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PHYSICAL, CHEMICAL AND FUNCTIONAL CHARACTERIZATION OF STARCH FROM *Manihot esculenta* MODIFIED WITH *Terminalia mantaly* GUM

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ABSTRACT

Starch extracted from the roots of *Manihot esculenta* and its composite blends with gum from *Terminalia mantaly* were studied for their physical, chemical and functional properties using standard experimental procedures. The proximate analysis of the starch gave values of 15.04 %, 84.96 %, 1.202 %, 0.97 %, 1.15 %, 0.635 %, and 96.655 % for moisture, dry matter, crude protein, ash, crude fibre, crude fat and carbohydrate respectively. The energy value was 394.715 Kcal/100 g. The amylose and amylopectin contents of the starch were 19.655 and 66.085 % respectively. There were significant differences in the water and oil absorption capacities, swelling power, solubility index, bulk/particle density and foaming capacity of the free starch and its blends while there were no significant differences in their gelation temperature and least gelation concentration. The peak and trough viscosities ranged from 399.08 (starch/gum ratio of 3.0:0.25) to 376.58 RVU (starch/gum ratio of 3.0:1.0) and 78.67 (starch/gum ratio of 3.0:0.25) to 115.58 RVU (starch/gum ratio of 3.0:1.0) respectively. Final viscosity ranged from 133.08 (starch/gum ratio of 3.0:0.25) to 187.83 RVU (starch/gum ratio of 3.0:1.0) while the pasting temperature and time ranged from 73.45 to 76.00 ℃ and 3.33 to 3.67 min, respectively. The morphology of the starch granules (size and shape) was studied with scanning electron microscope (SEM), which revealed that *M. esculenta* free starch showed asymmetric and irregular shaped granules with primarily ellipsoid and oval shapes. The modified starch showed oval, truncated and spherical granules. These variations in morphology of the granules could be attributed to the modification with *T. mantaly* gum as well as the biological origins of both the *M. esculenta* starch and the gums. Generally, there were improvements in the functional properties of the starch after modification.

Keywords*: Manihot esculenta*; *Terminalia mantaly*; Starch modification; Gum; Functional properties

INTRODUCTION

Cassava, *Manihot esculenta* Crantz is a perennial shrub belonging to the family Euphorbiaceae. It originated in South America and subsequently has been distributed to tropical and subtropical regions of Africa and Asia [1]. *M. esculenta* is a species whose roots are of great importance as a carbohydrate source in most of the world's lowland tropical areas. The cassava shrub may grow up to 2.75 m tall, with leaves that are deeply divided into 3–7 lobes. This food plant is also medicinally used to treat hypertension, headache, and other pains, irritable bowel syndrome and fever [2]. Cassava contains various chemical components such as balanophonin, scopoletin, and tannins which have been studied to exhibit anti-oxidant activity, anti-proliferative and anti-inflammatory properties [3].

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Terminalia mantaly belongs to the family of Combretaceae and commonly grows in savanna regions in Africa. The use of many parts of *T. mantaly* in traditional herbal medicine has been reported as a remedy for dysentery, gastroenteritis, hypertension, diabetes, and oral, dental, cutaneous and genital affections as well as the treatment of loss of voice [4]. The plant has also been reported to contain a variety of phytochemicals such as saponins, alkaloids, tannins, terpenes and flavonoids [5, 6]. The trunk of *T. mantaly* acts as a source of gum which if treated well can be utilized in the chemical industries. It is believed that a modified form of the gum from *T. mantaly* can be used to treat rheumatoid arthritis, osteoarthritis and ankylosing spondylitis [6, 7]. Gums from other plant sources have also been reported to contain bioactive constituents [8, 9, 10]. The aqueous and ethanolic extracts of *T. mantaly* have been reported to inhibit the growth of certain strains of *Styphylococcus aureus* and *Escherichia coli* [11].

The use of modified starch across numerous sectors is expanding as innovative experiments and new technologies in many food and non-food industrial sectors progress due to its high economic and social impact on human life [12]. Starch modification is considered necessary because some native starch granules may display certain unfavourable characteristics such as poor solubility, very high or very low viscosity, thermal decomposition, retrogradation, syneresis that may limit their industrial utilization. Modification enhances a wider starch applicability hence the need for the development of various techniques for the alterations of the characteristics of native starch granules through physical, chemical and enzymatic methods. Several starch modifications with plant gums such as modification of cassava and maize starches with gums from the seeds of *Delonix regia* and *Brachystegia eurycoma* and evaluating the starch-gum interactions have been reported [13, 14]. In this research, the physical, chemical and functional characterization of native starch granules from *M. esculenta* modified with *T. mantaly* gum are herein reported.

