PHYSICOCHEMICAL PROPERTIES AND MICROBIAL STABILITY OF COMPOSITE FLOUR PRODUCED FROM RICE AND UNRIPE PLANTAIN FOR *TUWO* PRODUCTION

Abstract

Tuwo shinkafa, a dumpling widely consumed in the northern part of Nigeria, is usually produced from non-parboiled, soft, mashed white rice. With the aim of enhancing its nutritional composition and making it suitable for consumers suffering from diabetes, obesity and other related health issues, the suitability of rice and unripe plantain composite flour for *tuwo* production was examined. Rice and unripe plantain flour were produced and mixed at varying ratios;100:0 (control), 95:5, 90:10, 85:15 and 80:20. The proximate, functional properties and microbial stability of the composite flour and sensory acceptability of the *tuwo* produced were investigated. The ash (0.88-3.76%), fibre (5.63-6.06%), swelling capacity (218.30-236.90%) and water absorption capacity (178.40-194.80%) of the rice-unripe plantain composite flour increased while the packed bulk density (0.18-0.32 g/ml) decreased with increase in the level of plantain flour substitution. The 100% rice flour exhibited the highest ($p < 0.05$) oil absorption capacity (65.83%). Although no bacterial growth was observed on all the fresh flour, the bacterial and fungal counts of the flour increased with increase in the level of plantain flour substitution and also as the storage duration increased. This study revealed that up to 20% unripe plantain flour could be substituted in rice flour for the production of highly nutritive, wholesome and acceptable *tuwo shinkafa*, though 10% substitution is recommended based on the sensory ratings.

Keywords: Unripe plantain flour, food safety, microbial stability, physicochemical properties, acceptability, rice flour, *tuwo shinkafa*

INTRODUCTION

Tuwo shinkafa is a popular meal in the northern part of Nigeria from where it is believed to have originated. It is usually made by mixing non-parboiled, soft, sticky white rice flour with boiling water and stirred until a smooth consistency gel is formed. This gel, moulded into a spherical shape, is usually consumed with accompaniment (Falade and Christopher, 2015) including soups such as *miyan kuka*. Rice (*Oryza sativa)* is a cereal of great importance in both developing and developed worlds. It is a semi-aquatic, annual grass plant which has been reported to contain substantial amount of carbohydrate, vitamins such as thiamine, niacin and riboflavin, minerals and little amount of protein and fat (Fresco, 2005; Umadevi et al., 2012). It is also gluten and cholesterol free. Oko et al. (2012) showed that rice contained substantial amount of calcium, magnesium and phosphorus with little quantities of iron, copper, zinc and manganese. Rice is being regarded as the queen among cereals owing to its relatively good nutritional quality and digestibility (Anjum et al, 2007). Freshly harvested rice grains contain about 80% carbohydrate which is made up of starch, glucose, sucrose and dextrin (Verma and Srivastav, 2017).

Rice is grown in all the ecological zones of Nigeria, with different varieties possessing adaptation traits suited to each ecological zone (Sanni et al., 2005). In Nigeria, *Oryza sativa* (Asian rice) and *Oryza glaberrima* (African rice) are the two commonly cultivated varieties of rice out of which *O. sativa* is the most widely cultivated (Abulude, 2004; Adeyemi et al., 1986). *Ofada* rice is the most cultivated rice in Nigeria especially in the South-western agro ecological zone and annual production of rice in Nigeria was estimated at about 3 million tonnes (Adebowale et al., 2010). The production and consumption of rice as a major dietary source of energy is at large in Nigeria and the use of rice flour as a staple food is on the increase worldwide. This staple food provides 700 calories/day-person for about 3000 million people of the world's population (Vlachos and Arvanitoyannis, 2008). Despite the nutritional value and worldwide consumption of rice and its products, its relatively high glycemic index which poses major threats to diabetics and dieters, is an impediment to its utilization.

Plantain (*Musa paradisiaca AAB*) is a popular dietary monocotyledonous perennial and most important staple crop in the tropical and sub-tropical regions of the world after rice, wheat and maize (Baiyeri et al., 2011; Kawongolo, 2013). It is a highly perishable climacteric fruit which when harvested at the mature but unripe stage ripens within two to seven days (Abiodun-Solanke and Falade, 2011). It is a source of essential nutrients and income for many households around the world including those in sub-Sahara Africa (Kawongolo, 2013) and Africa contributes over 12 million metric tons to the over 12 million metric tons annual world production of plantain. Nigeria is the biggest producer of plantains in West Africa with an estimated production of about 2,722,000 metric tons in 2009, majority of which were produced and harvested from the southern part of the country, with an average consumption level of 190 kg/person/year (FAO, 2009; 2011).

