FORTIFICATION OF CASSAVA STARCH WITH TIGER NUT RESIDUE AND DATE PALM FRUIT: EFFECT ON THE FUNCTIONAL, PROXIMATE AND SENSORY PROPERTIES OF TAPIOCA MEALS.

Salawu S. A. & Ajibode, O. O.

Department of Food Technology, the Federal Polytechnic Ilaro, Ogun State.

ABSTRACT

This study investigated the functional, proximate, and sensory characteristicproperties of tapioca fortified with tigernut residue and date palm fruit. Five sample formulations were prepared with varying amounts of cassava starch, tigernut residue, and date fruit, and each sample was analysed for moisture, protein, fat, fibre, carbohydrate content, water absorption, bulk density, swelling power, dispersibility and pasting properties. The results of the proximate analysis ranged from 3.78 to 10.15%, 7.05 to 8.24%, 1.84 to 2.46%, 4.85 to 6.80%, 13.70 to 17.21% and 59.20 to 66.09% for moisture, crude fat, total ash, fibre, protein and carbohydrates respectively. Functional properties analysis shows significant increase in the water absorption capacity and bulk density of tapioca enriched with tigernut residue and date palm fruit. The favourably pasting properties of the enriched tapioca makes sample suitable for thickening applications. Tapioca produced from 60% cassava starch, 25% tigernut, and 15% date palm fruit received highest sensory scores for taste and colour, indicating strong consumer preference. These findings support the addition of tigernut and date fruit as functional ingredients in tapioca to enhance nutritional and sensory quality. Enriched tapioca formulations offer a nutritious alternative to conventional starch products, meeting consumer demand for health-conscious and versatile food options. In conclusion, tigernut and date additions make tapioca a more nutritious and appealing product with broader applications in the food industry.

Key words: Food waste, Tapioca, Cassava starch, Tiger nut residue

1.0 INTRODUCTION

Cassava (*Manihot esculenta Crantz*), a staple root crop grown predominantly in tropical and subtropical regions around the world, is becoming a vital source of carbohydrates for over 500 million people globally, particularly in Africa (Olatunde & Adeciyan, 2021). Cassava has proven to be a sustainable crop in the face of unpredictable weather patterns and socio-political challenges due to its adaptability to poor soil, resistance to drought, versatility and resilience, serving as a critical food security crop in many regions. However, cassava's high post-harvest losses due to its perishable nature is limiting its overall economic and nutritional benefits in Nigeria. Tapioca is widely known and acceptable cassava product in many parts of Africa. It is rudimentarily processed at household level but large scale production of high-quality tapioca products is potentially feasible (Sengar, 2022).

Tapioca, derived from cassava starch, is a quick-cooking meal usually consumed as breakfast meals, snacks and other delicacies, particularly in Africa and Southeast Asia (Irungu *et al*., 2018). It is a convenient, storable, and nutritious food source. Fortification of cassava products such as tapioca and other starch derivatives with nutritional and therapeutic food ingredients can increase cassava's utilization. Hence, increasing the economic returns from cassava farming, reduce postharvest losses, and create new market opportunities (Adeniyi, 2022).

Tiger nut (*Cyperus esculentus*) is rich in carbohydrates, protein, vitamins C and E, and high-quality oil, and have applications in both food and non-food industries. These crops offer immense potential for improving food security and nutrition, particularly in Africa, where they remain underutilized (Cock, 2019). Tigernut residues are high nutrients food waste obtained after tiger nut milk extraction.

Scientific studies support its use in food products such as snacks, beverages, and flour-based products because of its superior nutritional profile (Agu et al., 2023; Nwakalor, 2024; Oladunjoye & Alade, 2024). Tiger nuts remained underused in food production and commercial applications because they contain high-quality oil and valuable nutrients. Their application remains limited to traditional consumption methods like raw or roasted nuts because food systems have not made significant efforts to integrate them.

The Nigerian "Debino" fruit of the date palm contains glucose and fructose natural sugars which serve as an excellent energy source. The fruit provides substantial amounts of fiber and essential nutrients including vitamins and antioxidants which boost its nutritional profile (Maqsood et al., 2020).

