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# Characterization of Starches from Some Selected White and Yellow Cassava Roots for Dry Starch Noodle Production

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## ABSTRACT

Starch noodle, originally produced from mung bean starch, is now patronized in many parts of the world. Although cassava is one of the most abundant sources of starch in Nigeria, previous works determining its applicability for noodle production are scarce in literature. This study therefore determined the chemical properties of starches from selected white and yellow cassava for dry starch noodle production. Descriptive attributes and sensory acceptability of the starch noodle produced were also determined using commercial starch noodle as reference sample. Data obtained were subjected to analysis of variance using SPSS (version 21). Chemical properties of cassava starches varied significantly ( $p < .05$ ). Using clustering and discriminant function analyses, two product clusters were identified with their distinct physical and sensory properties. This study showed that the most acceptable cassava starch noodles were obtained from TMS 01/1206 followed by TMS 01/1368, the least acceptable noodle was obtained from TME 419.

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## Introduction

Cassava (*Manihot esculanta* Crantz) is cultivated in the tropical regions for its starchy roots. These starchy roots are used for human consumption, animal feed and as raw material in many industries (Vimala, Thushara, Nambisan, & Janard, 2011). It also serves as a food security and income generation crop for many millions of people in the developing world (Scott et al., 2000). Cassava is drought tolerant, it requires limited land preparation and grows well in poor soil. All these attributes makes it an extremely adaptable crop.

Freshly harvested cassava roots contain about 70% moisture, 24% starch, 2% fiber, 7–12% protein, and 3% of other substances including minerals and trace amounts of fat (Burell, 2003). However, the major constraint to cassava utilization is that cassava deteriorates rapidly since it has a shelf-life of between 24 to 48 hours after harvest (Phillips, Taylor, Sanni, & Akoroda, 2004).

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Therefore, processing is necessary to reduce post-harvest loss of the roots, facilitate preservation, improve palatability and product quality (Food and Agricultural Organization, 2008; Phillips et al., 2004).

Cassava starch is an abundant substance, which is naturally produced from cassava roots, and is applicable in the food and non-food industries. It is used in the production of pudding, food additives (which are used to control the consistency and texture of sauces and soups), thickener, stabilizer, gelling agent, water retention agent and adhesives (Singh, Singh, Sharma, & Saxena, 2003). The use of starch in various products and manufacturing process is determined majorly by the functional properties it possess such as pasting properties, swelling power, and solubility, which varies based on the type of crop as well as ecological and agronomic factors (Peroni, Rocha, & Franco, 2006; Yuan et al., 2009).

Starch noodle, also known as Chinese vermicelli, Korean vermicelli, bean threads, bean thread noodles, crystal noodles, glass noodles, clear noodle, transparent noodle, FenShi, DongFen, bihon, or harusame, is one of the traditional oriental foods popularly consumed both as a noodle food and in other dishes throughout Asian countries (Collado, Mabesa, Oates, & Corke, 2001). It originated from the mainland of China and dates from at least 4000 years ago (Houyuan et al., 2014). Starch noodle is different from other types of noodles, such as pasta and wheat-flour noodles, since it is made from gluten-free starch. Starch noodle dough is made from 5% of gelatinized starch (acting as the “gluten” in wheat-flour dough) mixed with 95% of the remaining (native) starch to form a dough. Thus, the starch itself plays an essential role in both starch noodle processing and the final starch noodle quality.

Traditionally, mung-bean starch is considered to be the most suitable raw material for starch noodle making because of its high amylose content, which prevents stickiness in starch noodles. Mung-bean starch noodle is consequently regarded as the best of all kinds of starch noodles and favored for its desired appearance (Tan, Zai-Gui, & Tan, 2009). Due to the relatively high price and unavailability of mung-bean starch, and the abundance of cheaper starch sources, such as cereal, root and tuber starches, many efforts have been carried out to partially or totally substitute mung-bean starch in starch noodles with starches of other origins (Tan et al., 2009).

Noodles eaten in most households across Nigeria are usually produced from wheat flour (instant noodles) and/or composite flours. Nigeria has an unfavorable climatic conditions for the cultivation of wheat but suitable for the cultivation of tropical crops such as root and tuber. Cassava is a promising substitute for starch noodle production since it is quite cheap and abundantly available (Aniedu & Omodamiro, 2012). The use of cassava starch in starch noodle production will be advantageous as it will reduce the cost of importation of wheat/wheat flour and encourage the use of our locally grown agricultural produce.

Various food products (salad-cream, chin-chin, high-quality cassava flour, fufu, gari, cassava chips, cake) had been produced from cassava roots for value addition to enhance better and wide range utilization of the crop (Aniedu & Omodamiro, 2012). Use of cassava starch as dough improver as well as texturizing agent to improve the masticatory property of the wheat noodles was reported by. Incidentally, literature is scarce on the study of noodles produced purely from cassava starch, hence the need to determine cassava starch's suitability in starch noodle production.

This study was therefore conducted to evaluate the potential of cassava starches derived from yellow and white cassava varieties in dry noodle production. The suitability of the starches in noodle making was based on the quantitative descriptive and affective sensory tests of the cooked and uncooked dry starch noodles. Sensory data were correlated with some physical properties and chemical composition data of the starches.

## **Materials and method materials**

Starches were extracted from a total of eight varieties of cassava roots; four white varieties (TMS 30572, TME 419, TMS 96/1632, and TMS 98/0581) and four yellow varieties (TMS 01/1368, TMS 01/1412, TMS 01/1206, and TMS 01/1371), freshly harvested from the Research Farm of the International Institute of Tropical Agriculture (IITA), Mokwa, Niger State Nigeria. Starch noodles were produced from the extracted starch according to the modified method of Chen, Schols, and Voragen (2003). These cassava varieties were harvested at 15 months after planting and processed into starch immediately after harvesting. The reference starch noodle, produced from white flesh sweet potato starch was obtained from China. The starches extracted and the starch noodles produced were subjected to chemical analysis using standard analytical procedures (AOAC, 2005). Sensory evaluation of the starch noodles was also carried out.

## **Methods**

### ***Starch extraction***

The modified method of Aniedu and Omodamiro (2012), was used for the extraction of cassava starch. About 50 kg each, of the eight cassava varieties was peeled, washed, and grated with a mechanical grater. The pulp was sieved with a muslin cloth suspended in 70 L of water. This was done to separate the fibrous and coarse materials in the pulped cassava roots from the starch pulp. The pulp was allowed to settle for 8 h after sieving, before decanting the supernatant. The extracted starch was washed and then pressed to remove the water. The starch was dried at 60°C for 18 h in a cabinet dryer, packed in polyethylene bags, and kept in cold storage for further analyses.

## **Cassava starch noodles production**

Noodles were produced from different varieties of cassava starch using the modified method of Chen et al. (2003). This is illustrated in Figure 3. About 5% (12.5 g) of the cassava starch was dispersed in 100 ml of boiling water to gelatinize the starch. This was immediately transferred into the remaining 95% (237.5 g) dried starch powder and mixed together. The mixture was kneaded into dough with a smooth consistency and was then extruded through a single screw extruder (fabricated locally by NASOD Engineering Limited, Ogun State, Nigeria). A 2.5 mm die nozzle was used to extrude the cassava starch dough, which was manually fed through the bin feed hopper, at a barrel and die temperature of 100°C and a screw speed of 90 rpm. The noodle strands were cut immediately as they exited the die and dried in a cabinet dryer at a temperature of 60°C for 12 h. Thereafter, the dried noodles were packaged in high-density polyethylene bags and stored at room temperature ( $28 \pm 2^\circ\text{C}$ ) for further analysis.

## **Chemical analyses**

### ***Moisture content determination***

The moisture content of the starch samples was determined according to AOAC (2005) method. About 3 g of sample was weighed into a pre-weighed clean dried dish, after which the dish was placed in a well-ventilated oven (draft air Fisher Scientific Isotemp® Oven model 655 F, Springfield, USA) maintained at  $103 \pm 2^\circ\text{C}$  for 24 h. The loss in weight was recorded as moisture content.