Unripe plantain is well recognised for its richness in dietary fibre, resistant starch, vitamins and minerals with low quantities of protein and fat (Ayodele and Erema, 2010; Baiyeri et al., 2011; Agu and Okoli, 2014; Karim et al., 2020). Unripe plantain products have been reported to exhibit low glycemic index and blood glucose response (Ayodele and Erema, 2010). This indicates that unripe plantain diets would be ideal for diabetics, dieters and pregnant women. The dietary management of diabetes, obesity and other related health challenges could therefore be achieved through consumption of diets containing plantain flour. The inclusion of plantain flour in food formulation will not only improve the nutrients intake of the consumers but will also enhance the utilization of plantain and create varieties in human diet. Previously, a study has reported the production of acceptable dumpling dough from *ofada* rice and unripe plantain flour with appropriate dietary fibre ratio, cholesterol reduction and low weight gain potentials (Arueya and Akande, 2018) but existing gap relating to the keeping quality of the developed flour blends and acceptability of the final product still exists in the literature. Consequently, this study was designed to determine the effect of partial substitution of unripe plantain flour on the physicochemical properties and microbial stability of rice flour as well as to evaluate the sensory acceptability of cooked paste or dumpling (*tuwo shinkafa*) produced from the composite flour.

MATERIALS AND METHODS

Materials

Local rice (*ofada funfun/ Oryza sativa L.*) and fresh matured unripe plantains (*Agbagba*) at stage 1 of ripening (Aurore et al., 2009) were purchased at Oja-oba market in Ilorin and carefully transported to laboratory of the Department of Home Economics and Food science, University of Ilorin, Nigeria for processing. All chemicals and the equipment used were of analytical grade.

Rice flour production

The method of Ogunlakin et al. (2014) was adopted with little modification. The local rice was sorted, washed and cleaned. The cleaned rice was conditioned for 5 minutes and oven dried at 60^0C for 4 hours. The dried rice was milled, cooled, sieved through 100 mesh sieve and packaged in polyethylene bag.

Unripe plantain flour production

Plantain flour was produced according to Yarkwan and Uvir (2015) with little modification. Fingers were picked and washed in a bowl of portable water to remove the latex and avoid darkening of the pulp during peeling. The washed fingers were peeled and then sliced in thin slices of about 5.0 mm thick using a stainless steel knife. The slices were oven-dried at 60^0C for 24 hours after which they were cooled, milled, sieved into fine flour using a mesh net of about 0.2 mm mesh size and then packaged in polyethylene bag.

Formulation of composite flour

Composite flour for *tuwo* production was formulated from rice and unripe plantain flour as shown in Table 1.

Table 1: Formulation of rice and unripe plantain composite flour

Sample	Rice flour (%)	Unripe plantain flour (%)
$R_{100}P_0$	100	0
$R_{95}P_5$	95	5
$R_{90}P_{10}$	90	10
$R_{85}P_{15}$	85	15
$R_{80}P_{20}$	80	20

Proximate composition of rice-unripe plantain composite flour

The moisture, dry matter, ash and crude fibre contents of the flour samples were evaluated using standard methods (AOAC, 2005). Briefly, oven drying method at 105 ^{o}C for 5 hours for moisture evaluation, dry matter was obtained by subtracting the percentage moisture content from hundred, total ash determination by igniting 2 g of each sample at 550 ^{o}C for 4 hours using muffle furnace and crude fibre was determined using digestion method.

Functional properties of rice-unripe plantain composite flour

Packed bulk density

Five grams (5 g) of each sample was weighed into a 25 mL graduated measuring cylinder. The cylinder was gently tapped on the laboratory table several times until there was no further diminution of the sample level. The volume of the sample was taken and the tapped bulk density was calculated thus (Onwuka, 2005);

$$Packed\ bulk\ density\ (g/ml) = \frac{Weight\ of\ sample}{Volume\ of\ sample\ after\ tapping}$$

Swelling capacity

The method described by Ukpabi and Ndimele (1990) was used with modifications for the determination of swelling capacity of the rice-plantain composite flour. Five grams of flour sample was transferred into a 50 mL graduated measuring cylinder. The sample was gently levelled by tapping the cylinder and the initial volume was recorded. Fifty millilitre of distilled water was poured into the cylinder. The cylinder was covered, inverted for proper mixing and then allowed to stand for 4 hours. The swelling capacity was taken as the percent multiple of the initial volume.