Processed foods can use date palm fruits as a natural sweetener alternative because of their high sugar levels and nutritional benefits. The market opportunity for date palm-based products grows due to rising demand for healthy food options among diabetic individuals and health-aware consumers who seek low-glycemic alternatives. Health-conscious consumers can benefit from date palm as a replacement for refined sugars in processed foods according to Eke-Ejiofor (2019). Despite the significant potential of date palm and tiger nut alongside cassava there exists a considerable gap in their utilisation for value-added products.

Cassava, though widely grown and consumed, is often underused in its most nutritious forms. Furthermore, crops like date palm and tiger nuts, which are rich in essential nutrients, remain largely underexploited. The potential of cassava, date palm, and tiger nuts to contribute to food security and economic development remains poorly exploited, hence the need for this research to evaluate the functional, proximate, and sensory characteristics of tapioca from cassava starch fortify with tiger-nut and date palm fruits using different proportions.

MATERIALS AND METHODS

Source of Materials

Freshly harvested cassava roots were sourced from a farm settlement in Oja-Odan, Yewa North Local Government, Ogun state. Tiger-nut tubers and dates palm fruits were purchased from Sayedero Market in Ilaro, Ogun state. Analytical qualified reagents and equipment were used for all analyses.

Methods

Production of Cassava Starch

Cassava starch was produced employing the method described by Thuppahige *et al.* (2023). Fresh cassava roots were thoroughly washed to remove dirt and the outer parts were peeled off. After peeling, the roots were washed and cut into small sizes for easy grating. The cassava roots were poured into a grater and grated until smooth pulp was obtained. It was poured into a bowl and water was added and mixed thoroughly. After it was mixed it was poured into a muslin cloth in order to filter off the fibers. The resulting filtrate was poured into a container and allowed to settle for 2 hours. Water was decanted off from the starch. The starch was then rewashed with portable water, allowed to settle and thereafter the supernatant was decanted. The starch was drained using muslin cloth to 25% moisture content before packed into a ziplock pack.

Production of tiger-nut residue

Tiger nut residues were produced adopting the method described by Senya *et al.* (2021). Tigernut tubers were sorted and thoroughly washed with clean water to remove soil, dirt and other contaminants. The cleaned tigernut tubers were crushed using a high-speed blender until they formed a fine, thick paste. The blended mixture was then sieved to separate the liquid extract from the fibrous residue. The resulting tiger nut residue was spread on trays and placed in a cabinet dryer set to 60 °C, where it dried for 12 hours. The dried tiger nut residues were hammer milled and sieved through 100 µm screen.

Production of date palm flour

The date fruits were first deseeded by hand (the seeds were removed manually). The deseeded dates were then arranged on trays and dried in the cabinet dryer at 60°C for 8 hours, ensuring less than 10 % moisture content. After drying, the dates were ground into a fine powder and sieved through 100 µm screen for uniformity in particle size. The entire process was carried out as described by Rambabu *et al.* (2020).

Product Formulation and Production of Tapioca

Moist cassava starch, tiger nut residue and date palm flour were each weighed according to the specified formulation ratios as shown in Table 1. These ingredients were thoroughly blended in a mixing bowl. The mixture was roasted using an electrically powered rotary dryer for 20 minutes at 100 ^{O}C. The production of pre-gelatinized starch (Tapioca) was ensured by turning off the fan in the rotary dryer for the first 10 minutes of roasting the mixture. Then the partially gelatinized starch was dried by turning on the fan of the rotary dryer (Adebowale *et al*., 2008).

Table 1: Tapioca Formulations

Sample	Cassava Starch	Tiger-nut Residue	Date Palm Flour
T_{100}	100	0	0
$T_{70}R_{30}D_{0}$	70	30	0
$T_{65}R_{30}D_{5}$	65	30	5
$T_{60}R_{30}D_{10}$	60	30	5
$T_{60}R_{25}D_{15}$	60	25	15

ANALYSES

Proximate Analysis

The proximate composition of samples was analysed for moisture, ash, fat, protein and crude fibre using the standard and recommended methods of Association of Official Analytical Chemist (AOAC, 2018).