### ***Protein determination***

The crude protein of the starch samples was determined by Kjeldahl method using Kjeltac™ model 2300 protein analyzer, according to AOAC (2005) method. About 0.2 g of sample was digested at 420°C for 1 h to liberate the organically bound nitrogen in the form of ammonium sulfate. The ammonia in the digest (ammonium sulfate) was then distilled off into a boric acid receiver solution, and then titrated with standard hydrochloric acid. A conversion factor of 6.25 was used to convert from total nitrogen to percentage crude protein (displayed on the screen of the protein analyzer)

### ***Fat content determination***

The fat content of the starch samples was determined according to AOAC (2005) method. Crude fat was extracted from 3 g of the sample with hexane using a fat extractor (Soxtec System HT-2 fat extractor, Apeldoorn, The

Netherlands), and the solvent was evaporated off to get the fat. The difference between the initial and final weight of the extraction cup was recorded as the crude fat content.

$$\% \text{Fat} = \frac{\text{Weight of flask + fat} - \text{Weight of sample after drying}}{\text{Weight of sample before drying}} \times 100 \quad (1)$$

### Ash content determination

Ash was determined according to AOAC (2005) method. It involves burning off moisture and all organic constituents at 600°C for 5 h in a furnace (United States of America (USA)). The weight of the residue after incineration was then recorded as the ash content.

$$\% \text{ Ash} = \frac{(\text{Weight of crucible + ash}) - (\text{Weight of crucible})}{\text{Weight of sample}} \times 100 \quad (2)$$

### Determination of total carbohydrate

The total carbohydrate content of the cassava starch was determined by difference. This was done by subtracting the sum of % moisture (MC), % crude protein (CP), % crude fat (CF), % crude fiber (CFB), and % ash (Ash) contents from 100.

$$\text{Total carbohydrate}(\%) = 100 - (\% \text{MC} + \% \text{CP} + \% \text{CF} + \% \text{CFB} + \% \text{Ash}) \quad (3)$$

### Amylose content determination of cassava starch

The method of Pereira et al. (2017) was used to determine the amylose content of the eight starch samples. It is a colorimetric method in which amylose forms starch iodine complex (dark blue color) due to its high affinity for iodine. About 0.1 g of the starch sample was solubilized with 1 ml of 95% ethanol and 9 ml of 1 M NaOH, and heated in a water bath for 10 min; 1 ml of the extract was made up to 10 ml with distilled water. To 0.5 ml of the diluted extract, 0.1 ml N acetic acid and 0.2 ml iodine solution (0.2 g I<sub>2</sub> + 2.0 g KI<sub>2</sub> in 100 ml of distilled water) were added to develop a dark blue color. The colored solution was made up to 10 ml with distilled water and allowed to stand for 20 min for complete color development. The solution was vortexed and its absorbance was read on a spectrophotometer (UV Visible Spec. T60) at 620 nm. Absorbance of standard corn amylose with known amylose concentration was used to estimate the amylose content in the sample as follows:

$$\% \text{ Amylose} = \frac{\% \text{ Amylose of standard} \times \text{Absorbance of sample}}{\text{Absorbance of standard}} \quad (4)$$

### Determination of color of cassava starch

The method described by Onitilo, Sanni, Daniel, Maziya-Dixon, and Dixon (2007) was used for color determination using a colorimeter (Chroma meter CR-410 KONICA MINOLTA, INC., Japan). The colorimeter operates on the Commission Internationale de l'Eclairage (CIE)  $L^*$ ,  $a^*$  and  $b^*$  color scheme. The colorimeter was standardized ( $L = 93.24$ ,  $a = 00.96$ , and  $b = 02.75$ ) with a sheet of Business Xerox 80 g/m<sup>2</sup> white paper. About 3 g of each starch sample were weighed on a clean white paper and the colorimeter was placed on the sample in such a way that its sensor is allowed to touch the starch sample. The reading was taken directly for  $L^*$ ,  $a^*$  and  $b^*$ .  $L^*$  symbolize a light to dark direction,  $a^*$  symbolize red to green direction and  $b^*$  symbolize yellow to blue direction.

### Quantitative descriptive analysis of dry (uncooked) and cooked cassava starch noodles

An untrained panelist group comprising 22 members (15 females and 7 males) among the postgraduate and undergraduate students of the Federal University of Agriculture, Abeokuta, were recruited to develop a list of descriptors for the sensory attributes for the raw and cooked cassava starch noodles produced. The ages of the participants ranged from 21 to 35 years. The participants were invited to the sensory analysis laboratory of the Department of Food Science and Technology after previous contact and consent to participate in the training. Panelists were initially screened based on their sensorial acuity to appearance and texture of food in order to finally qualify them to participate in the descriptive sensory evaluation of the noodles. At the end of the screening exercise which lasted for two consecutive sessions, seven panelists (6 males and 1 female) were finally selected to participate in the quantitative descriptive analysis. The noodles samples were served to each panelist separately for assessment, after which a general discussion was done on the plausible descriptive notes (attributes) for the cassava starch noodles. Finally, the descriptors developed are brownness, grayness, transparency, glossiness, flexibility, opacity, brittleness, and patchiness. The eight coded samples of the raw cassava starch noodles and a commercial starch noodle as reference were presented for evaluation. Perceived intensities were scored using questionnaires containing lines graduated on a 1–15 scale with intervals measured in centimeters (Iwe, 2002). Where the mark of '1' corresponds to the lowest intensity and mark of '15'

corresponds to highest intensity of the attributes. The dry noodle samples were then cooked by dipping noodle strands in boiled water for 60 s. The cooked noodle strands were then drained in a plastic drainer and kept wet until ready for use in sensory evaluation.

### **Preference test for dry (uncooked) and cooked cassava starch noodles**

Coded samples of uncooked cassava starch noodles were presented for evaluation with a commercial starch noodle as reference. Sample attributes were rated using a scoring scale of 1-9 (9-point Hedonic scale) for preference testing, where 1 = dislike extremely and 9 = like extremely. All products were presented under the same condition. About 60 panelists, consisting mainly students of the Federal University of Agriculture, Abeokuta participated in the test, and they made their responses on questionnaire which had been designed in line with the test procedures (Iwe, 2002). The attributes evaluated in the dry noodles include color, transparency, glossiness, flexibility, brittleness, opacity, patchiness, and overall acceptability while those evaluated in cooked noodles were color, transparency, glossiness, stickiness, slipperiness, taste, patchiness, overall acceptability

## **Results and discussion**

### ***Chemical composition of cassava starch***

The chemical composition of cassava starch is presented in Table 1. The chemical composition of the starch samples was significantly different from each other ( $p < 0.05$ ). The protein (1.02–1.97%), fat (1.04–1.18%) and ash (0.07–0.48%) contents were generally low. This is expected as these solid matters are regarded as residues (impurities) which are not easily removable during starch extraction from any plant sources. The values are in agreement with those reported by some previous authors as reviewed by Zhu (2015). The presence of these residual substances is still acceptable for food applications (Egharevba, 2019). As low as these dry matter contents are, they might have significant influence on the food applications of any starch. Amylose contents of flours as well as its structure, could be more important than any other chemical constituent for noodle making. Guo, Jackson, Graybosch, and Parkhurst (2003) and Heo, S. Park, S. Park, Park, and Park (2012) had earlier reported that amylose content of the wheat flour used correlated significantly with textural properties of flour noodles. Amylose contents of the cassava samples ranged from 16.00% to 28.75%. TMS 01/1206 had the lowest amylose content, while TMS 01/1412 had the highest.

