

Effect of replacement of cassava starch with sweet potato starch on the functional, pasting and sensory properties of tapioca grits

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ABSTRACT

This study investigated the effect of replacement of cassava starch (CS) by 20, 40, 60, 80 and 100% with sweet potato starch (SPS) on the physicochemical and sensory properties of tapioca (a meal made by roasting and partial gelatinization of CS). Amylose content ranged from 23.89% to 30.25% with SPS inclusion from 0 through 100%. Peak viscosity and breakdown decreased while final viscosity and setback increased, with increasing SPS. Peak time and peak temperature were in the ranges of 4.3–5.0 min and 50.20–75.0 °C, respectively. Least gelation capacity (L.G.C.), swelling capacity (S.C.) and water absorption capacity (W.A.C.) increased by 16.67–80.67%, 7.17–21.18% and 0.33–10.90%, respectively. All tapioca samples were generally accepted, though 100% CS tapioca was most accepted. Tapioca sample with 20% SPS was most accepted among the various CS-SPS blends. Sensory impairment was attributed to caramelization of sucrose remnant in the SPS extract. The increased functional properties, particularly W.A.C. and S.C., of tapioca in this study is an indication of less soaking time which can reduce the drudgery associated with the preparation of tapioca. The study also reveals a strategy to diversify the traditional base source of the meal.

1. Introduction

The only known, main root ingredient for the production of tapioca grits is cassava (*Manihot esculenta* crantz), even though there are many other root and tuber crops which are also locally available in the tropics. Cassava is a major root crop in the tropics and its starchy roots are a significant source of calories for more than 500 million people worldwide. Cassava is processed for several reasons including shelf-life extension, palatability improvement, and detoxification. Some of the common cassava products in Nigeria are *gari*, *fufu*, *elubo*, *abacha* and tapioca. Meanwhile, tapioca referred to in this study is the food product from cassava root, which became popular in Southern part of Nigeria during the 20th century, mostly among the inhabitants of Lagos and its environs (Otegbayo, Samuel, & Alalade, 2013). It does not denote cassava as being referred to in some parts of the world (Ezeh, 2015).

Tapioca is a partially gelatinized dried cassava starch, which appears as flakes or irregularly shaped granules (Eke, Achinewhu, & Sanni, 2010a). Tapioca pearls are small, typically white spheres, each about 2 mm in diameter (Balogun, Karim, Kolawole, & Solarin, 2012). The status of the product in Nigeria was formerly described as that of a smuggled good (Eke et al., 2010a). This necessitated that its production

processes be studied for onward transfer to local processors. Tapioca is made by drying and heating of cassava starch for partial hydrolysis and gelatinization (Otegbayo et al., 2013). The resulting tapioca grits are softened before consumption and usually taken with milk and chopped coconut, making it a vehicle for some important nutrients. For enhanced eating quality and protein supplementation, it is also sometimes taken with *akara* (fried cowpea balls) in Nigeria. The meal is savored by people of all ages and classes, most especially as a breakfast meal. Studies have shown that replacement, or substitution, of traditionally used food ingredients with novel ones can promote utilization of lesser known food materials (Bamidele, Fasogbon, Oladiran, & Akande, 2015; Karim, Balogun, Akintayo, & Awoyale, 2016), create varieties (Karim et al., 2016), improve nutritional status (Balogun et al., 2012; Oluwamukomi & Jolayemi, 2012; Otegbayo et al., 2013), and provide health benefits (Ojo & Akande, 2013).

Attempts have been made by different researchers to improve the nutritional value and functionality of tapioca. Balogun et al. (2012) investigated the feasibility of improving the protein content of the product by supplementation with defatted soy flour, and found out that the sample with 20% defatted soy flour had the highest protein, and was also rated highest in terms of overall acceptability. Otegbayo et al.