MATERIALS AND METHODS

Sample Collection and Identification

M. esculenta tubers used for the preparation of the starch were harvested from a farm in Mbutu Ngwa village in Isiala Ngwa South L.G.A. of Abia State, Nigeria. *T. mantaly* gum was harvested from the tree plant located in front of the College of Physical and Applied Sciences, Michael Okpara University of Agriculture, Umudike. For the purpose of proper identification, the plant materials (leaves and stems) were also harvested. They were then identified and authenticated at the Plant Taxonomy Section, Forestry Department, Michael Okpara University of Agriculture, Umudike, Abia state, Nigeria.

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Starch Extraction

Starch extraction was carried out using the wet method as described by Igwe *et al.* [15]. One kilogram of fresh tubers were thoroughly washed with water and then peeled with the aid of a clean kitchen knife and thoroughly washed again before being chopped into small pieces of approximately 1 cm length and then crushed in a blender to produce a pulp. The pulp was suspended in ten times its volume of deionized water and filtered through a clean muslin cloth. The filtrate was allowed to stand for 2 h until the starch settled. Afterwards, the starch was separated from the supernatant and suspended again in water. This washing procedure was repeated five times until a white starch and a translucent supernatant were obtained. The starch was collected and dried at room temperature under forced air circulation for approximately 12 h. The extraction of *M. esculenta* starch required the use of sodium sulfite as an antioxidant at a concentration of 0.03% in accordance with established food legislation to avoid enzymatic oxidation. This antioxidant was only employed during the first extraction phase i.e. during tuber milling.

Preparation of Terminalia mantaly Gum

The exudate was hydrated in a 0.5: 95.5 (v/v) $CHCl_3$/water mixture for five days with intermittent stirring; extraneous materials were removed by straining through a muslin cloth. Absolute ethanol was used to precipitate the gum from the solution. The precipitated gum was filtered, washed with diethyl ether, and then dried in a hot air oven at 45°C for 20 hours. The resultant pure gum was pulverized using a laboratory blender and passed through a 500 µm sieve and then transferred into an air-tight container where it was stored properly.

Starch/Gum Blending

M. esculenta starch was thoroughly mixed with *T. mantaly* gum powder with the aid of a blender in the following starch/gum ratio: 3.0:0.0, 3.0: 0.25, 3.0:0.5, 3.0:0.75 and 3.0: 1.0. A uniform blending was achieved in 10 min.

Chemical Analyses

Proximate Analysis

Moisture and total ash contents were determined by the method described by AOAC [16]. Crude protein, fibre and fat contents were determined by the method described by James [17]. Carbohydrate content was calculated by difference as described by James [17]. The difference in value was taken as the percentage of total carbohydrate content of the sample. Calculated thus:

$$\%\,\text{Carbohydrate} = 100 - (\%\text{Protein} + \%\text{Moisture} + \%\text{Fat} + \%\text{Ash})$$

Amylose and Amylopectin Determination

The starch amylose and amylopectin contents were determined according to the method described by Valcárcel-Yamani *et al*. [18]. A

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volume of 5.0 mL of dimethyldisulfide and urea (UDMSO) at 6 M, 9:1 was added to 40 mg of isolated starch sample; the suspension was vigorously shaken and incubated in a boiling water bath for 30 min, then placed on a stove at 100 °C for 90 min. A 0.5 mL aliquot of this solution was diluted to 50 mL with distilled water and 1.0 mL I2-KI (2 mg I2, 20 mg KI/mL). Finally, the absorbance at 635 nm was measured with a UV-Vis B582 spectrophotometer. The amylose content was determined with a standard curve, using stock amylose (from potato starch, Sigma-Aldrich Co. St. Louis, USA) and amylopectin (from potato starch, Sigma-Aldrich CO, St. Louis, USA, A8515) solutions.