**Table 1.** Proximate Composition of Cassava Starches

| Cassava varieties | Moisture content (%)      | Protein (%)               | Fat (%)                   | Ash (%)                  | Carbohydrate (%)           | Amylose                   |
|-------------------|---------------------------|---------------------------|---------------------------|--------------------------|----------------------------|---------------------------|
| TMS 01/1368       | 6.00 ± 0.01 <sup>a</sup>  | 1.75 ± 0.03 <sup>c</sup>  | 1.15 ± 0.02 <sup>b</sup>  | 0.07 ± 0.02 <sup>a</sup> | 91.04 ± 0.01 <sup>c</sup>  | 24.10 ± 0.13 <sup>d</sup> |
| TMS 01/1412       | 9.00 ± 1.00 <sup>b</sup>  | 1.97 ± 0.05 <sup>d</sup>  | 1.10 ± 0.07 <sup>b</sup>  | 0.32 ± 0.01 <sup>b</sup> | 87.60 ± 0.01 <sup>a</sup>  | 28.75 ± 0.41 <sup>e</sup> |
| TMS 01/1206       | 7.33 ± 1.15 <sup>ab</sup> | 1.02 ± 0.12 <sup>a</sup>  | 1.04 ± 0.02 <sup>ab</sup> | 0.42 ± 0.01 <sup>c</sup> | 90.19 ± 1.29 <sup>bc</sup> | 15.99 ± 0.83 <sup>a</sup> |
| TMS 01/1371       | 5.33 ± 1.15 <sup>a</sup>  | 1.90 ± 0.13 <sup>cd</sup> | 1.36 ± 0.12 <sup>c</sup>  | 0.42 ± 0.01 <sup>c</sup> | 90.99 ± 1.17 <sup>c</sup>  | 21.50 ± 0.69 <sup>c</sup> |
| TMS 30572         | 5.33 ± 1.15 <sup>a</sup>  | 1.02 ± 0.12 <sup>a</sup>  | 1.18 ± 0.08 <sup>b</sup>  | 0.43 ± 0.03 <sup>c</sup> | 92.03 ± 1.16 <sup>c</sup>  | 19.71 ± 0.14 <sup>b</sup> |
| TME 419           | 8.67 ± 1.15 <sup>b</sup>  | 1.02 ± 0.12 <sup>a</sup>  | 1.15 ± 0.08 <sup>b</sup>  | 0.35 ± 0.01 <sup>b</sup> | 88.82 ± 0.96 <sup>ab</sup> | 19.63 ± 0.07 <sup>b</sup> |
| TMS 96/1632       | 6.67 ± 1.15 <sup>a</sup>  | 1.02 ± 0.12 <sup>a</sup>  | 1.11 ± 0.10 <sup>b</sup>  | 0.48 ± 0.02 <sup>d</sup> | 90.73 ± 1.33 <sup>bc</sup> | 28.44 ± 0.22 <sup>e</sup> |
| TMS 98/0581       | 5.33 ± 1.15 <sup>a</sup>  | 1.56 ± 0.02 <sup>b</sup>  | 0.95 ± 0.07 <sup>a</sup>  | 0.36 ± 0.05 <sup>b</sup> | 91.79 ± 1.17 <sup>c</sup>  | 23.92 ± 0.07 <sup>d</sup> |

The values presented are mean and standard deviation (mean ± standard deviation).

Mean values having different superscripts within a column are significantly different from each other ( $p < 0.05$ ).

**Table 2.** Color of Cassava Starch Samples

| Cassava varieties | L*                         | a*                       | b*                        |
|-------------------|----------------------------|--------------------------|---------------------------|
| TMS 01/1368       | 101.05 ± 0.09 <sup>c</sup> | 0.33 ± 0.02 <sup>b</sup> | 7.87 ± 0.01 <sup>d</sup>  |
| TMS 01/1412       | 96.49 ± 0.06 <sup>a</sup>  | 1.18 ± 0.01 <sup>g</sup> | 7.78 ± 0.00 <sup>c</sup>  |
| TMS 01/1206       | 99.80 ± 0.02 <sup>b</sup>  | 0.61 ± 0.01 <sup>e</sup> | 8.20 ± 0.00 <sup>e</sup>  |
| TMS 01/1371       | 117.17 ± 0.61 <sup>f</sup> | 0.14 ± 0.02 <sup>a</sup> | 13.24 ± 0.07 <sup>g</sup> |
| TMS 30572         | 101.84 ± 0.01 <sup>d</sup> | 0.37 ± 0.01 <sup>c</sup> | 7.38 ± 0.01 <sup>b</sup>  |
| TME 419           | 105.29 ± 0.02 <sup>e</sup> | 0.96 ± 0.01 <sup>f</sup> | 6.96 ± 0.01 <sup>a</sup>  |
| TMS 96/1632       | 102.29 ± 0.18 <sup>d</sup> | 1.27 ± 0.02 <sup>h</sup> | 8.96 ± 0.09 <sup>f</sup>  |
| TMS 98/0581       | 99.47 ± 0.49 <sup>b</sup>  | 0.41 ± 0.01 <sup>d</sup> | 7.00 ± 0.01 <sup>a</sup>  |

Mean values having different superscripts within column are significantly different from each other ( $p < 0.05$ ).

## Color of cassava starch

The color of cassava starch is presented in Table 2. The L\*, a\*, and b\* values of the cassava starch varieties were significantly different at  $p < 0.05$ . The L\* values ranged from 96.49 to 117.17, with TMS 01/1412 having the lowest value while TMS 01/1371 had the highest value. The a\* values ranged from 0.14 to 1.27, with TMS 01/1371 having the lowest value, while TMS 96/1632 had the highest value. The b\* values ranged from 6.96 to 13.24. TME 419 had the lowest value, while TMS 01/1371 had the highest value.

## Quantitative descriptive analysis of the dry (uncooked) and cooked cassava starch noodles

The QDA of uncooked cassava starch noodles is presented in Figure 1. The descriptive attributes were significantly different from each other at  $p < .05$ . Brownness ranged 1.49 to 10.94, with the reference sample having the lowest brownness value, while TMS 01/1206 had the highest value. Greyishness ranged from 1.63 to 13.97, with TMS 01/1368 having the lowest value, while

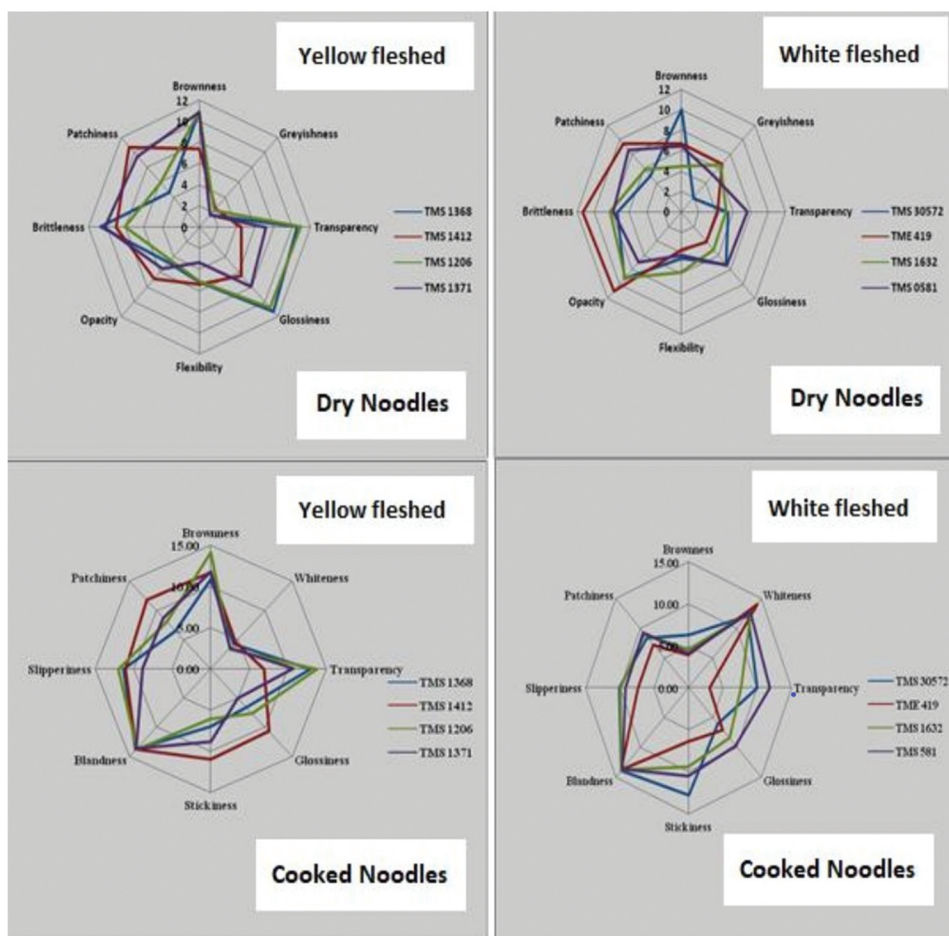


**Figure 1.** Web diagram showing the quantitative descriptive attribute scores of the dry (I–II) and cooked noodle (III–IV) samples.