Pasting properties

The pasting properties of the samples was carried out using a Rapid Visco Analyser (RVA) (Model RVA 4500, Perten Instrument and Australia) supplied with a 1000 cmg sensitivity cartridge. Each sample was weighed to an exact precision of 3.5 g, and 25 ml of distilled water was added to it in a dry, empty canister. The canister was put into the RVA as recommended. After gently swirling the mixture. The slurry was heated from 50 to 95 °C at a rate of 1.5 °C/min, held at that temperature for 15 min, and then cooled to 50 °C. Thermocline for Windows Software. attached to a computer was used to record the pasting profile's peak, trough, breakdown, final viscosity, setback, peak time, and pasting temperature profile indices as described by Awoyale *et al*. (2023).

Functional analysis

Bulk density

The method of Sanni *et al*., (2019) was followed. Ten (10 g) grams of the gari were transferred into 50 ml measuring cylinder. The cylinder was tapped repeatedly for 5 minutes. The bulk density was calculated as the mass of mucilage over the volume at the end of tapping. The mean value was recorded from duplicate determinations.

Bulk density (g/mL) = Weight flour (g)/ Volume (mL)

Swelling index

Exactly 2 g of sample was weighed into measuring cylinder, 10 ml of distilled water was carefully added and the volume occupied by the sample was recorded. The sample was allowed to stand undisturbed for 2 hours and the volume occupied after swelling was recorded.

Swelling index = Volume occupied by sample after swelling / Volume occupied before swelling

Water absorption capacity

The water absorption capacity was determined by the method described by Oyeyinka *et al*. (2014). Sample (1 g) was weighed into a dry, clean centrifuge tube of a known weight. Oil (10 mL) was poured into the tube and properly mixed.The suspension was allowed to stand for 30 minutes and centrifuged at 3,500 rpm for 30 minutes, Supernatant was discarded and the tube with its content reweighed. Gain in weight expressed as a percentage of water bound was calculated as the WAC of the sample.

Sensory evaluation

Sensory evaluation was carried out using 25 semi-trained panel chosen from students and staff of Federal Polytechnic, Ilaro, Ogun state, who were regular consumer of the product (tapioca). Each samples were prepared separately. The samples were served in different cups and each cup was labelled. Little quantity of sugar and milk were added equally to the samples to taste. It was served to the panelist in the sensory room with pure water given to each of them. A 9-point Hedonic Scale described by Adebowale and Komolafe (2018) was given to panellist to evaluate the sample with scores ranging from 1 to 9 which represent Dislike and Like extremely, respectively. The panellists were instructed to rinse their mouth with water after each sample taste so as to prevent carry over flavour. The parameters evaluated include taste, colour, flavour, mouth feel, willingness to buy and overall acceptability.

Statistical Analysis

Descriptive statistics (mean and standard deviation) and a-one way Analysis of Variance (ANOVA) were conducted using Statistical Package for Social Sciences (SPSS), version 20.