Energy Value

The gross food energy value (E.V) of *M. esculenta* starch was estimated in Kcal/100 g energy using the Atwater Factor Method as described by Osborn and Voogt [19], by using the equation below.

$$\text{E.V} = [(\%\text{Crude Fat} \times 9) + (\%\text{Crude Protein} \times 4) + (\%\text{Carbohydrate} \times 4)]$$

Physical and Functional Properties

Water and Oil Absorption Capacities (WAC and OAC)

The WAC and OAC were calculated using the method described by Sosulski *et al.* [20]. One gram of flour was combined with distilled water (10 mL; refined soy bean oil for OAC) and incubated at 30°C for 30 min. After that, the centrifugation was done at 3000 rpm for 30 min. The sediment's weight was calculated. The WAC and OAC were determined as a percentage of the wet weight of the flour.

$$\%\ \text{WAC} = \frac{\text{Weight of the water added to the sample} - \text{weight of the water removed from the sample}}{\text{weight of the flour sample}} \times 100$$

$$\%\ \text{OAC} = \frac{\text{Weight of the oil added to the sample} - \text{weight of the oil removed from the sample}}{\text{weight of the flour sample}} \times 100$$

Swelling Power and Solubility

The swelling power and solubility patterns of *M. esculenta* starch and its blends with *T. mantaly* gum were determined as described in Kusumayanti *et al*. [21] at different temperatures (50, 60, 70, 80 and 90). Sample (0.5 g dry weight) was suspended in 20 ml water in centrifuge tube (50 ml) of known weight, heated for 30 min at specified temperature, swirling at every 5 min, and then centrifuged at 8000 rpm for 20 min using Beckman Coulter Centrifuge (Avant J-26 XPI, High Performance Centrifuge, USA). The supernatant was discarded and the sediment mass was measured as Wsd. The swelling power (g/g) was calculated as the ratio of Wsd to the original sample weight (Ws). The volume of the supernatant was measured and was collected on a pre-weighed evaporating crucible dish, oven dried at 105 °C for 12 h and the dried residue was weighed as Wd. The solubility was then

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expressed as a percentage of dried supernatant weight to the original sample weight (Ws).

$$\text{Swelling Power (g/g)} = \frac{\text{Wsd}}{\text{Ws (dry basis)}}$$

$$\text{Solubility (\%)} = \frac{\text{Wd}}{\text{Ws (dry basis)}} \times 100$$

Where, Wsd = dried sediment mass, Ws = original sample weight, Wd = dried residue

2.7.3: Gelatinization Temperature (GT)

The gelatinization temperature (GT) was determined according the method described by Chandra *et al.* [22]. One gram of flour was weighed, and distilled water (10 mL) was added. Until a solid gel is formed, the mixture was incubated in a water bath. The temperature, which plays a role in the gel formation, was measured as the GT.

Least Gelation Concentration

The least gelation concentration (LGC) was determined by the method of Sathe *et al.* [23]. Suspensions of 2, 4, 6 and 8 up to 20 g/100 ml distilled water were prepared and 10 ml of each dispersion was transferred into a test tube. The test tubes were then heated for 1 h in a boiling water bath, followed by rapid cooling in ice and further cooling for 2 h at 4 °C. The least gelation concentration was determined as the concentration when the sample in the inverted test tube will not slip.

Bulk Density

The bulk density (BD) of the sample was determined using the method described by Onwuka [24]. About 5 g of the flour sample was weighed into 50 ml graduated measuring cylinder. The sample was packed by gently tapping the cylinder on the bench top 10 times from a height of 5 cm. The volume of the sample was recorded.

$$\text{Bulk density (g/}cm^3\text{)} = \frac{\text{Weight of sample}}{\text{Volumn of sample after tapping}}$$

Foaming Capacity

The foaming capacity (FC) was studied by the method of Coffman and Garcia [25] with slight modification. 2 g of the sample was weighed and added to 50 ml distilled water in a 100 ml measuring cylinder. The resulting suspension was homogenized by properly shaking for 5 min to foam. The total volume after 30 seconds was recorded. The percentage increase in volume after 30 seconds is expressed as foaming capacity.

$$Foaming\ capacity\ (\%) = \frac{\text{Volume after homogenization} - \text{volume before homogenization}}{\text{Volume before homogenization}} \times 100$$

Pasting Properties

Pasting characteristics were determined using a rapid visco analyzer (RVA) (Model RVA 3D+ Newport Scientific Australia). About 3 g of the starch samples were weighed into a previous dried canister and 25 ml of distilled water was dispensed into the canister containing the sample. The suspension was thoroughly mixed and the

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canister was fitted into the rapid visco analyzer as recommended. Each suspension was kept at 50°C for 1 min and then heated up to 95 with a holding time of 2 min. followed by cooling to 50°C with 2 min holding time. The rate of heating and cooling were at a constant rate of 11.55°C per min. Peak viscosity, trough, breakdown, final viscosity and setback were read from the pasting profile with the aid of a thermocline for windows software connected to a computer.