the reference sample had the highest value. Transparency ranged from 4.13 to 10.94, with TME 419 having the lowest value, while TMS 01/1206 had the highest value. Glossiness ranged from 4.07 to 11.30, with TME 419 having the lowest value, while TMS 01/1206 had the highest value. Flexibility ranged from 3.31 to 8.73, with TMS 01/1371 having the lowest value, while the reference sample had the highest value. Opacity ranged from 4.43 to 10.93, with TMS 01/1206 having the lowest value, while TME 419 had the highest value. Brittleness ranged from 7.37 to 11.36, with TMS 30572 having the lowest value, while TME 419 had the highest value. Patchiness ranged from 4.37 to 10.71, with the reference sample having the lowest value, while TMS 01/1412 had the highest value.

### **Sensory preference of the dry (uncooked) and cooked cassava starch noodles**

The preference test scores for raw cassava starch noodles are presented in [Table 3](#). The attributes investigated were significantly different from each other at  $p < .05$ . Color ranged from 5.4 to 8.4, with TME 419 having the lowest value, while TMS 01/1206 had the highest value. Transparency ranged from 5.3 to 8.4, with TME 419 having the lowest value, while TMS 01/1206 had the highest value. Glossiness ranged from 5.3 to 8.4, with TME 419 having the lowest value, while TMS 01/1206 had the highest value. Flexibility ranged from 4.1 to 7.2, with TME 419 having the lowest value, while the reference sample had the highest value. Brittleness ranged from 5.3 to 7.3, with the reference sample having the lowest value, while TMS 01/1206 had the highest value. Opacity ranged from 4.8 to 6.0, with TMS 01/1371 having the lowest value, while TMS 01/1412 and TME 419 had the lowest value. Patchiness ranged from 5.2 to 6.2. The reference starch noodle sample had the lowest value while TMS 01/1206 had the highest value. Overall acceptability ranged from 5.4 to 8.4, with TME 419 having the lowest value, while TMS 01/1206 had the highest value.

### **Correlating the cassava starch properties and the noodles properties**

The matrix in [Table 4](#) shows that all the proximate chemical components including the amylose content had no significant correlation with any of the sensory attribute for the uncooked noodles. Similar trend was observed for the cooked noodles ([Table 5](#)). Only the lightness (L) of the raw starch showed significant correlations with the texture and overall acceptability of uncooked noodles. Increased glossiness of the noodles appeared to positively influence the scores of appearance, texture and overall acceptability, whereas opacity negatively correlated with the acceptability of appearance and texture of the uncooked noodles. The glossiness and opacity are somewhat optical properties of the noodle samples. It is interesting to note the significant correlation between these two optical properties and sensory score of the noodle texture. The underlying reason for this observation is unknown yet.

In order to vividly show the relationship between the chemical compositions of dry cassava starches (independent factors) and the sensory quality of uncooked and cooked starch noodles (the dependent factors), principal component plots were derived ([Figure 2A-B](#)). For the uncooked starch noodles, the first Principal Component (PC1) accounted for 37.7% of the data variation while the second Principal Component (PC2) accounted for only 18.0% of the data variation. From the plot, the descriptive attributes (grayness, opacity and patchiness) had significant negative loading effects while transparency, glossiness, flexibility and brownness had significant positive loading effects on PC1.



Table 3. Sensory Preference Scores of Dry (Uncooked) and Cooked Cassava Starch Noodles