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(2013) conducted a similar research and reported that incorporation of full fat soy flour into tapioca at 15% level compared favorably well with that of 100% cassava tapioca in terms of functional properties. Eke et al. (2010a) studied the effects of cassava varieties on the functional and rheological properties of tapioca grits and found that water absorption, swelling power and viscosity of tapioca grits were influenced by varietal differences. No doubt, these are commendable researches, and with useful findings. However, there seems to be no published work on the use of other root or tuber crop for tapioca production. This means there is currently little or no information on the suitability of another root or tuber crop in the production of tapioca.

The use of sweet potato (*Ipomoea batatas*) was therefore intended in this study as a partial-to-full replacement of cassava in the production of tapioca grits in order to create another variety of the product and also to investigate what effect this replacement might have on the physicochemical properties of the meal, including water absorption and swelling capacities, which are indices of soakability and soaking period. Sweet potato starch has been reported to have higher water absorption capacity/swelling power (Adebowale, Sanni, & Fadahunsi, 2011; Agnes, Felix, & Ugochukwu, 2017) owing to its phosphorus or phosphate monoester content (Noda, 2010). Noda (2010) found that starches of sweet potato and cassava studied had average of 192 ppm and 94 ppm of phosphorus, respectively. In this study, functional, pasting and sensory properties of tapioca grits made separately from cassava and sweet potato starches as well as their blends at different levels are reported.

2. Materials and methods

Variety of cassava roots known as *oko iyawo*, and sweet potato tubers (both freshly harvested) used in this study were obtained from a local market at Tanke in Ilorin, Nigeria and were processed immediately.

2.1. Starch extraction from cassava root and sweet potato tubers

Starch was extracted from the freshly harvested and sweet potato tubers using the method described by Samuel, Otegbayo, and Alalade (2012). Freshly harvested cassava roots and sweet potato tubers were separately peeled, washed thoroughly with clean water and then grated into pulps. The resulting pulps were sieved through a piece of muslin cloth for starch extraction. The filtrate was allowed to settle for 4 h to obtain starch sediment which was then washed 4 times, followed by sun-drying at 28–30 °C and 70–80% RH for 5 h to minimize damaging effect on native starch granules (Eke, Achinewhu, & Sanni, 2010b). The resulting dry cake was milled into powders using a locally fabricated hammer mill with a 250 µm aperture size screen, cooled at ambient temperature, packaged in polythene bags (Fig. 1) and kept in cool dry place for subsequent use and analyses.



Fig. 1. Dried cassava and sweet potato starches

CS: Cassava starch

PS: Sweet Potato starch.

Table 1

Formulation of cassava and sweet potato starch blends for tapioca production.

Starch blends	Cassava (%)	Sweet potato (%)
C ₁₀₀ S ₀	100	0
C ₈₀ S ₂₀	80	20
C ₆₀ S ₄₀	60	40
C ₄₀ S ₆₀	40	60
C ₂₀ S ₈₀	20	80
C ₀ S ₁₀₀	0	100

2.2. Preparation of tapioca from cassava and sweet potato starches

In addition to 100% cassava starch and 100% sweet potato starch, a Mixture Design was used to formulate 4 blends of cassava-sweet potato starches, by replacing cassava starch with sweet potato starch at 20, 40, 60 and 80% (Table 1). These were moistened to 40% moisture content and then roasted in a flat hot pan (rubbed with little vegetable oil to minimize stickiness and burning) at 120–150 °C with constant stirring for 20 min (Eke et al., 2010b). The tapioca was then thinly spread on a tray to cool at ambient temperature, packaged in polyethylene bags (Fig. 2) and kept in a cool dry place for subsequent analyses.

2.3. Starch yield determination

Freshly harvested cassava roots and sweet potato tubers used were both weighed prior to peeling. After starch extraction and drying, starches obtained were weighed and their respective starch percentage yields were calculated as follows:

$$\% \text{starch yield} = \frac{W_2}{W_1} \times 100\%$$

Where W_1 = weight of unpeeled cassava/sweet potato tuber, W_2 = weight of dried extracted starch.