Water and oil absorption capacity

The method of Sosulski et al. (1976) was adopted in determining the water and oil absorption capacity of the flour. One gram of flour sample was mixed with 10 mL distilled water or 10 mL refined soybean oil (specific gravity, 0.9092) in a 50 mL centrifuge tube for water and oil absorption capacity, respectively. The mixture was allowed to stand at room temperature for 30 min and then centrifuged at 2000 ×g for 30 min. The percentage water or oil bound per gram flour was recorded as the water and oil absorption capacity, respectively.

Storage and microbial analysis of rice–unripe plantain composite flour

Microbial analysis was carried out on each flour sample. Then, a portion of each flour samples was transferred into different polyethylene bags and stored at room temperature (27 ± 2 ◦C) for 8 weeks during which microbial analysis was being carried out fortnightly.

The total viable bacterial and fungal counts of the flour were investigated using pour plate method (Aruwa and Akinyosoye, 2015). One gram of each flour sample was aseptically weighed and mixed with 9 mL of sterilized distilled water in a test tube. One millilitre of each suspension was taken for serial dilution (10^{-2} and 10^{-4}) and 1 mL aliquots were inoculated into sterile Petri dishes containing nutrient agar and potato dextrose agar, which have been prepared according to the manufacturers' instructions, for the enumeration of total bacteria and fungi, respectively. The nutrient agar's plates were incubated at 37◦C for 24 hours while potato dextrose agar plates were incubated at room temperature (26 ± 2◦C) for 3–5 days. The colonies were then counted using the Stuart scientific colony counter and expressed as colony forming units per gram (cfu/g) of flour.

Preparation and sensory acceptability of *tuwo shinkafa* produced from rice-unripe plantain composite flour

The method described by Bolade et al. (2002) for production of maize *tuwo* was adopted for the preparation of rice-plantain *tuwo shinkafa*. The overall ratio of flour to water used was 1:3.5 (w/v). Twenty five percent (25%) of the water was initially mixed with 20% of the measured flour to form slurry. Sixty percent of the measured water was heated to boiling point and the initially-prepared flour slurry was gradually added to the boiling water with continuous stirring until a gel-like consistency was obtained. The remaining flour (80%) was then added gradually to the boiling gel-like mass, with continuous stirring, until a satisfactory gel was obtained. The last quantity of water (15%) was added to the gel and covered for about 5 min without stirring (for effective cooking). It was vigorously stirred again and ready to be served. The resulting rice-based final product obtained is termed *tuwo shinkafa*.

The sensory qualities of *tuwo shinkafa* produced from rice and plantain composite flour were evaluated using multiple comparison test (Akeem et al., 2023). The acceptability of the products in terms of colour, taste, mouldability, aroma, texture and overall acceptability was assessed by 30 untrained panellists comprising of students and members of staff of University of Ilorin, based on a 9-point hedonic preference scale (1 = dislike extremely, 2 = dislike very much, 3 = dislike moderately, 4 = dislike slightly, 5 = neither like nor dislike, 6 = like slightly, 7 = like moderately, 8 = like very much and 9 = like extremely). Drinkable water was provided for the panellists to rinse their mouths after evaluating each randomly presented coded sample.

Statistical analysis

All experiments were conducted in triplicates except where it is stated otherwise. The data were subjected to one-way analysis of variance (ANOVA) and significant difference among means was determined by Duncan's multiple range test ($p < 0.05$) using SPSS software version 15.0 (SPSS Inc., Chicago, IL).