| Dry noodle sensory attributes |                        |                         |                         |                         |                         |                         |                           |                        |  |
|-------------------------------|------------------------|-------------------------|-------------------------|-------------------------|-------------------------|-------------------------|---------------------------|------------------------|--|
| Noodles samples               | Color                  | Transparency            | Glossiness              | Flexibility             | Brittleness             | Opacity                 | Patchiness                | Overall acceptability  |  |
| TMS 01/1368                   | 7.6 ± 0.6 <sup>d</sup> | 7.6 ± 0.9 <sup>e</sup>  | 7.6 ± 0.9 <sup>e</sup>  | 5.6 ± 1.5 <sup>c</sup>  | 6.5 ± 1.3 <sup>c</sup>  | 5.1 ± 1.6 <sup>ab</sup> | 5.9 ± 1.7 <sup>bcd</sup>  | 7.6 ± 0.6 <sup>d</sup> |  |
| TMS 01/1412                   | 6.9 ± 1.4 <sup>c</sup> | 5.4 ± 1.4 <sup>a</sup>  | 5.4 ± 1.4 <sup>a</sup>  | 5.6 ± 1.2 <sup>c</sup>  | 6.5 ± 1.7 <sup>bc</sup> | 6.0 ± 1.6 <sup>c</sup>  | 6.1 ± 2.2 <sup>d</sup>    | 6.9 ± 1.4 <sup>c</sup> |  |
| TMS 01/1206                   | 8.4 ± 0.8 <sup>e</sup> | 8.4 ± 0.9 <sup>f</sup>  | 8.4 ± 0.9 <sup>f</sup>  | 5.4 ± 1.4 <sup>c</sup>  | 7.3 ± 1.3 <sup>d</sup>  | 5.4 ± 1.1 <sup>ab</sup> | 6.2 ± 0.8 <sup>d</sup>    | 8.4 ± 0.8 <sup>e</sup> |  |
| TMS 01/1371                   | 6.8 ± 1.1 <sup>c</sup> | 6.0 ± 1.7 <sup>bc</sup> | 6.0 ± 1.7 <sup>bc</sup> | 4.8 ± 1.3 <sup>b</sup>  | 6.5 ± 1.5 <sup>bc</sup> | 4.8 ± 1.0 <sup>a</sup>  | 6.0 ± 1.6 <sup>cd</sup>   | 6.8 ± 1.1 <sup>c</sup> |  |
| TMS 30572                     | 6.9 ± 1.0 <sup>c</sup> | 5.6 ± 1.2 <sup>ab</sup> | 5.6 ± 1.2 <sup>ab</sup> | 5.2 ± 1.2 <sup>bc</sup> | 6.0 ± 2.0 <sup>bc</sup> | 5.6 ± 1.5 <sup>bc</sup> | 6.1 ± 1.0 <sup>d</sup>    | 6.9 ± 1.0 <sup>c</sup> |  |
| TME 419                       | 5.4 ± 1.3 <sup>a</sup> | 5.3 ± 1.4 <sup>a</sup>  | 5.3 ± 1.4 <sup>a</sup>  | 4.1 ± 1.4 <sup>a</sup>  | 6.1 ± 1.9 <sup>bc</sup> | 6.0 ± 1.4 <sup>c</sup>  | 5.8 ± 1.4 <sup>abcd</sup> | 5.4 ± 1.3 <sup>a</sup> |  |
| TMS 96/1632                   | 7.1 ± 1.6 <sup>c</sup> | 5.7 ± 1.6 <sup>ab</sup> | 5.7 ± 1.6 <sup>ab</sup> | 5.3 ± 1.0 <sup>c</sup>  | 5.8 ± 1.7 <sup>ab</sup> | 5.2 ± 1.4 <sup>ab</sup> | 5.5 ± 1.4 <sup>abc</sup>  | 7.1 ± 1.6 <sup>c</sup> |  |
| TMS 98/0581                   | 5.6 ± 0.9 <sup>a</sup> | 6.3 ± 0.8 <sup>cd</sup> | 6.3 ± 0.8 <sup>cd</sup> | 4.8 ± 1.5 <sup>b</sup>  | 5.9 ± 1.4 <sup>bc</sup> | 4.9 ± 1.5 <sup>a</sup>  | 5.4 ± 1.1 <sup>ab</sup>   | 5.6 ± 0.9 <sup>a</sup> |  |
| Reference                     | 6.4 ± 1.4 <sup>b</sup> | 6.7 ± 1.6 <sup>d</sup>  | 6.7 ± 1.6 <sup>d</sup>  | 7.2 ± 1.3 <sup>d</sup>  | 5.3 ± 1.7 <sup>a</sup>  | 5.1 ± 2.0 <sup>ab</sup> | 5.2 ± 1.6 <sup>a</sup>    | 6.4 ± 1.4 <sup>b</sup> |  |
| Cooked noodle attributes      |                        |                         |                         |                         |                         |                         |                           |                        |  |
| Noodles samples               | Color                  | Transparency            | Glossiness              | Stickiness              | Slipperiness            | Taste                   | Patchiness                | Overall acceptability  |  |
| TMS 01/1368                   | 7.6 ± 0.6 <sup>c</sup> | 7.6 ± 0.9 <sup>d</sup>  | 5.4 ± 1.4 <sup>a</sup>  | 5.6 ± 1.2 <sup>b</sup>  | 7.6 ± 0.6 <sup>d</sup>  | 4.8 ± 1.5 <sup>a</sup>  | 6.1 ± 2.2 <sup>b</sup>    | 7.6 ± 0.6 <sup>c</sup> |  |
| TMS 01/1412                   | 6.9 ± 1.4 <sup>b</sup> | 5.4 ± 1.4 <sup>a</sup>  | 8.4 ± 0.9 <sup>d</sup>  | 5.3 ± 1.0 <sup>b</sup>  | 7.1 ± 1.6 <sup>c</sup>  | 4.6 ± 1.2 <sup>a</sup>  | 8.4 ± 0.9 <sup>c</sup>    | 6.9 ± 1.4 <sup>b</sup> |  |
| TMS 01/1206                   | 8.4 ± 0.8 <sup>d</sup> | 8.4 ± 0.9 <sup>e</sup>  | 7.6 ± 0.9 <sup>c</sup>  | 4.8 ± 1.5 <sup>a</sup>  | 8.4 ± 0.8 <sup>e</sup>  | 4.8 ± 1.5 <sup>a</sup>  | 6.1 ± 1.0 <sup>b</sup>    | 8.4 ± 0.8 <sup>d</sup> |  |
| TMS 01/1371                   | 6.8 ± 1.1 <sup>b</sup> | 6.0 ± 1.7 <sup>bc</sup> | 5.3 ± 1.4 <sup>a</sup>  | 5.2 ± 1.2 <sup>ab</sup> | 6.4 ± 1.4 <sup>b</sup>  | 4.6 ± 1.2 <sup>a</sup>  | 6.1 ± 1.0 <sup>b</sup>    | 6.8 ± 1.1 <sup>b</sup> |  |
| TMS 30572                     | 6.9 ± 1.0 <sup>b</sup> | 5.6 ± 1.2 <sup>ab</sup> | 5.6 ± 1.2 <sup>a</sup>  | 7.2 ± 1.3 <sup>c</sup>  | 6.9 ± 1.0 <sup>c</sup>  | 4.9 ± 1.5 <sup>a</sup>  | 6.0 ± 1.6 <sup>b</sup>    | 6.9 ± 1.0 <sup>b</sup> |  |
| TME 419                       | 5.4 ± 1.3 <sup>a</sup> | 5.3 ± 1.4 <sup>a</sup>  | 6.7 ± 1.6 <sup>b</sup>  | 5.2 ± 1.2 <sup>ab</sup> | 5.6 ± 0.9 <sup>a</sup>  | 4.8 ± 1.5 <sup>a</sup>  | 5.2 ± 1.6 <sup>a</sup>    | 5.4 ± 1.3 <sup>a</sup> |  |
| TMS 96/1632                   | 7.1 ± 1.6 <sup>b</sup> | 5.7 ± 1.6 <sup>ab</sup> | 5.7 ± 1.6 <sup>a</sup>  | 5.6 ± 1.5 <sup>b</sup>  | 6.9 ± 1.4 <sup>c</sup>  | 4.6 ± 1.2 <sup>a</sup>  | 6.0 ± 1.6 <sup>b</sup>    | 7.1 ± 1.6 <sup>b</sup> |  |
| TMS 98/0581                   | 5.6 ± 0.9 <sup>a</sup> | 6.3 ± 0.8 <sup>c</sup>  | 6.3 ± 0.8 <sup>b</sup>  | 5.4 ± 1.4 <sup>b</sup>  | 6.8 ± 1.1 <sup>c</sup>  | 4.8 ± 1.5 <sup>a</sup>  | 6.0 ± 1.6 <sup>b</sup>    | 5.6 ± 0.9 <sup>a</sup> |  |
| Reference                     | 5.4 ± 1.3 <sup>a</sup> | 5.4 ± 1.4 <sup>a</sup>  | 5.4 ± 1.4 <sup>a</sup>  | 4.8 ± 1.5 <sup>a</sup>  | 5.3 ± 1.4 <sup>a</sup>  | 4.8 ± 1.5 <sup>a</sup>  | 5.2 ± 1.6 <sup>a</sup>    | 5.6 ± 0.9 <sup>a</sup> |  |

Mean values having different superscripts within a column are significantly different from each other (*p* < 0.05).

**Table 4.** Pearson Correlation Coefficients Showing Linear Relationships between the Starch Properties and Product Attributes for the Uncooked Noodle Samples