2.4. Amylose content determination

Suspension of ground tapioca grits (20 mg) in 0.5 N KOH solution (10 ml) was transferred into a 100 ml volumetric flask. This was diluted to the mark with distilled water, and to aliquot (10 ml) of this, 5 ml of 0.1 N HCl, followed by 0.5 ml of iodine reagent, was added, then diluted to 50 ml. Absorbance was taken at 625 nm. Amylose content was measured from a standard curve prepared from different amylose concentrations (Adejumo, Aderibigbe, & Owolabi, 2013).

2.5. Functional properties determination

Water absorption capacity: Suspension of 1 g of tapioca grits in 20 ml distilled water was centrifuged in a preweighed centrifuge tube at 3500 rpm for 45 min. The resulting supernatant was decanted and





Fig. 2. Tapioca grits produced from cassava and sweet potato starches and their blends.

water absorption capacity was taken as the weight gained by the sample after decantation (Karim et al., 2016).

Oil absorption capacity: Tapioca sample (1 g) was mixed with refined soybean oil (10 ml) and allowed to stand at room temperature for 30 min, followed by centrifugation at 3500 rpm for 30 min. Oil bound per gram of sample was taken (Oyeyinka et al., 2013).

Least gelation capacity: test tubes containing different concentrations (2–20%, w/v) of tapioca dispersions in 5 ml distilled water were heated at 90 °C in a water bath, then rapidly cooled under running tap water. This was further cooled at 4 °C for 2 h. Least gelation concentration was taken as the concentration of sample at which it did not slip when its test tube was inverted (Ajani et al., 2016).

Swelling capacity: this was tested following the procedure previously described (Karim et al., 2016). Tapioca sample (10 g) was transferred into a clean, dry calibrated measuring cylinder. The cylinder was adequately tapped and the volume occupied by the tapioca sample was taken. Distilled water (50 ml) at ambient temperature was then added and the resulting mixture was allowed to stand for 4 h. Swelling capacity was the ratio of the original volume to the final volume.

2.6. Pasting properties determination

Pasting properties of tapioca produced from cassava and sweet potato starch blends were measured using a Rapid Visco Analyser (RVA) (Newport Scientific Instruments, Australia), following the RVA corn starch method (Ribotta, Colombo, & Rosell, 2012). Briefly, suspension containing 3.0 g (db) of ground tapioca grits in 25 ml of distilled water was prepared and stirred thoroughly in RVA first at 960 rpm for 10 s and then at 160 rpm throughout the remainder of the test period.

2.7. Sensory evaluation of tapioca produced from cassava and sweet potato starch blends

Fifty (50) semi-trained panelists, very familiar with sensory qualities of tapioca meal were selected from among students of the Department of Home Economics and Food Science, University of Ilorin, Nigeria, following screening. The various tapioca grits were soaked in water in ratio 3:1 (i.e., 3 cups of water to 1 cup of tapioca grits) overnight, after which the presoaked tapioca grits were boiled in 2 cups of water with constant stirring until a clear and translucent color was

attained (Eke et al., 2010b). This was then served, with 1 and 2 teaspoonfuls of sugar and powder milk, respectively, to the panelists. The selected panelists were instructed to assess the product for color, aroma, taste, texture and overall acceptability, using a 9-point hedonic scale of preference on which 9 represents “like extremely” and 1 represents “dislike extremely”. Prior to the sensory analysis, the panelists were screened with respect to their interest and ability to differentiate food sensory properties.

2.8. Statistical analysis

All the data generated from the analyses above were subjected to Analysis of Variance, and the obtained means were separated by Multiple Paired Comparison Test (Duncan test) using Statistical Package for Social Science (version 20).

3. Results and discussions

3.1. Starch yield

Starch obtained from cassava roots was 3% higher (wet basis) than from sweet potato tubers (Fig. 3). Previous studies similarly found higher starch yield from cassava, as compared to that from sweet potato tubers (Eke-Ejiofor, 2015; Ziska et al., 2009). The yields of starch for both crops are within the values reported in literature. Taiana, Hugo, and Rosinelson (2012) reported 12.31–21.76% for cassava while Tuffour (2013) reported 14.6–25.1% for non hi-starch sweet potato. Meanwhile, value as high as 30% has also been noted for cassava (Nuwamanya, Baguma, Emmambux, Taylor, & Patrick, 2010).