Morphological Property

Morphological characterization of the free starch of *M. esculenta* and its blend were carried out via scanning electron microscopy (SEM) using a modular high vacuum coating system (model SU900, bal-Tech) and FEI quanta 600 FEG model microscope. Samples were prepared and fixed in stubs on double sided carbon tape and coated with platinum for plating in modular equipment at a pressure of 5.00 KV.

Statistical Analysis

Statistical treatment was performed by analysis of variance (ANOVA). Results were expressed as the mean and standard deviation of triplicate determinations.

RESULTS AND DISCUSSION

Proximate Composition

The proximate composition of *M. esculenta* starch is shown in Table 1.

Table 1: Proximate Composition of Cassava Starch

Proximate Composition (%)	***M. esculenta* Starch**
Moisture content	15.04±0.11
Dry matter	84.96±0.11
Crude protein	1.202±0.07
Ash	0.97±0.007
Crude fibre	1.15±0.007
Fat	0.635±0.01
Carbohydrate	96.05±0.06
Amylose	19.655±0.14
Amylopectin	66.085±0.02
Energy value (Kcal/100 g energy)	394.715±0.04

Data are means ± standard deviations of triplicate determinations.

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The chemical composition of *M. esculenta* starch is shown in Table 1. The moisture content of the starch was found to be 15.04 %. Flours with moisture content less than 14 % have been reported to have the ability of resisting microbial growth and help to improve storage stability [26]. Therefore, the higher the moisture content the higher the rate of spoilage. The ash content was 0.97 % which suggests that there was low percentage of the presence of inorganic constituents [17]. A value of 0.635 % for the crude fat represents the residual fat content. Fats play significant role in the body metabolism. Apart from their energy yielding function, they also constitute a component of the membrane structure [27]. The protein content was 1.202 % while the crude fibre content was 1.15 %. Dietary fibre is the portion of plant food that cannot be digested by human alimentary enzymes. However, dietary fibre helps to form softer bulky stools and has also been associated with protection against colon and rectal cancer [27].

Table 2: Functional properties of *M. esculenta* free and modified starch with *T. mantaly* gum
Data are means ± standard deviations of triplicate determinations

Parameters	Free Starch	Starch/Gum Blend 3.0:0.5 (g/g)	Starch/Gum Blend 3.0:1.0 (g/g)
Water absorption capacity (WAC) (%)	54.10±0.07	59.25±0.5	61.35±0.2
Oil absorption capacity (OAC) (%)	76.05±0.5	78.08±0.2	81.89±0.05
Swelling power (SP) (g/g)	12.20±0.2	3.65±0.2	2.08±0.1
Solubility index (SI) (%)	40.09±0.6	10.15±0.2	8.76±0.5
Gelation temperature (GT) (℃)	68.29±0.2	68.35±0.1	68.36±0.2
Least gelation concentration (LGC) (%)	16.82±0.2	16.20±1.8	15.10±1.2
Bulk density (BD) (g/cm^3)	0.55±0.01	0.87±0.002	0.92±0.001
Foaming capacity (FC) (%)	29.36±0.5	13.25±1.03	12.68±0.8

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The result for the amylose and amylopectin contents showed that the starch contained a high percentage of amylopectin (66.085 %) and a very low percentage of amylose (19.655 %). As a result of this, it is suggested that the starch will be less soluble in water compared to other starches. The starch contained a value of food energy (394.754 Kcal/100 g energy) which was due to its fat content of 0.365 %, carbohydrate content of 96.05 % and protein content of 1.202 %. *M. esculenta* starch is a good source of carbohydrate needed in the body for the generation of energy.The value of carbohydrate obtained in this study can be compared to a value of 89.62 % reported for cassava starch by Ojo *et al*., [28] and 93.4 % reported for potato starch by Schirmer *et al*. [29].