|            | Pro   | Fat   | Ash   | CHO   | Amyl  | L*          | a*    | b*    | Brown       | Transp       | Gloss        | Flex  | Opac         | Brittle | Patch | App         | Texture     | OVAC |
|------------|-------|-------|-------|-------|-------|-------------|-------|-------|-------------|--------------|--------------|-------|--------------|---------|-------|-------------|-------------|------|
| Pro        | 1.00  |       |       |       |       |             |       |       |             |              |              |       |              |         |       |             |             |      |
| Fat        | 0.26  | 1.00  |       |       |       |             |       |       |             |              |              |       |              |         |       |             |             |      |
| Ash        | -0.49 | 0.04  | 1.00  |       |       |             |       |       |             |              |              |       |              |         |       |             |             |      |
| CHO        | -0.21 | 0.04  | 0.10  | 1.00  |       |             |       |       |             |              |              |       |              |         |       |             |             |      |
| Amyl       | 0.46  | -0.10 | -0.16 | -0.25 | 1.00  |             |       |       |             |              |              |       |              |         |       |             |             |      |
| L*         | 0.13  | 0.23  | 0.02  | -0.34 | 0.23  | 1.00        |       |       |             |              |              |       |              |         |       |             |             |      |
| a*         | -0.03 | 0.16  | -0.38 | -0.50 | 0.48  | 0.09        | 1.00  |       |             |              |              |       |              |         |       |             |             |      |
| b*         | 0.35  | 0.76  | -0.33 | 0.34  | 0.17  | -0.09       | 0.23  | 1.00  |             |              |              |       |              |         |       |             |             |      |
| Brown      | 0.24  | 0.43  | -0.33 | 0.25  | -0.60 | 0.22        | -0.25 | 0.23  | 1.00        |              |              |       |              |         |       |             |             |      |
| Transp     | 0.12  | -0.17 | -0.42 | 0.38  | -0.40 | 0.22        | -0.26 | -0.06 | 0.65        | 1.00         |              |       |              |         |       |             |             |      |
| Gloss      | 0.26  | -0.05 | -0.49 | 0.34  | -0.33 | 0.32        | -0.21 | 0.00  | <b>0.78</b> | <b>0.95</b>  | 1.00         |       |              |         |       |             |             |      |
| Flex       | 0.26  | -0.10 | -0.10 | -0.15 | 0.49  | 0.62        | 0.52  | -0.38 | -0.27       | 0.13         | 0.18         | 1.00  |              |         |       |             |             |      |
| Stickiness | -0.14 | -0.46 | -0.10 | -0.13 | 0.11  | -0.44       | 0.25  | 0.04  | -0.66       | <b>-0.85</b> | <b>-0.90</b> | -0.15 | 1.00         |         |       |             |             |      |
| Opac       | -0.53 | 0.01  | 0.39  | -0.13 | -0.03 | -0.05       | 0.44  | 0.54  | 0.13        | -0.03        | -0.08        | -0.43 | 0.04         | 1.00    |       |             |             |      |
| Bland      | 0.31  | 0.49  | -0.53 | -0.40 | -0.03 | -0.21       | -0.16 | -0.10 | -0.30       | -0.51        | -0.52        | -0.46 | 0.17         | 0.31    | 1.00  |             |             |      |
| Slip       | 0.48  | 0.10  | 0.17  | -0.62 | 0.23  | -0.21       | 0.00  | -0.31 | 0.65        | <b>0.85</b>  | <b>0.87</b>  | 0.38  | <b>-0.76</b> | -0.12   | -0.54 | 1.00        |             |      |
| App        | -0.07 | -0.15 | -0.29 | 0.06  | -0.43 | 0.55        | 0.00  | -0.30 | 0.57        | 0.64         | <b>0.77</b>  | 0.53  | <b>-0.80</b> | -0.20   | -0.31 | <b>0.87</b> | 1.00        |      |
| Texture    | 0.25  | -0.07 | -0.27 | -0.16 | -0.07 | 0.77        | 0.10  | -0.30 | 0.57        | 0.64         | <b>0.73</b>  | 0.57  | -0.67        | -0.25   | -0.58 | <b>0.88</b> | <b>0.91</b> | 1.00 |
| OVAC       | -0.03 | 0.07  | -0.09 | 0.07  | -0.16 | <b>0.83</b> | 0.17  | -0.16 | 0.56        | 0.64         | <b>0.73</b>  | 0.57  | -0.67        | -0.25   | -0.58 | <b>0.88</b> | <b>0.91</b> | 1.00 |

Amyl: amylose content, Pro: protein content, CHO: carbohydrate content, Fat: fat content, Ash: ash content, Transp: transparency, Gloss: glossiness, Opac: opacity, Patch: patchiness, Flex: flexibility, Brittle: brittleness, App: appearance, texture, OVAC: overall acceptability].

**Table 5.** Pearson Correlation Coefficient Showing Linear Relationships between the Starch Properties and Product Attributes for the Cooked Noodle Samples

|         | Pro          | Fat          | Ash   | CHO   | Amyl  | L*    | a*           | b*    | Brown       | Transp | Gloss | Sticky | Opac  | Bland       | Slip  | Patch       | Texture | Taste | OVAC |
|---------|--------------|--------------|-------|-------|-------|-------|--------------|-------|-------------|--------|-------|--------|-------|-------------|-------|-------------|---------|-------|------|
| Pro     | 1.00         |              |       |       |       |       |              |       |             |        |       |        |       |             |       |             |         |       |      |
| Fat     | 0.26         | 1.00         |       |       |       |       |              |       |             |        |       |        |       |             |       |             |         |       |      |
| Ash     | -0.49        | 0.04         | 1.00  |       |       |       |              |       |             |        |       |        |       |             |       |             |         |       |      |
| CHO     | -0.21        | 0.04         | 0.10  | 1.00  |       |       |              |       |             |        |       |        |       |             |       |             |         |       |      |
| Amyl    | 0.46         | -0.10        | -0.16 | -0.25 | 1.00  |       |              |       |             |        |       |        |       |             |       |             |         |       |      |
| L*      | <b>-0.81</b> | -0.42        | 0.58  | -0.05 | -0.02 | 1.00  |              |       |             |        |       |        |       |             |       |             |         |       |      |
| a*      | -0.10        | -0.49        | 0.47  | 0.01  | -0.22 | 0.07  | 1.00         |       |             |        |       |        |       |             |       |             |         |       |      |
| b*      | 0.24         | -0.25        | -0.20 | 0.10  | 0.05  | -0.48 | 0.60         | 1.00  |             |        |       |        |       |             |       |             |         |       |      |
| Brown   | 0.44         | 0.25         | -0.24 | -0.24 | -0.20 | -0.60 | 0.05         | 0.20  | 1.00        |        |       |        |       |             |       |             |         |       |      |
| Transp  | 0.20         | -0.15        | -0.23 | 0.61  | -0.27 | -0.46 | 0.23         | 0.43  | 0.52        | 1.00   |       |        |       |             |       |             |         |       |      |
| Gloss   | 0.16         | <b>-0.76</b> | 0.01  | -0.46 | 0.58  | 0.30  | 0.37         | 0.12  | -0.15       | -0.19  | 1.00  |        |       |             |       |             |         |       |      |
| Sticky  | 0.15         | 0.00         | 0.31  | 0.25  | 0.40  | 0.28  | -0.22        | -0.61 | -0.28       | -0.05  | 0.24  | 1.00   |       |             |       |             |         |       |      |
| Opac    | -0.46        | 0.29         | -0.19 | -0.02 | -0.09 | 0.37  | <b>-0.82</b> | -0.64 | -0.20       | -0.35  | -0.40 | -0.01  | 1.00  |             |       |             |         |       |      |
| Bland   | 0.14         | -0.29        | -0.27 | -0.02 | 0.05  | -0.15 | -0.02        | 0.10  | 0.70        | 0.64   | 0.21  | -0.02  | -0.01 | 1.00        |       |             |         |       |      |
| Slip    | 0.37         | -0.19        | 0.37  | -0.42 | 0.56  | 0.16  | 0.25         | -0.21 | 0.09        | -0.21  | 0.70  | 0.62   | -0.44 | 0.14        | 1.00  |             |         |       |      |
| Patch   | 0.24         | -0.31        | -0.21 | -0.40 | -0.03 | -0.22 | 0.23         | 0.21  | <b>0.82</b> | 0.45   | 0.36  | -0.22  | -0.23 | <b>0.87</b> | 0.29  | 1.00        |         |       |      |
| Texture | -0.17        | -0.18        | -0.09 | 0.46  | -0.10 | 0.15  | -0.29        | -0.33 | 0.27        | 0.61   | -0.08 | 0.38   | 0.32  | <b>0.75</b> | -0.03 | 0.38        | 1.00    |       |      |
| Taste   | -0.48        | -0.32        | -0.22 | 0.43  | -0.65 | 0.24  | -0.14        | -0.28 | -0.22       | 0.25   | -0.26 | -0.03  | 0.35  | 0.03        | -0.55 | -0.13       | 0.42    | 1.00  |      |
| OVAC    | -0.03        | 0.07         | -0.09 | 0.07  | -0.16 | -0.18 | -0.07        | 0.14  | <b>0.77</b> | 0.61   | -0.18 | -0.23  | 0.14  | <b>0.87</b> | -0.10 | <b>0.74</b> | 0.65    | -0.06 | 1.00 |

Amyl: amylose content, Pro: protein content, CHO: carbohydrate content, Fat: fat content, Ash: ash content, color parameters (L: Lightness, a: redness, b: yellowness), descriptive attributes (Brown: brownness, Brittle: brittleness, Flex: flexibility, Grey: grayness, Gloss: glossiness, Opac: opacity, Patch: patchiness, Transp: transparency) and affective sensory attributes (App: appearance, taste, texture, OVAC: overall acceptability).