3.2. Amylose content of tapioca produced from cassava-sweet potato starch blends

The amylose contents (23.89–30.25%) of the tapioca samples increased with increasing levels of sweet potato starch, suggesting that the amylose content of sweet potato starch used in this study is higher than that of cassava starch. Values ranging from 18.30 to 22.95% have been recorded as the amylose contents of tapioca grits made from different varieties of cassava roots. While the amylose contents of most cassava starches are approximately within the range of 20–30%

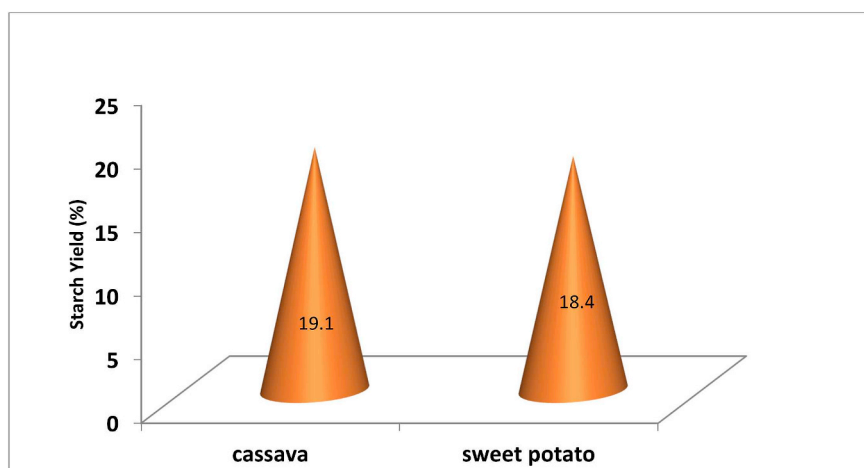


Fig. 3. Percentage yields of cassava and sweet potato starches.

(Nuwamanya et al., 2010; Vasconcelos, Brito, Carmo, Oliveira, & Oliveira, 2017), values within the range of 27–38% have been reported for sweet potato starches (Vargas-Aguilar, 2016). This difference in amylose content is an indication of variation in the functional and pasting properties of the various tapioca samples during soaking and heating, as amylose is known to greatly determine properties of starch and starch-based foods (Nuwamanya, Baguma, Wembabazi, & Rubaihayo, 2011).

3.3. Functional properties of tapioca produced from cassava-sweet potato starch blends

3.3.1. Water absorption capacity (WAC) and oil absorption capacity (OAC)

There was a significant ($p < 0.05$) difference between the WAC (122.5–1350 g/g) of the various tapioca blends (Table 2). The amount of water absorbed by the tapioca samples increased with increasing levels of sweet potato starch, which could be due to the presence of more hydrophilic components such as high phosphate monoester content in sweet potato starch. Differences in the amylose contents of the tapioca samples may also explain the variation in their WAC. The WAC for 100% cassava tapioca recorded in this study is similar to that (125%) previously reported by Otegbayo et al. (2013). Agnes et al. (2017) earlier found that sweet potato starch had higher WAC than cassava starch. The higher water absorption of sweet potato could help

Table 2

Functional properties of tapioca produced from cassava and sweet potato starch blends.

Sample	Water absorption capacity (%)	Oil absorption capacity (%)	Swelling capacity (%)	Least gelation capacity (%)
C ₁₀₀ S ₀	122.00 ^e ± 0.00	108.90 ^b ± 0.10	325.00 ^e ± 4.5	7.14 ^a ± 0.2
C ₈₀ S ₂₀	122.25 ^e ± 0.07	108.94 ^b ± 0.40	344.50 ^d ± 9.5	8.33 ^b ± 0.1
C ₆₀ S ₄₀	124.50 ^d ± 0.00	111.00 ^a ± 0.10	350.00 ^{cd} ± 2.8	9.09 ^c ± 0.8
C ₄₀ S ₆₀	129.50 ^c ± 0.07	111.20 ^a ± 0.20	360.00 ^{bc} ± 9.9	10.34 ^d ± 0.2
C ₂₀ S ₈₀	131.00 ^b ± 0.14	109.00 ^b ± 0.40	370.50 ^{ab} ± 3.5	11.45 ^e ± 0.3
C ₀ S ₁₀₀	135.20 ^a ± 0.14	109.80 ^{ab} ± 0.10	381.00 ^a ± 8.4	12.90 ^f ± 0.2