RESULTS AND DISCUSSION

Proximate composition of rice-unripe plantain composite flour

The influence of partial substitution of rice flour with unripe plantain flour on the moisture, dry matter, ash and fibre contents is shown in Table 2. Moisture content is an important quality attribute on which the shelf stability and microbial growth susceptibility of any food depend. The moisture content of the flour blends ranged from 7.59-8.79% for 5% and 10% unripe plantain flour substituted samples, respectively. Although significant ($p < 0.05$) difference existed between 100% rice flour and the unripe plantain flour substituted samples, the moisture contents of all the flour samples were below 10%. The low moisture content obtained for the flour samples in this study agreed with the recommended standard of SON (2007) which stated that long term safe keeping of flour require the moisture level to be below 10%. This implied that the flour samples could be stored for a long time without biochemical or microbial deterioration. The solid component of the flour samples ranged between 91.21% and 92.41% for 10% and 5% unripe plantain flour substituted samples, respectively. Substitution of unripe plantain flour (5-20%) in rice flour significantly ($p < 0.05$) affected the dry matter content of the flour blends.

The ash content recorded for100% rice flour was 0.88% and this was observed to increase significantly ($p < 0.05$) with increase in the level of unripe plantain flour substitution. The ash content obtained for 100% rice flour was similar to 0.80% reported by Juliano and Bechtel (1985), mean value of 0.99% reported for 20 rice varieties (Oko et al., 2012) and fell within the range of 0.39-0.90% reported for six rice varieties marketed in Penang Island, Malaysia (Thomas et al., 2013). The increment in ash content of unripe plantain flour substituted samples could therefore be attributed to high ash content of plantain flour. This is plausible since ash content as high as 5.44% has been reported for oven-dried unripe plantain flour (Yarkwan and Uvir, 2015). Ash content is a nutritional component that reflects the total amount of inorganic matter or mineral composition of food. Previous studies had shown that plantain contained high amount of essential minerals such as potassium, calcium, phosphorus and iron, and various vitamins such as A, B_1, B_2 and C (Chandler, 1995; Karim et al., 2020). The inclusion of unripe plantain flour in rice flour could therefore be employed as a strategy to tackle micronutrients deficiency in both developing and developed countries.

The crude fibre content (5.63-6.06%) of the flour samples generally increased with increase in the level of unripe plantain flour substitution, though significant ($p > 0.05$) differences were only recorded after 10%, 15% and 20% substitution levels. This increment could be due to the high fibre content (10.11%) of the oven-dried unripe plantain flour as reported by Yarkwan and Uvir (2015). Dietary fibre is a functional nutritional component of great importance in human diet due to its ability to increase faecal output, lower risk of bowels disorders, faecal pH, blood pressure and reduce incidence of colon cancer, coronary heart disease, stroke, diabetes, obesity, blood pressure as well as certain gastrointestinal diseases (Anderson et al., 2009).

Table 2: Proximate composition of rice-unripe plantain composite flour

Sample	Moisture (%)	Dry matter (%)	Ash (%)	Fibre (%)
$R_{100}P_0$	7.91^{c}	92.09^{b}	0.88^{e}	5.63^{d}
$R_{95}P_5$	7.59^{d}	92.41^{a}	1.64^{d}	5.64^{d}

$R_{90}P_{10}$	8.79^{a}	91.21^{d}	2.14^{c}	5.72^{c}
$R_{85}P_{15}$	8.03^{b}	91.97^{c}	3.20^{b}	5.86^{b}
$R_{80}P_{20}$	7.60^{d}	92.40^{a}	3.76^{a}	6.06^{a}

Values are means of triplicate determinations. Means with the same superscript along the same column are not significantly ($p > 0.05$) different.

$R_{100}P_0$ = 100% rice flour; $R_{95}P_5$ = 95% rice flour + 5% unripe plantain flour; $R_{90}P_{10}$ = 90% rice flour + 10% unripe plantain flour; $R_{85}P_{15}$ = 85% rice flour + 15% unripe plantain flour; $R_{80}P_{20}$ = 80% rice flour + 20% unripe plantain flour

Functional properties of rice-unripe plantain composite flour

The packed bulk density (0.18-0.32 g/ml), swelling capacity (218.30-236.90%), water (178.40-194.80%) and oil (62.84-65.83%) absorption capacities of rice-unripe plantain composite flour are presented in Table 3. Substitution of unripe plantain flour (5-20%) in rice flour resulted in significant ($p < 0.05$) decrease in packed bulk density of the flour blends. Similar trends have been reported for the bulk density of wheat-plantain flour (Ogunlakin et al., 2014), wholemeal wheat-unripe plantain flour (Inyang and Asuquo, 2016), plantain-tigernut flour (Adegunwa et al., 2017) and *ofada* rice-plantain flour (Arueya and Akande, 2018), indicating higher particle compactness of plantain flour. Bulk density of a food material is essential in determining material handling, packaging requirement and food applications (Adebowale et al., 2008) since it depends on individual particle's mass, size, property, density and geometry (Kolawole et al., 2016). The lower bulk density of unripe plantain flour substituted samples could be advantageous in the formulation of complementary foods as postulated by Akpata and Akubor (1999).