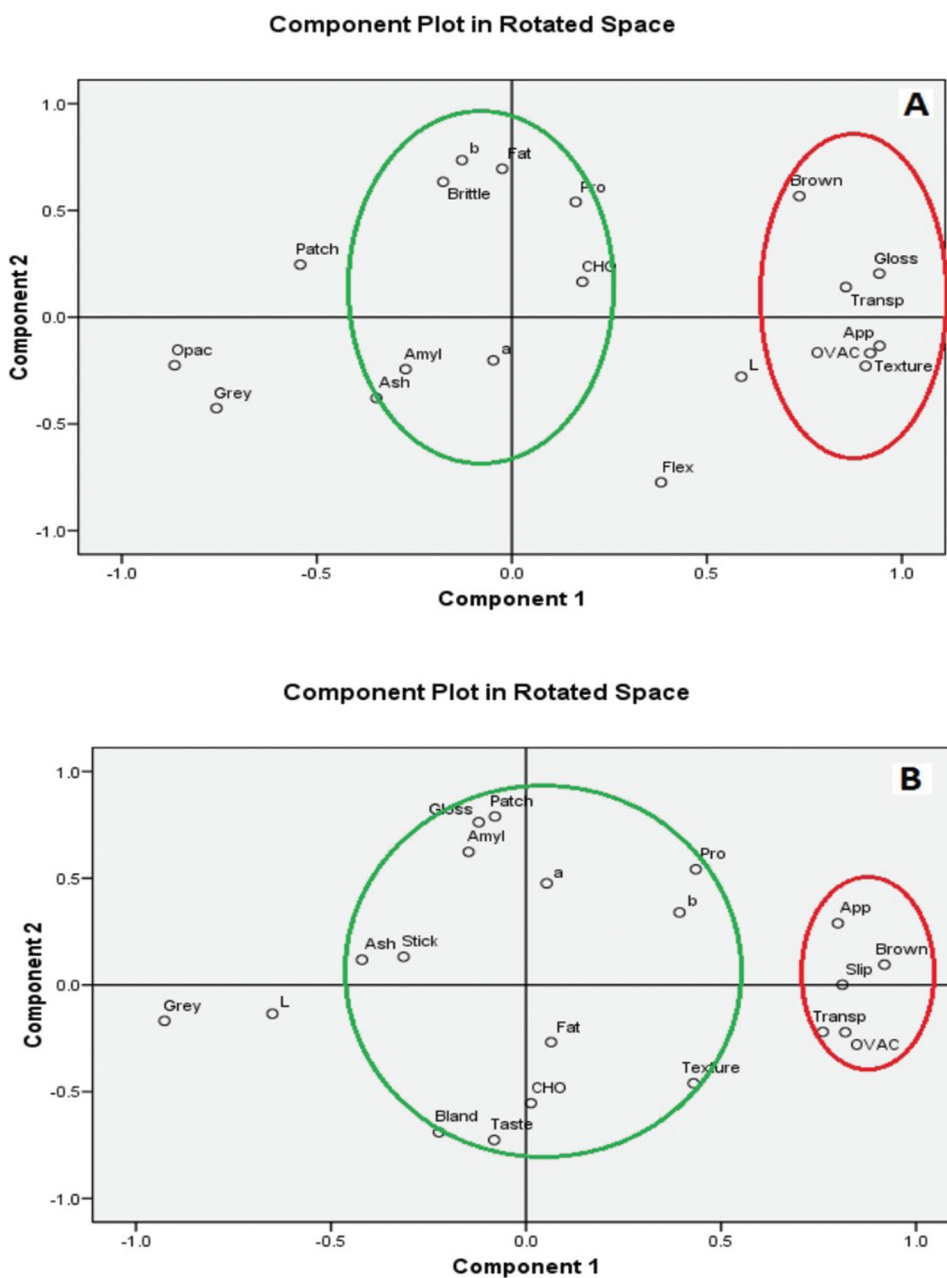


**Figure 2.** Principal component plots of dry starch composition (Amyl: amylose content, Pro: protein content, CHO: carbohydrate content, Fat: fat content, Ash: ash content), color parameters (L: Lightness, a: redness, b: yellowness), descriptive attributes (Brown: brownness, Brittle: brittleness, Flex: flexibility, Grey: grayness, Gloss: glossiness, Opac: opacity, Patch: patchiness, Transp: transparency) and affective sensory attributes (App: appearance, Taste, texture, OVAC: overall acceptability) of (A) uncooked and (B) cooked starch noodles using correlation matrix.

**Table 6.** Comparison of the Properties of Cooked and Uncooked Noodle Samples from the Two Product Clusters

| Property     | Uncooked noodles |           |            | Property     | Cooked noodles |           |            |
|--------------|------------------|-----------|------------|--------------|----------------|-----------|------------|
|              | Cluster 1        | Cluster 2 | Difference |              | Cluster 1      | Cluster 2 | Difference |
| Lightness    | 89.22            | 79.23     | 9.99       | Lightness    | 97.36          | 101.11    | -3.75      |
| Redness      | 5.82             | 5.68      | 0.14       | Redness      | 2.19           | 1.55      | 0.64       |
| Yellowness   | 27.18            | 28.17     | -0.99      | Yellowness   | 16.39          | 1.83      | 14.56      |
| Brownness    | 10.94            | 7.66      | 3.28       | Brownness    | 9.55           | 5.14      | 4.41       |
| Grayness     | 1.93             | 4.05      | -2.12      | Grayness     | 6.90           | 13.16     | -6.26      |
| Transparency | 10.75            | 5.67      | 5.08       | Transparency | 10.64          | 6.52      | 4.12       |
| Glossiness   | 11.05            | 6.39      | 4.66       | Glossiness   | 7.99           | 6.56      | 1.43       |
| Flexibility  | 5.13             | 4.50      | 0.63       | Stickiness   | 8.76           | 9.56      | -0.80      |
| Opacity      | 4.59             | 8.12      | -3.53      | Blandness    | 13.74          | 13.85     | -0.11      |
| Brittleness  | 9.35             | 9.00      | 0.35       | Slipperiness | 10.41          | 8.72      | 1.69       |
| Patchiness   | 5.26             | 8.21      | -2.95      | Patchiness   | 8.93           | 7.92      | 1.01       |
| Appearance   | 7.06             | 5.82      | 1.24       | Appearance   | 6.65           | 5.85      | 0.80       |
| Texture      | 6.20             | 5.55      | 0.65       | Texture      | 6.26           | 6.23      | 0.03       |
| OVAC         | 8.00             | 6.45      | 1.55       | Taste        | 4.70           | 4.85      | -0.15      |
|              |                  |           |            | OVAC         | 7.07           | 6.15      | 0.92       |

OVAC: overall acceptability.

Cluster analysis was used firstly to explore any clear partition among the cassava varieties in terms of their noodle making (physical and sensory) qualities. Due to the differences in the scales of measuring the variables, their values were standardized before being used in the clustering protocol. For the two types of noodles, two distinct clusters were formed (Figure 3). White cassava varieties dominated cluster 2 of the dry uncooked noodles, while the yellow varieties dominated the cluster 1 of the cooked noodles. Canonical discriminant function analysis (CDFA) showed that the varietal classification was 100% correct for both noodle types. Appearance score was the only variable included in the discriminant function for the uncooked noodles while for the cooked noodles, L, a, b, brownness, grayness, glossiness were included in the discriminant function (DF). The uncooked noodles from cluster 1 had higher lightness, brownness, transparency, and glossiness. The difference between the yellowness and brownness of the dry noodles from clusters 1 and 2 was not insignificant. However, when the noodles were cooked, the color difference between the noodles in cluster 1 increased. Yellowness and brownness of cooked noodles from cluster 1 became considerably increased compared to the dry noodles. The yellowness of these noodles could be partly due to the residual carotenoid pigment in their starches. Sensory acceptability of the dry noodles from cluster 1 was equally higher than those of cluster 2.

