IOSR Journal of Environmental Science, Toxicology and Food Technology. 12(6), 14–21.
Lavenburg, V.M., Rosentrater, K.A., Jung, S., 2021. Extraction methods of oils and phytochemicals from seeds and their environmental and economic impacts. Processess. 9, 1839. https://doi.org/10.3390/pr9101839
Makinde, F.M., Adeyemi, A.T., 2018. Quality characteristics of biscuits produced from composite flours of wheat, corn, almond and coconut. Annals of Food Science and Technology. 19(2), 216–225.
Ogundele, O.M., Minnaar, A., Emmambux, M.N., 2017. Effects of micronization and dehulling of pre-soaked Bambara groundnut seeds on microstructure and functionality of the resulting flours. Food Chemistry. 214, 655–663. https://doi.org/10.1016/j.foodchem.2016.07.022
Raghavendra, S.N., Rastogi, N.K., Raghavarao, K.S.M.S., Tharanathan, R.N., 2004. Dietary fiber from coconut residue: Effects of different treatments and particle size on the hydration properties. European Food Research and Technology. 218, 563–567. https://doi.org/10.1007/s00217-004-0889-2
Samuel, F.O., Otegbayo, B.O., Alalade, T., 2012. Nutrient and anti-nutrient contents of soy-enriched tapioca. Food and Nutrition Science. 3(3), 784. http://dx.doi.org/10.4236/fns.2012.36105
Singh, G.H., Singh, N., 2002. Extrusion behaviour and product characteristics of brown and milled rice grits. International Journal of Food Properties. 5(2), 307–316. https://doi.org/10.1081/JFP-120005787
SON., 1988. Nigeria industrial standard for gari, Standard Organization of Nigeria, 189p.
Trinidad, T.P., Valdez, D.H., Loyola, A.S., Mallillin, A.C., Askali, F.C., Castillo, J.C., Masa, D.B., 2003. Glycaemic index of different coconut (Cocos nucifera)-flour products in normal and diabetic subjects. British Journal of Nutrition. 90(3), 551–556. https://doi.org/10.1079/bjn2003944
Wokadala, O.C., Ray, S.S., Emmambux, M.N., 2012. Occurrence of amylose-lipid complexes in teff and maize starch biphasic pastes. Carbohydrate Polymers. 90(1), 616–622. https://doi.org/10.1016/j.carbpol.2012.05.086
Zhao, Y., Wu, X., Wang, Y., Jing, R., Yue, F., 2017. Comparing physicochemical properties of hawthorn superfine and fine powders. Journal of Food Processing and Preservation. 41(2), e12834. https://doi.org/10.1111/jfpp.12834