RESULTS AND DISCUSSION

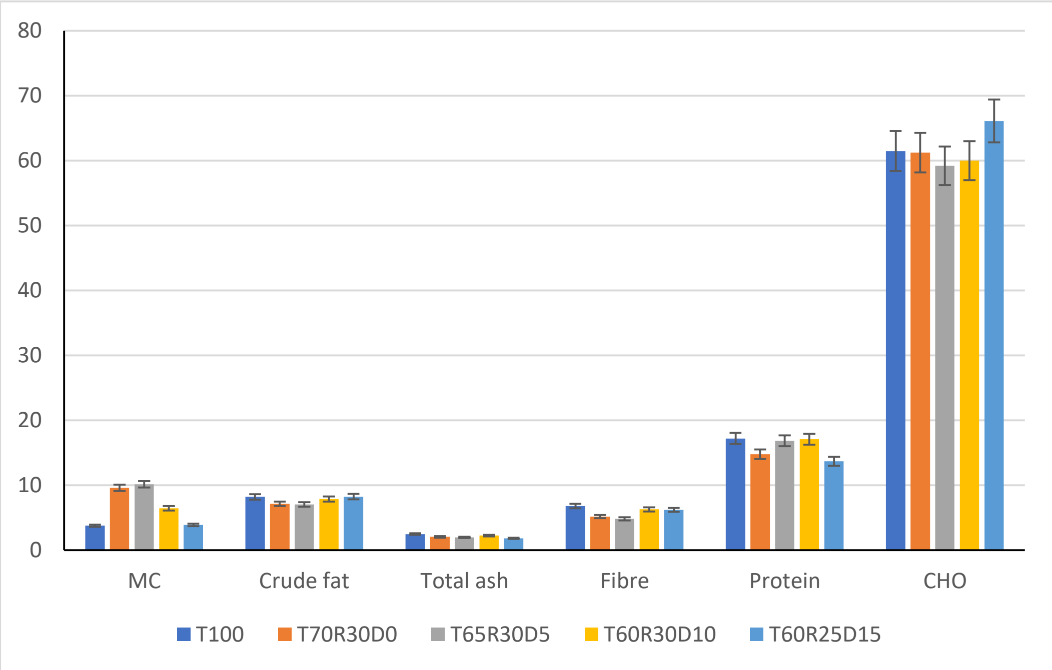

FIGURE 1: Proximate Composition of Tapioca-Tigernut blends

PROXIMATE COMPOSITION OF TAPIOCA-TIGERNUT BLENDS

Proximate composition of Tapioca-tigernut blends showed significant variation ($p < 0.05$) across all samples (Table 1). Moisture content ranged from 3.78% in T_{100} (100% starch) to 10.15% in $T_{65}R_{30}D_5$ (65% starch, 30% tigernut residue, 5% date fruit). Higher moisture content in samples containing tigernut residue and date fruit (especially $T_{65}R_{30}D_5$) suggests increased water retention due to the fibrous nature of these ingredients. Moisture content is critical as it influences shelf life; higher moisture may predispose the product to microbial spoilage if not adequately stored (Tapia et al., 2020).

Crude fat ranged from 7.05% in $T_{65}R_{30}D_5$ to 8.24% in Sample E. Sample E was observed with higher tigernut proportions, which may be attributed to higher inclusion of tigernut residue rich in fats. Higher fat content suggests better palatability but may reduce shelf-life via oxidative rancidity. Obinna-Echem *et al.* (2020) reported a similar increase in fat content with tigernut-based composite flour.

Crude ash values ranged from 1.84% in Sample E to 2.49% in T_{100}. The higher ash content in T_{100} may suggest that cassava starch may have higher mineral residues than samples with higher tiger nut and date fruit content. However, according to Ariyo et al. (2021), tiger nut and date fruits contribute beneficial minerals essential for meeting daily mineral needs.

For crude fibre, values ranging from 4.85% to 6.80% were recorded in $T_{65}R_{30}D_5$ and the control, respectively. Fiber content decreases as date fruit proportion increases, possibly due to date's lower fiber content than tigernut. A similar trend was reported by Yilmaz-Akyuz (2019), where tigernut increased fiber levels in food products.

Protein content (13.70% - 17.21%), also showed significant difference ($p < 0.05$). The addition of tigernut residue increases protein content. This compares favourably with the values reported Oladunjoye and Alade (2024), who reported increased protein levels in tigernut and cowpea blends, aligning with the moderate protein boost in samples containing tigernut in this study.

Carbohydrate (59.20 - 66.09%) content revealed a decrease in value with increasing inclusion of tigernut and date fruit. This may be attributed to the relatively lower starch content of tigernut and date fruit. The values obtained are in line with the report of Peter-Ikechukwu (2020), for composite flour from date fruit pulp, toasted watermelon seed and wheat. High carbohydrate content enhances energy value, making the product ideal as a high-energy snack.