The swelling capacity and water absorption capacity of the composite flour generally increased with increase in the level of unripe plantain flour substitution. This was similar to the report of Inyang and Asuquo (2016) for wholemeal wheat and unripe plantain composite flour. Arueya and Akande (2018) also observed increase in swelling capacity with increase in the levels of plantain substitution in *ofada* rice. Swelling capacity is associated with binding within the starch granules of the micelle network (Kolawole et al., 2016) and the increment in swelling capacity of the unripe plantain flour substituted samples could be due to lower amylose and higher amylopectin content of plantain flour compared to rice flour.

Water absorption capacity reflects the ability of a food material to associate with water under limited water condition with the aim of improving handling (Giami and Bekebian, 1992). Similarly, increase in water absorption capacity with increase in plantain flour substitution in wholemeal wheat flour (Inyang and Asuquo, 2016) and tigernut flour (Adegunwa et al., 2017) have been reported by previous researchers. The increment in water absorption capacity of unripe plantain flour substituted samples might be associated with presence of hydrophilic amino acids, dietary fibre and low amylose to amylopectin ratio in the unripe plantain flour. The higher water absorption capacity obtained for the rice-unripe plantain composite flours suggested that they would be very useful for aqueous food formulation such as bakery products which need proper hydration.

The oil absorption capacity of the composite flour decreased disproportionately with increase in the level of substitution of unripe plantain flour. The decrease in oil absorption capacity of the flour blends following incorporation of plantain flour was similar to the observation of Inyang and Asuquo (2016) on wholemeal wheat-plantain composite flour. The oil binding capacity of a food material is an indicator of its ability to absorb and retain oil, which consequently affects the flavour, mouthfeel, palatability and shelf life of food products such as bakery, soup mixes or meat products where fat absorptions are desired (Seena and Sridhar, 2005). The differences in oil binding capacity could be as a result of variations in the presence of non-polar side chains, which might bind the hydrocarbon side chains of oil among the flours (Adebowale and lawal, 2004).

Table 3. Functional properties of rice-unripe plantain composite flour

Sample	Packed bulk density (g/ml)	Swelling capacity (%)	Water absorption capacity (%)	Oil absorption capacity (%)
$R_{100}P_{0}$	0.32 ± 0.00^{a}	218.30 ± 0.35^{c}	178.40 ± 0.27^{c}	65.83 ± 1.32^{a}
$R_{95}P_{5}$	0.26 ± 0.00^{b}	219.70 ± 0.60^{bc}	184.80 ± 2.91^{b}	62.84 ± 2.0^{ab}
$R_{90}P_{10}$	0.22 ± 0.00^{c}	230.10 ± 3.36^{abc}	189.20 ± 4.06^{ab}	65.19 ± 1.18^{ab}
$R_{85}P_{15}$	0.21 ± 0.00^{d}	233.50 ± 2.37^{ab}	189.30 ± 1.11^{ab}	63.25 ± 0.76^{ab}
$R_{80}P_{20}$	0.18 ± 0.00^{e}	236.90 ± 11.50^{a}	194.80 ± 0.30^{a}	63.93 ± 2.27^{ab}

Values are means of triplicate determinations ± SD. Means with the same superscript along the same column are not significantly ($p > 0.05$) different.

$R_{100}P_{0}$ = 100% rice flour; $R_{95}P_{5}$ = 95% rice flour + 5% unripe plantain flour; $R_{90}P_{10}$ = 90% rice flour + 10% unripe plantain flour; $R_{85}P_{15}$ = 85% rice flour + 15% unripe plantain flour; $R_{80}P_{20}$ = 80% rice flour + 20% unripe plantain flour

Microbial stability of rice-unripe plantain composite flour

Food safety, acceptability, shelf stability and fitness for consumption depend largely on its microbial stability. The total bacterial and fungal counts of rice-unripe plantain composite flour during 8 weeks storage are shown in Tables 4 and 5, respectively. No bacterial growth was observed on the fresh flour samples. After two weeks of storage, bacterial growth (1.0 - 2.30 × 10^4 cfu/g) was recorded for the flour samples and this growth was observed to increase with increase in the level of unripe plantain flour substitution and storage time up to the 8 weeks storage period (2.20 - 3.50 × 10^4 cfu/g). The result was similar to that of Oviasogie *et al.* (2016) who reported that the total bacterial count (cfu/g) of all wheat-plantain flour increased with increasing level of plantain flour during the nine weeks period of storage. High bacteria counts could be an indication of potential health hazards and food spoilage.