Values are means ($n = 3$) ± standard deviation; means having different superscripts within same column differ significantly ($p < 0.05$). Keys.

C₁₀₀S₀: 100% cassava starch and 0% sweet potato starch; C₈₀S₂₀: 80% cassava starch and 20% sweet potato starch; C₆₀S₄₀: 60% cassava starch and 40% sweet potato starch; C₄₀S₆₀: 40% cassava starch and 60% sweet potato starch; C₂₀S₈₀: 20% cassava starch and 80% sweet potato starch; C₀S₁₀₀: 0% cassava starch and 100% sweet potato starch.

reduce the typically long soaking time associated with tapioca. It will also reflect in the viscosity of tapioca pudding (Leonel, Freitas, & Mischon, 2009).

The OAC did not follow a steady trend as observed for WAC (Table 2). Tapioca samples having closest proportions of cassava and sweet potato starches (i.e., C₆₀S₄₀ and C₄₀S₆₀) absorbed more oil (Table 2). This suggests there are possibly some interesting interactive effects that are yet unclear between the materials. Babu and Parimalavalli (2012) previously reported that oil absorption capacity is influenced by the lipophilic nature on the granular surface and interiors of starches. Oil absorption capacity is important since oil improves palatability, and plays a vital role in shelf life of food. It is particularly important for tapioca, since the meal is usually taken with milk (an oil in water emulsion).

3.3.2. Swelling capacity

The swelling capacities (344%–381%) of tapioca samples made from the various cassava-sweet potato starch blends were significantly ($p < 0.05$) higher than that from 100% cassava sample (325%) (Table 2). Tapioca made from 100% sweet potato starch had higher (20%) swelling capacity than the one made from 100% cassava starch. This can be partly attributed to the higher WAC of sweet potato starch as recorded in this study (Table 2). Swelling capacity is an indication of water absorption index of starch granules and reflects the extent of associative force within starch (Agnes et al., 2017). The high swelling index of sweet potato tapioca in this study does not agree with the report of Alcázar-Alay and Meireles (2015). These authors reported that swelling capacity of starch is directly associated with its amylopectin content, and that amylose acts as a diluent, inhibiting swelling. In this study, tapioca samples with more sweet potato starch had higher amylose content (Fig. 4) as well as higher swelling capacity. However, extent of swelling is not just influenced by amylose-amylopectin proportions, but also by granule size, presence of pores and variation in other structural characteristics of starch granules (Cornejo-Ramírez et al., 2018). Moreover, Nuwamanya et al. (2011) noted that swelling is well correlated to amylose as well as its properties, and that existence of phosphate groups increases water binding capacity, hence swelling of starches.

3.3.3. Least gelation capacity (LGC)

The result of gelation analysis shows that the amount of the tapioca samples needed to form gels increased as the level of sweet potato starch increased (Table 2). Sample from 100% cassava starch had the lowest value (7.14%) while 100% sweet potato substituted tapioca had the highest (12.90%). Previous study by Otegbayo et al. (2013) showed that least gelation capacity of cassava tapioca is 8.0%. Adebawale et al.