Table 1: Functional Properties of Tapioca-Tigernut Blends

Samples	Bulk density	Water absorption	Swelling power	Least gelation
T_{100}	0.88±0.00b	276.09±0.02b	5.08±0.03b	44.50±0.70ab
$T_{70}R_{30}D_0$	0.91±0.00a	281.64±0.03a	5.38±0.03a	47.00±1.41a
$T_{65}R_{30}D_5$	0.86±0.03c	272.86±0.04c	4.62±0.03d	42.50±0.71bc
$T_{60}R_{30}D_{10}$	0.87±0.00d	265.23±0.07d	4.81±0.00c	40.00±0.00c
$T_{60}R_{25}D_{15}$	0.82±0.00e	175.57±0.04e	4.21±0.02e	40.00±2.83d

Values are mean ± Standard Deviation. Means in the sane column with different letters are significantly (p<0.05) different.

KEY:

T_{100}=100% Starch

$T_{70}R_{30}D_0$=70% Starch, 30%, Tiger-nut Residue

$T_{65}R_{30}D_5$= 65% Starch, 30% Tiger nut Residue, 5% Date fruit.

$T_{60}R_{30}D_{10}$= 60% Starch, 30% tiger nut Residue, 10% Date fruit.

$T_{60}R_{25}D_{15}$= 60% Starch, 25% Tiger nut Residue, 15% Date fruit.

FUNCTIONAL PROPERTIES OF TAPIOCA-TIGERNUT BLENDS

The values obtained for bulk density (BD) ranged from 0.82 g/mL in Sample E to 0.91 g/mL in $T_{70}R_{30}D_0$. The higher bulk density of $T_{70}R_{30}D_0$, suggests that adding tigernut residue increases the bulk density of the blend. Products that require compact packaging benefit from higher bulk density which improves packaging efficiency. $T_{60}R_{25}D_{15}$ displays lower bulk density because of its higher date fruit content which proves beneficial for specific snack products that require lighter texture. The research conducted by Bamigbola *et al.* (2021) on plantain flour mixed with tigernut residue, found a similar pattern. The results of this investigation agree with the findings of these authors with respect to the bulk density values obtained. The study showed significant differences in water absorption capacity (WAC) with values spanning between 175.57% and 281.64% ($p < 0.05$). The superior water absorption capacity (WAC) of $T_{70}R_{30}D_0$ demonstrates the tigernut residue's ability to retain water. Products requiring to hold moisture may benefit from a high WAC since it contributes to making the final product softer. Sample E's reduced water absorption capacity may likely restrict moisture retention and produce drier textures which may affect consumer preference based on the product's intended use. According to research by Ayeni, et al. (2024) tigernut composite blends demonstrated elevated water absorption capacity compared to the control. Enhancing texture quality with high WAC may provide significant benefits for baked goods that require moisture retention.

The study demonstrated significant variations ($p<0.05$) in swelling power which ranged from 4.2 to 5.38. T70R30D0 demonstrates high swelling power which enhances starch gelatinisation to improve dough viscosity and texture. For gel-based foods such as custard products where both gel consistency and viscosity matter, swelling power becomes a crucial factor. This study's findings align with the work published by Adegunwa et al. (2017), which demonstrated that plantain and tigernut flour showed increased swelling power due to starch presence.

The lowest gelation concentration revealed significant ($p < 0.05$) variability at 40.00% for Samples D and E and at

47.00% for T70R30D0. Samples D and E have lower LGC, indicating that they would need low concentration to improve textural stability in the product, particularly in products that need gelled consistency. T70R30D0 may require a higher concentration for form required gelation in food products because it has the highest LGC, indicating that it would lower its effectiveness in some products but improve structural stability in products needing firm gels. This supports the findings of Alimi et al. (2025), who reported that gel formation in food can be influenced by the inclusion of composite flours with reduced gelation levels.