The fungal count of the rice-unripe plantain flour samples varied between 2.00 × 10^4 cfu/g and 4.60 × 10^4 cfu/g within the 8 weeks of storage. Similar to bacterial count, the fungal count of the composite flour increased with increase in the level of unripe plantain flour substitution and storage time. This result was also similar to that of Oviasogie *et al.* (2016) who reported increase in the fungal growth with increasing levels of plantain flour substitution and storage time. These implied that substitution of unripe plantain flour in rice flour enhance the susceptibility of the resulting composite flour to microbial contamination and growth. The rapid microbial proliferation on the flour samples could be attributed to nutrient availability and favourable micro-environment with resultant recovery of homeostatic imbalance (Ogbulie et al., 1993). Fungal growth has been associated with the formation of heat stable mycotoxins which is a major concern for food quality and safety (Dalié et al., 2010, Tang et al., 2019).

Table 4: Total bacterial count of rice-unripe plantain composite flour during 8 weeks storage period

Sample	Week 0 (× 10^4 cfu/g)	Week 2 (× 10^4 cfu/g)	Week 4 (× 10^4 cfu/g)	Week 6 (× 10^4 cfu/g)	Week 8 (× 10^4 cfu/g)
$R_{100}P_0$	-	1.0	1.6	2.0	2.2
$R_{95}P_5$	-	1.4	1.8	2.3	2.6
$R_{90}P_{10}$	-	1.8	2.0	2.5	2.9
$R_{85}P_{15}$	-	2.0	2.2	2.7	3.1
$R_{80}P_{20}$	-	2.3	2.6	3.0	3.5

$R_{100}P_0$ = 100% rice flour; $R_{95}P_5$ = 95% rice flour + 5% unripe plantain flour; $R_{90}P_{10}$ = 90% rice flour + 10% unripe plantain flour; $R_{85}P_{15}$ = 85% rice flour + 15% unripe plantain flour; $R_{80}P_{20}$ = 80% rice flour + 20% unripe plantain flour

Table 5: Total fungal count of rice-unripe plantain composite flour during 8 weeks storage period

Sample	Week 0 (× 10^4 cfu/g)	Week 2 (× 10^4 cfu/g)	Week 4 (× 10^4 cfu/g)	Week 6 (× 10^4 cfu/g)	Week 8 (× 10^4 cfu/g)
$R_{100}P_0$	2.0	2.2	2.6	2.8	3.4
$R_{95}P_5$	2.3	2.5	2.9	3.2	3.8
$R_{90}P_{10}$	2.5	2.7	3.2	3.6	4.0
$R_{85}P_{15}$	2.7	3.0	3.5	3.9	4.2
$R_{80}P_{20}$	3.0	3.3	3.6	4.2	4.6

$R_{100}P_0$ = 100% rice flour; $R_{95}P_5$ = 95% rice flour + 5% unripe plantain flour; $R_{90}P_{10}$ = 90%

rice flour + 10% unripe plantain flour; $R_{85}P_{15}$ = 85% rice flour + 15% unripe plantain flour; $R_{80}P_{20}$ = 80% rice flour + 20% unripe plantain flour