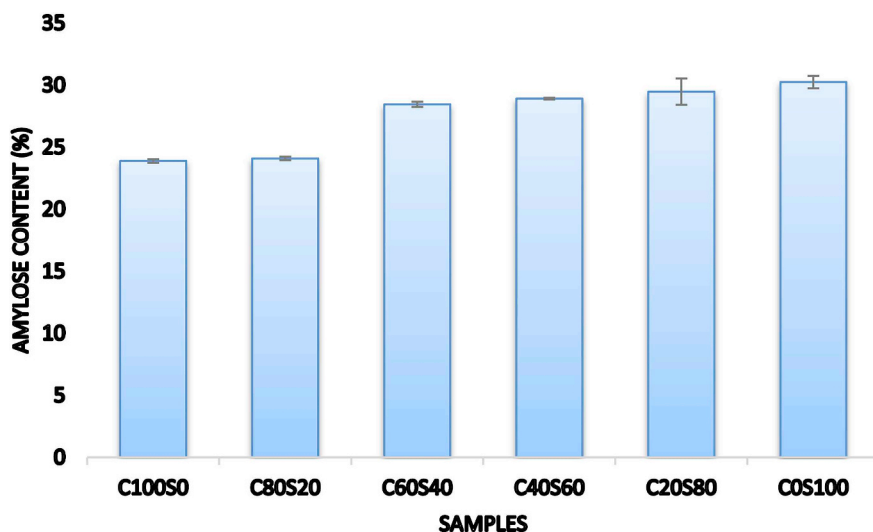


Fig. 4. Amylose content of tapioca produced from cassava-sweet potato starch blends

Keys
 C₁₀₀S₀: 100% cassava starch and 0% sweet potato starch;
 C₈₀S₂₀: 80% cassava starch and 20% sweet potato starch;
 C₆₀S₄₀: 60% cassava starch and 40% sweet potato starch;
 C₄₀S₆₀: 40% cassava starch and 60% sweet potato starch;
 C₂₀S₈₀: 20% cassava starch and 80% sweet potato starch;
 C₀S₁₀₀: 0% cassava starch and 100% sweet potato starch.

(2011) reported that the LGCs of cassava-sweet potato starch blends were higher than that of cassava or sweet potato starch alone, implying that less amount of sweet potato tapioca blend would be required to form paste during processing.

3.4. Pasting properties of tapioca produced from cassava and sweet potato starch blends

Tapioca made from 100% cassava starch showed significantly ($p < 0.05$) higher peak viscosity (5699.50 RVU) than sample made from 100% sweet potato starch (4165.00 RVU) as well as those made from the blends of the two starches (Table 3). With increasing levels of sweet potato starch, there was a gradual decline in the peak viscosity of the tapioca samples. Peak viscosity of starchy foods are influenced by a number of factors including differences in starch granule size, starch composition, and presence of non-starch components such as fibre and lipids. Previous studies have shown that sweet potato starch showed lower viscosity than cassava starch (Vargas-Aguilar, 2016). Furthermore, Adebawale et al. (2011) noted that 100% cassava starch had higher peak viscosity than cassava-sweet potato starch blends. Peak viscosity means the maximum viscosity developed during or after heating (Eke-Ejiofor, 2015).

There was a significant ($p < 0.05$) difference between 100% sweet potato tapioca and other samples in terms of trough viscosity, with 100% cassava tapioca having the highest value. Trough is the minimum viscosity following attainment of peak viscosity (Bolarinwa, Olaniyan, Adebayo, & Ademola, 2015) and indicates water holding capacity of starch paste at constant temperature. Onwurafor, Umego, Uzodinma,

and Samuel (2017) noted that higher viscosity breakdown of starch implies lower ability to withstand heat and shear stress during cooking. Ojo, Ariahu, and Chinma (2017) also reported a similar result while comparing cassava and mushroom starch blends.

Final viscosities of the tapioca samples increased with increasing levels of sweet potato starch (Table 3). Final viscosity which has been described as the viscosity attained after cooling of cooked starch to 50 °C (Mandge, Sharma, & Dar, 2014) reveals the ability of starch to form a viscous gel or paste following cooking and cooling. The final viscosity of tapioca from 100% cassava was significantly ($p < 0.05$) lower than those of samples prepared from sweet potato starch and the blends of cassava and sweet potato starches. Thus, it is probable that more highly viscous gel will be formed with cassava-sweet potato tapioca during cooling than with 100% cassava tapioca. The result of final viscosity is in agreement with earlier report on the pasting properties of cassava and sweet potato starch blends (Ojo et al., 2017).