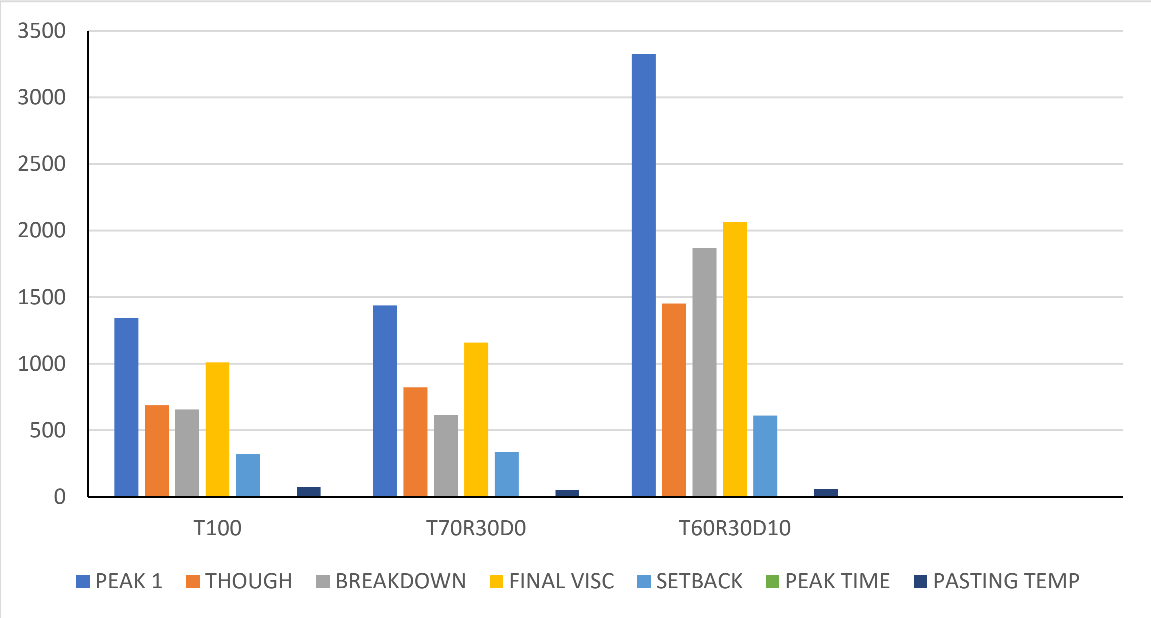

Figure 2: Pasting Properties of Tapioca-Tigernut blends

PASTING PROPERTIES OF TAPIOCA-TIGERNUT BLENDS

The peak viscosity values were between 1345.50 (T_{100}) and 3324.50 ($T_{65}R_{30}D_5$). The dough viscosity can be improved through the higher volume of $T_{65}R_{30}D_5$ and absorb water when heated since the peak viscosity is higher. According to (Ojo et al., 2017), products high gel strength, such as stiff dough, may be improved by the presence of high peak viscosity, which may present $T_{65}R_{30}D_5$ as a suitable option for such use. There were wide variations ($p < 0.05$) in trough viscosity range, ranging from 688.50 (T100) to 1452.50 ($T_{65}R_{30}D_5$). A more uniform dough structure can be obtained from $T_{65}R_{30}D_5$'s higher trough viscosity, exhibiting a more stable paste on holding. Food products that require constant viscosity during the cooking process benefit by this stability. Tigernut mix in cassava foods possesses higher trough viscosity, enhancing product stability during the cooking process, as Nedviha and Harasym (2024) have established. The breakdown viscosities were between 616.00 ($T_{70}R_{30}D_0$) and 1872.00 ($T_{65}R_{30}D_5$). The latter is higher in breakdown (lower stability to shear and heat), which could result in the final product being softer. Greater shear stress resistance is indicated by a reduced breakdown, suggesting $T_{70}R_{30}D_0$, would yield a stronger and harder product. This agrees with the report of Adebayo and Otunola, (2015), where the tigernut residue in starch-based products was explored.