Similar variance was explained by the PC1 (28.1%) and PC2 (20.2%) for the cooked starch noodles. As shown in the correlation matrices (Table 6), most of the raw starch properties are glaringly separated from the cooked and uncooked noodle properties. The only exception is that shown by the negative correlation between the amylose content of the starches and the taste acceptability score of their respective cooked noodle samples. The two properties assumed opposite location on the plane of the PC2 (Figure 2B). This agrees with the result of Pearson's linear correlation ( $r = -0.65$ ,  $p > .05$ ). This implies that the results of PCA and Pearson's correlation agree tactically. The former shows the correlations spatially, whereas the latter gives quantitative idea of their relationship.

## Discussion

The crude protein content of the cassava starches has a positive correlation to the color, transparency, glossiness, flexibility and overall acceptability of the uncooked cassava starch noodles. This implies that, as the crude protein of the cassava starches increased, the color, transparency, glossiness, flexibility

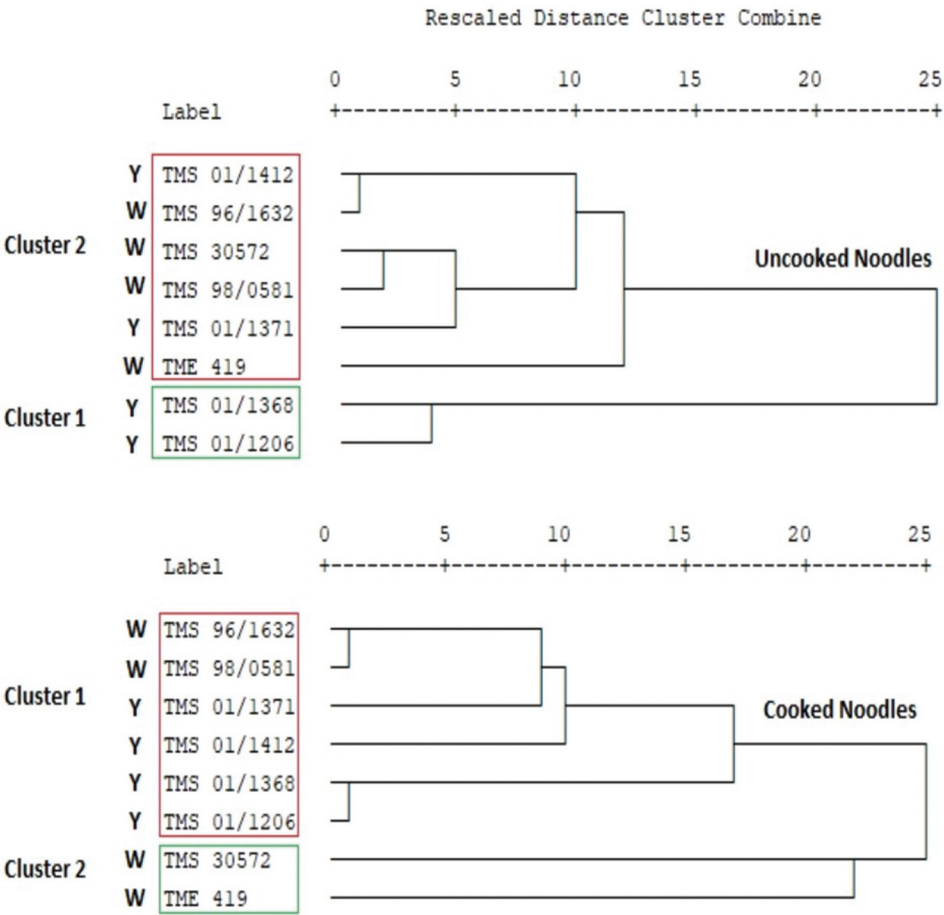


**Figure 3.** Dendrograms showing two distinct clusters of cassava varieties based on the tri stimulus color, descriptive and affective sensorial attributes of the dry and cooked noodles.

and overall acceptability of the uncooked cassava starch noodles also increased. So also the crude fat content of the cassava starches. As the crude fat increased, the color, transparency, glossiness, brownness, and general acceptability increased, while greyishness of the uncooked cassava starch noodles decreased.

The moisture content of the cassava starches is negatively correlated to the brown color and glossiness of the uncooked cassava starch noodles. That is, increase in the moisture content of the cassava starches led to a decrease in the brown color and glossiness of the uncooked cassava starch noodles. As the ash content of the cassava starches increased, the lightness, color and overall acceptability of uncooked cassava starch noodles increased, indicating a positive correlation between the ash content of the cassava starches and the sensory qualities of the uncooked starch noodles.

Amylose is the component of starch that influences the quality of starch-based food products. It is the most important factor affecting starch gel strength because of its prompt association, retrogradation and its interaction with lipids to form a helical complex and with amylopectin to give strong gel networks (Tan et al., 2009). The amylose content of cassava starch samples obtained in this study is lower than those previously reported for mung bean starch, but within the range of those previously reported for other materials that had been used in the production of starch noodles, like sweet potato starch (Young, Dennis, James, & Patricia, 1996), potato starch (Tan et al., 2009), corn starch (Sandhu, Singh, & Kaur, 2004), and most especially pea starch, whose starch is the second excellent material for starch noodle production after mung bean starch (Ratnayake, Hoover, & Warkentin, 2002; Tan et al., 2009).

The desired starches for noodle manufacture should have high value for lightness and low value for chroma (Tan et al., 2009). The lightness values reported in this study for uncooked noodles are higher than the result previously reported for uncooked mung bean starch noodles (57.99) and sweet potato starch noodles (48.62) (Thao & Noomhorm, 2011). Ash content of the cassava starches has a positive correlation with the lightness of uncooked starch noodles, while the carbohydrate content of the cassava starches is negatively correlated to the lightness of uncooked starch noodles.

Sensory evaluation is the expression of an individual like or dislike of a product as a result of biological variation in man and what people perceive as appropriate sensory properties. It is a unique source of product information not easily obtained by other means. It concerns itself with measuring the responses of people to products in terms of appearance, aroma, taste, texture and after taste, without the benefit of label, pricing or other imagery (Iwe, 2002).

Quantitative descriptive analysis (QDA) is a descriptive test that indicates the sensory properties of a product in a reproducible manner. The separate attributes contributing to the formulation of the overall impression of the product are identified, and their intensities assessed so as to establish a description of the appearance and/or texture of the product (Iwe, 2002). Quantitative descriptive analysis tests are recommended for product development and quality control. The success of a QDA test depends on the ability of the assessors to work together as a group and express their opinions clearly (Iwe, 2002). The descriptive attributes developed in this study for uncooked starch noodles are all significantly different from each other.

In the sensory evaluation study (preference test) of uncooked cassava starch noodles, the mean score of samples reported in this study for color, transparency, glossiness, flexibility, brittleness, opacity, patchiness and general acceptability revealed that panelists detected a significant difference in all the samples, including the reference noodle sample. However, uncooked cassava starch noodles were more acceptable in terms of color, transparency and

glossiness when compared with the reference noodle sample (made from sweet potato starch). This indicates that some cassava varieties can suitably replace at least sweet potato starch for starch noodles production.

## Conclusions

This study has shown that in spite of the significant differences in the color and chemical properties of the cassava starches, they can be acceptable as raw materials in noodle making. It was also found that these properties may not be directly useful to screen them for noodle making purposes due to their low correlations with the sensory properties of the noodles. Their suitability got partitioned along variety along their dry and cooked forms. Varieties TMS 01/1368 and TMS 01/1206 consistently showed their suitability in the dry and cooked forms. The most acceptable cassava starch noodles were obtained from TMS 01/1206 followed by TMS 01/1368, while the least acceptable noodle was obtained from TME 419.

## Disclosure statement

No potential conflict of interest was reported by the author(s).

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