Setback reveals retrogradation tendency of amylose present in starch (Jude-Ojei, Lola, Ajayi, & Seun, 2017). This ranges between 871.5 and 1797.5 RVU for the various tapioca samples, increasing with increasing sweet potato levels. This can be attributed to the higher amylose content of sweet potato starch (Fig. 4). However, the increase in setback was not significant ($p > 0.05$) till 60% inclusion level of sweet potato starch.

The peak time (4.30–5.00 min) recorded in the study is similar to the range (4.37–5.41 min) reported by Eke-Ejiofor (2015) for starches from cassava and sweet potato varieties studied. This implies tapioca made from cassava and sweet potato starch blends would attain their highest levels of viscosity within 5 min of heating. There was a

Table 3
 Pasting properties of tapioca produced from cassava-sweet potato starch blends.

Sample	Peak (RVU)	Trough (RVU)	Breakdown (RVU)	Final viscosity (RVU)	Setback (RVU)	Peak time (mins)	Pasting temp (°C)
C ₁₀₀ S ₀	5699.5 ^a ± 91.3	2253.0 ^c ± 69.3	3446.5 ^a ± 21.9	3124.5 ^d ± 3.54	871.5 ^d ± 72.8	4.300 ^d ± 0.47	50.20 ^f ± 0.55
C ₈₀ S ₂₀	4592.0 ^b ± 94.8	2168.5 ^{cd} ± 91.9	2432.5 ^b ± 103.9	3133.0 ^d ± 52.3	964.5 ^{cd} ± 61.5	4.566 ^c ± 0.47	63.03 ^e ± 0.61
C ₆₀ S ₄₀	4114.0 ^d ± 70.7	2225.5 ^c ± 13.4	1888.5 ^d ± 6.4	3298.0 ^c ± 59.4	1072.5 ^c ± 72.8	4.766 ^b ± 0.05	70.15 ^c ± 0.00
C ₄₀ S ₆₀	4218.5 ^c ± 150.6	2068.0 ^d ± 35.3	2150.5 ^c ± 185.9	3077.5 ^d ± 31.8	1009.5 ^{cd} ± 35.4	4.634 ^a ± 0.05	65.20 ^d ± 1.20
C ₂₀ S ₈₀	3928.5 ^d ± 10.6	2465.0 ^b ± 72.1	1463.5 ^c ± 61.5	3788.5 ^b ± 19.1	1323.5 ^b ± 91.2	4.900 ^a ± 0.05	72.57 ^b ± 0.04
C ₀ S ₁₀₀	4165.0 ^c ± 108.9	2856.5 ^a ± 17.7	1308.5 ^c ± 91.2	4654.0 ^a ± 127.3	1797.5 ^a ± 109.6	5.000 ^a ± 0.00	75.00 ^a ± 0.71

Values are means ($n = 3$) ± standard deviation; means having different superscripts within same column differ significantly ($p < 0.05$).

Keys.

C₁₀₀S₀: 100% cassava starch and 0% sweet potato starch; C₈₀S₂₀: 80% cassava starch and 20% sweet potato starch; C₆₀S₄₀: 60% cassava starch and 40% sweet potato starch; C₄₀S₆₀: 40% cassava starch and 60% sweet potato starch; C₂₀S₈₀: 20% cassava starch and 80% sweet potato starch; C₀S₁₀₀: 0% cassava starch and 100% sweet potato starch.

Table 4

Sensory scores of tapioca produced from cassava and sweet potato starch blends.