The final viscosity values were significantly different ($p < 0.05$) and ranged from 1009.50 to 2063.50 in T_{100} and $T_{65}R_{30}D_5$, respectively. The elevated ultimate viscosity of T65R30D5 implies improved gelation on cooling and the creation of a stronger, more stable final product. Materials that require not losing structure during cooling, i ncluding some baked items, may be suited for such property as observed in $T_{65}R_{30}D_5$. Ayo et al. (2018) noted that the inclusion of fibrous and starchy materials like tigernut and date fruit can elevate final viscosity of acha flours.

For setback viscosity values ranged from (321.00 to 611.00) in T_{100} and $T_{65}R_{30}D_5$ respectively. A higher setback in

$T_{65}R_{30}D_5$ suggests a higher propensity for retrogradation or gel hardening upon cooling. This is ideal for products where a firmer texture is preferred post-cooling. T_{100}'s low setback suggests a softer texture when cooled, which would be beneficial for products that need a spreadable or creamy texture, which is in line with the finding of Bamigbola *et al.* (2021).

Peak time varied from 3.83 min ($T_{65}R_{30}D_5$) to 5.03 min ($T_{70}R_{30}D_0$), with significant differences ($p < 0.05$). The shorter peak time in $T_{65}R_{30}D_5$ implies faster gelatinization, which could be suitable for quick-cooking applications. The longer peak time in $T_{70}R_{30}D_0$ indicates slower gelatinization, favouring products that benefit from extended cooking times for gradual thickening. Similar trends were observed , where tigernut and cassava blends had faster peak times, enhancing quick-cooking properties. However, pasting temperature ranged from 51.60 °C to 76.35 °C for $T_{70}R_{30}D_0$ and A respectively, with significant differences ($p < 0.05$).

The lower pasting temperature in sample $T_{70}R_{30}D_0$ suggests easier gelatinization, which would be beneficial in energy-saving cooking processes. The higher pasting temperature in T suggests that more heat is needed to start gelatinization, which is beneficial for products that need a longer cooking time. This was however, in line with report of Adebayo and Arinola (2017) who recommended using tigernut for baking and production complementary foods.