Sensory characteristics of rice-unripe plantain *tuwo shinkafa*

Table 6 shows the mean scores for colour (5.33-7.73), taste (5.63-6.53), mouldability (6.13-6.73), aroma (4.90-6.87), texture (5.67-6.53) and overall acceptability (5.87-7.33) of rice-unripe plantain *tuwo shinkafa* based on the panellists' perceptions. The unripe plantain flour substituted *tuwo shinkafa* compared favourably with 100% rice *tuwo shinkafa* in terms of taste, mouldability, aroma, texture and overall acceptability. It was observed that while the mean scores for the colour of unripe plantain flour substituted *tuwo shinkafa* samples significantly ($p < 0.05$) decreased, their mouldability and aroma were generally enhanced. Colour is an important quality index which influences consumer's choice, preference and acceptability of food products (Akeem et al., 2018). The perceived low colour quality of the unripe plantain flour substituted *tuwo shinkafa* samples by the panellists might be due to the colour of the unripe plantain which was physically observed to be yellowish compared to the whitish colour of the rice they are familiar with. The increased mouldability of the unripe plantain flour substituted *tuwo shinkafa* samples might by due to the relatively higher amylopectin to amylose ratio of unripe plantain flour compared to 100% rice flour. Mouldability is a unique characteristic of food that enhances its swallowability at the point of consumption (Bolade and Adeyemi, 2014). Aroma is an integral part of taste and general acceptability of food. The general increase in aroma of the composite flour *tuwo shinkafa* perceived by the panellists as the level of substitution of unripe plantain flour increased might be due to the characteristic flavour of the plantain flour. This is plausible since plantains are known to have high starch content and characteristic flavour which change with acid composition during ripening (Falade and Oyeyinka, 2015). The decision to swallow or chew a food depends on its textural characteristics. No significant difference existed among the mean sensory scores obtain for the texture of *tuwo shinkafa* samples. The 10% unripe plantain substituted *tuwo shinkafa* received the highest ($p < 0.05$) overall acceptability score (7.33) among the samples. This shows that up to 20% unripe plantain could be substituted in rice flour for the production of acceptable *tuwo shinkafa* since none of the sensory qualities of the unripe plantain *tuwo shinkafa* was rated below 5 (neither like nor dislike). However, based on mean sensory ratings, 10% unripe plantain flour is recommended for substitution in rice flour for the production of *tuwo shinkafa*.

Table 6: Mean sensory scores of rice-unripe plantain *tuwo shinkafa*

Sample	Colour	Taste	Moudability	Aroma	Texture	Overall acceptability
$R_{100}P_0$	7.73±1.02^{a}	6.53±1.36^{a}	6.13±1.91^{ab}	4.90±1.31^{c}	6.53±1.63^{a}	6.27±1.09^{bc}
$R_{95}P_5$	6.80±0.81^{b}	6.50±1.31^{a}	6.27±1.05^{a}	5.20±1.10^{c}	6.23±1.55^{a}	6.53±1.25^{b}
$R_{90}P_{10}$	5.67±1.42^{c}	6.37±1.43^{ab}	6.40±1.19^{a}	5.97±1.30^{b}	5.83±1.58^{a}	7.33±1.05^{a}
$R_{85}P_{15}$	5.33±1.24^{c}	5.67±1.37^{b}	6.47±1.07^{a}	5.97±1.38^{b}	5.73±1.39^{a}	5.97±1.04^{bc}
$R_{80}P_{20}$	5.50±1.38^{c}	5.63±1.50^{b}	6.73±1.20^{a}	6.87±1.21^{a}	5.67±1.77^{a}	5.87±1.30^{c}

Values are means of thirty determinations ± SD. Means with the same superscript along the same column are not significantly ($p > 0.05$) different

$R_{100}P_0$ = 100% rice flour; $R_{95}P_5$ = 95% rice flour + 5% unripe plantain flour; $R_{90}P_{10}$ = 90% rice flour + 10% unripe plantain flour; $R_{85}P_{15}$ = 85% rice flour + 15% unripe plantain flour; $R_{80}P_{20}$ = 80% rice flour + 20% unripe plantain flour

CONCLUSION

Substitution of unripe plantain flour in rice flour enhanced the nutritional value (ash and fibre) and some functional properties (swelling capacity and water absorption capacity) of the flour blends. The microbial analysis showed increase in bacterial and fungal counts with increase in unripe plantain flour substitution and storage period. Thus, there may be need for the use of effective packaging materials to control microbial growth during long term storage of rice-unripe plantain flour blends. This study revealed that unripe plantain flour up to 20% could be substituted in rice flour for the production of highly nutritive, wholesome and acceptable *tuwo shinkafa*, though 10% substitution is recommended based on the sensory ratings.

Ethics

The study proposal was presented and then approved by the Research and Ethical committee of the Department of Home Economics and Food Science, University of Ilorin, Nigeria. The assessors are regular consumers of *tuwo shinkafa* (rice dumpling) and they gave their informed consent to participate in the sensory evaluation.

AUTHOR DISCLOSURE STATEMENT

The authors declare no conflict of interest.

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