Sample	Appearance	Texture/mouthfeel	Taste	Aroma	Overall acceptability
C ₁₀₀ S ₀	7.78 ^a ± 0.84	7.02 ^a ± 0.82	7.04 ^a ± 1.11	7.14 ^a ± 1.13	7.52 ^a ± 0.71
C ₈₀ S ₂₀	6.90 ^b ± 0.78	6.92 ^a ± 0.72	7.10 ^a ± 0.76	6.66 ^b ± 0.89	6.90 ^b ± 0.71
C ₆₀ S ₄₀	6.60 ^b ± 0.68	6.88 ^a ± 0.87	6.90 ^a ± 0.74	6.62 ^b ± 0.95	6.87 ^b ± 0.68
C ₄₀ S ₆₀	6.34 ^c ± 0.92	6.64 ^b ± 1.17	6.90 ^a ± 0.69	6.70 ^b ± 0.89	6.74 ^b ± 0.83
C ₂₀ S ₈₀	6.24 ^c ± 0.96	6.38 ^b ± 1.19	6.14 ^b ± 0.88	5.96 ^c ± 1.05	6.16 ^c ± 0.74
C ₀ S ₁₀₀	5.28 ^d ± 1.36	5.74 ^c ± 1.44	6.08 ^b ± 1.19	5.62 ^c ± 1.16	5.72 ^d ± 1.03

Means having different superscripts within same column differ significantly ($p < 0.05$).

Keys.

C₁₀₀S₀: 100% cassava starch and 0% sweet potato starch; C₈₀S₂₀: 80% cassava starch and 20% sweet potato starch; C₆₀S₄₀: 60% cassava starch and 40% sweet potato starch; C₄₀S₆₀: 40% cassava starch and 60% sweet potato starch; C₂₀S₈₀: 20% cassava starch and 80% sweet potato starch; C₀S₁₀₀: 0% cassava starch and 100% sweet potato starch.

significant increase in pasting temperature from 50.20 °C for 100% cassava tapioca to 75.00 °C for 100% sweet potato tapioca. This shows that replacement of cassava starch with sweet potato starch will increase the gelatinization temperature of tapioca. This is consistent with the finding of Vargas-Aguilar (2016) who stated that cassava had a relatively lower gelatinization (pasting) temperature than other starches studied. As reviewed by Vargas-Aguilar (2016), pasting temperature of cassava and sweet potato starches could be within the ranges of 49–64 °C and 63–74 °C, respectively, depending on factors such as genetic composition and growing environment. The higher pasting temperature of sweet potato starch may be associated with its higher amylose content (Fig. 4), as pasting temperature and amylose content are positively correlated (Ayetigbo, Latif, Abass, & Müller, 2018). It can also be due to starch-sucrose interaction (Sharma, Oberoi, Sogi, & Gill, 2009). Ziska et al. (2009) noted that about 30% of the carbohydrate present in sweet potato is in form of sucrose.

3.5. Results of sensory evaluation of tapioca produced from cassava and sweet potato starch blends

The sensory attributes of the tapioca samples significantly ($p < 0.05$) decreased with increasing levels of sweet potato starch, particularly in appearance, aroma and overall acceptability (Table 4). However, the various cassava-sweet potato tapioca blends were generally accepted by the panelists, most especially tapioca sample having 20% sweet potato starch. The sensory impairment may be attributed to a number of factors. It has been reported that sweet potato starch contains some level of sucrose (Ziska et al., 2009). This might have probably caramelised during heating, thereby impairing the whiteness of the starch. Presence of sucrose in starch has been reported to decrease starch whiteness (Craig, Manifigat, Seib, & R.C., 1989). The whiter color of tapioca made from 100% cassava starch may explain why the panelists rated it higher in appearance and overall acceptability. Tapioca is traditionally produced from cassava starch, and typically white in color.

4. Conclusions

Water absorption capacity and swelling capacity of tapioca were improved with increasing sweet potato levels, indicating potential reduction in soaking of tapioca grits. Peak viscosity and breakdown decreased while the final viscosity and setback increased with increasing sweet potato levels. Though the sensory quality of tapioca produced from cassava-sweet potato starch blends was lower than that of tapioca made from 100% cassava starch, all the various blends were generally accepted, with 20% sweet potato starch inclusion giving the most accepted blend. This study has shown that the need to diversify the base ingredient for tapioca meal as well resuscitate the popularity of the product can be achieved by partial replacement of cassava starch by sweet potato starch.

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