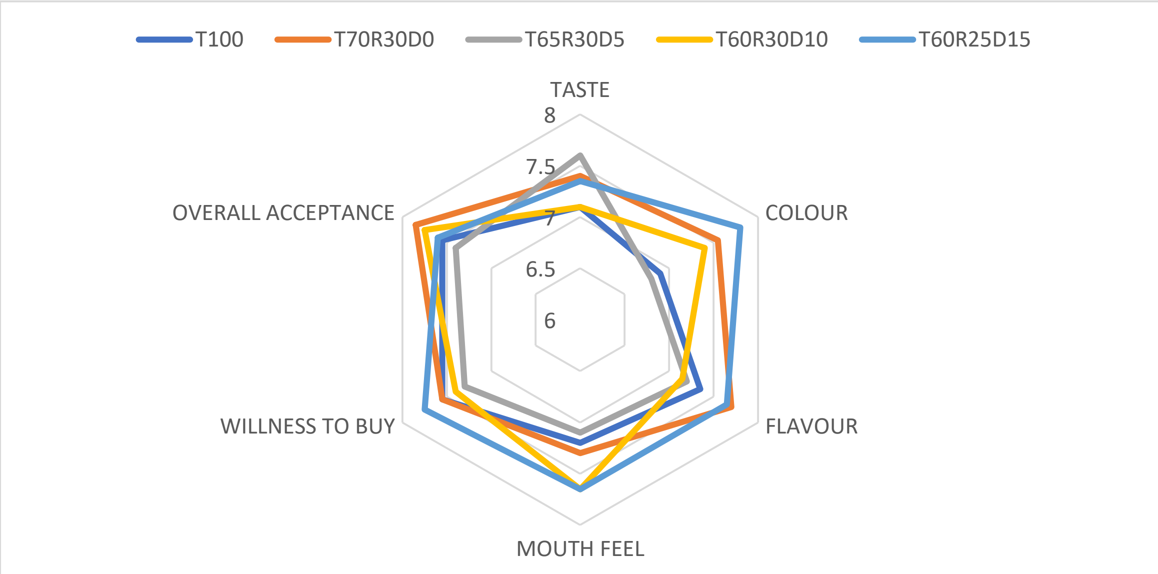

Figure 3: Sensory Properties of Tapioca-Tigernut blends

SENSORY PROPERTIES OF TAPIOCA-TIGERNUT BLENDS

Sensory properties of tapioca-tiger nut blends are presented in Figure 3. There was no significant difference ($p > 0.05$) in scores for taste, ranging between 7.10 and 7.60. However, T_{100} had the lowest taste score while $T_{65}R_{30}D_5$ recorded the highest value. Since there is no noticeable difference, consumers who are used to the conventional flavour of tapioca would accept such formulations, as the addition of date fruit and residue from tigernut does not considerably change the flavour of the tapioca. This concurs with the observation of Olatoye et al. (2021), which indicates that nutrient-enriched products may be used without affecting taste preference. Colour values varied significantly ($p>0.05$) between samples, ranging from 6.80 ($T_{65}R_{30}D_5$) to 7.80 ($T_{60}R_{25}D_{15}$). Consumers prefer the enhanced colour that date fruit contributes, making $T_{60}R_{25}D_{15}$'s with higher colour rating and a bigger percentage of date fruit a valuable alternative. The preference for deeper colour observed in $T_{60}R_{25}D_{15}$ is consistent with Okafor et al., (2017) who reported that date fruit enhanced colour attributes in cassava-based snacks.

Flavour scores between 7.15 ($T_{60}R_{30}D_{10}$) and 7.70 ($T_{70}R_{30}D_0$) were not significantly different among samples ($p > 0.05$). The almost uniform equality of the flavour ratings between the samples suggests that tapioca acceptability may not be influence by flavour. However, $T_{70}R_{30}D_0$ was most preferred in terms of flavour. $T_{70}R_{30}D_0$ may be better accepted among consumers because of its consistency, which maintains its traditional flavour but with a higher nutritional value. Mouthfeel scores, however, varied from 7.10 to 7.65, and there were no differences that could be detected among samples ($p > 0.05$). Regardless of date fruit to tigernut proportion, mouthfeel scores show that all samples have a texture that is acceptable to consumers. This indicates that such ingredients maintain the desired mouthfeel of the product without adversely affecting its smoothness or consistency. As demonstrated in this study, tigernut and date addition to cassava products provided a good mouthfeel in studies by Eke-Ejiofor & Beleya (2018). There were no significant differences among samples in willingness to buy scores ranging from 7.30 in $T_{65}R_{30}D_5$ to 7.75 in $T_{60}R_{25}D_{15}$ ($p > 0.05$). This indicate that all the formulated blends have a marketable potentials based consumer preference despite variability in other sensory score. Also, There was no significant ($p > 0.05$) variation among samples for total acceptability scores with values ranging from 7.40 ($T_{65}R_{30}D_5$) to 7.85 ($T_{70}R_{30}D_0$). As evident from the studies of Alamu et al. (2013), who reported that high total acceptance by the product is proof of improved viability as a breakfast or snack, supplemented in nutritional terms.

CONCLUSIONS

To establish the nutritional and sensory advantages of using date palm fruits, tigernut residue, and cassava starch to enrich tapioca, the study evaluated the functional, proximate, and sensory properties of the product. Date fruit and tigernut residue addition had a remarkable improvement in the nutritional content of tapioca based on proximate analysis. Tigernut greatly improved water absorption, bulk density, and swelling capacity, all of which are advantageous to forming soft, wet textures in snack foods, by functional properties tested. The addition of date fruit and tigernut improved the pasting characteristics also. Improved gel structures and cooking stability were indicated by the considerably higher peak and finishing viscosities of samples containing these ingredients. From sensory testing, all enriched tapioca can be a good substitute for plain tapioca by combining consumer-appealing sensory characteristics with enhanced nutritional benefits. exhibiting better stability and firmer gel networks during preparation.

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