Water and Oil Absorption Capacities (WAC and OAC):

These express the ability of the sample to absorb water and oil respectively. The WAC for the free starch was 54.10 % which increased to 59.25 and 61.35 % while that of OAC was 76.05 % which increased to 78.08 and 81.89 % after blending with *T. mantaly* gum in the starch/gum ratio of 3.0:0.5 and 3.0:1.0 g/g respectively. A similar result was reported by Igwe and Nwokocha [13,14] for maize starch blended with *Delonix regia* and *Brachystegia eurycoma* gums. The presence of the gum most probably distorted the initial amylose and amylopectin ratio in the free starch. Polysaccharides are known to be hydrophilic and are responsible for high WAC exhibited by certain flours [15]. The difference in WAC and OAC observed could be as a result of increase in polysaccharides made possible by modification with *T. mantaly* gum.

Functional Properties

The functional properties of the free starch of *M. esculenta* and its blends are shown in Table 2.

Swelling Power (SP): The swelling power is the ability of the sample to absorb water and swell. A significant decrease in SP was observed after blending. The free starch had a SP of 12.20 g/g which reduced to 3.65 and 2.08 g/g in the starch/gum blends. Umar et al. [30] reported that highly associated starch granules display a greater resistance towards swelling due to extensive and strongly bonding micelle structure which affects the film forming capabilities of starch. Hence, the lower SP observed in the starch composite blends could be due to stronger association or bonding forces in the starch granules made possible by the *T. mantaly* gum.

Solubility Index (SI): Solubility indicates the extent of dispersion of granules after cooking. There is a significant difference between the solubility of the free starch (40.09 %) and the composite blends (10.15 and 8.76 % for 3.0:0.5 and 3.0:1.0 starch/gum ratio respectively). Solubility decreased with increase in gum ratio in the blend. High solubility has been associated

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with high content of amylose which is believed to leach out easily during the swelling process [31]. Therefore, the decrease in solubility of the composite blends may be as a result of low content of amylose in the composite blends.

Gelation Temperature (GT): This is the temperature at which a gel forms from a liquid solution or mixture. It is the point at which the molecules in the solution begin to form a network structure, leading to the formation of a gel. There was no significant difference in the gelation temperature of the free starch (68.29 ℃) and that of the composite blends (68.35 and 68.36 ℃). The insignificant difference could be attributed to the different concentrations of the gel-forming agents in the mixture.

Least Gelation Concentration (LGC): The least gelation concentration is the lowest concentration required for the formation of a self-supporting gel [28]. There were no much differences in the values of LGC for the free starch (16.82 %) and the composite blends (16.20 % for 3.0:0.5 starch/gum blend and 15.10 % for 3.0:1.0 starch/gum blend). However, the blended starch samples showed lower values of gelation capacities than that of the free starch. Boye and Pletch [32] reported that samples with lower least gelation capacity have greater gelling capacity. Therefore the blended samples in this study would have better gelling capacity than the free starch. Variation in gelling properties has been associated to the relative ratio of different constituents such as proteins, lipids and carbohydrate [33]. The value of LGC of 16.82 % reported for the free starch of *M. esculenta* is comparable to the values of 18.53 and 18.73 % reported by Ojinnaka *et al*. [34] for purple and white cultivars of aerial yam (*Dioscorea bulbifera*) respectively.

Bulk Density (BD): Bulk density (BD) is the amount of powder by weight that is present in a defined volume. It helps to ascertain the sample heaviness, handling requirement and the type of packaging materials suitable for storage and transportation of food materials [15]. A high bulk density is very important in packaging and transportation, and is desirable as it can significantly reduce costs. The bulk density of the free starch was 0.55 g/cm^3 which increased to 0.87 and 0.92 g/cm^3 in starch/gum ratios of 3.0:0.5 and 3.0:1.0 respectively. Igwe *et al*., [15] reported bulk density values of 0.54 g/cm^3 for the free starch of *Dioscorea sagittifolia*; 0.85 and 0.86 g/cm^3 for its composite starch/gum blends of 3.0:0.5 and 3.0:1.0 with *T. mantaly* gum respectively. These values are comparable to the values of bulk density obtained in this study.

Foaming Capacity (FC): Foaming capacity (FC) is used to determine the ability of the starch to foam which is dependent on the presence of the flexible protein molecules which decrease the surface tension of water [35]. As shown in Table 2, the foaming capacity of the free starch was 29.36 % which decreased to 13.25 and 12.68 % for starch/gum ratio of 3.0:0.5 and 3.0:1.0, respectively. The gum must have reduced the

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protein content of the free starch giving rise to lower values of FC.

Pasting Properties

The pasting properties and viscosity profiles of the free and modified *M. esculenta* starch are presented in Table 3 and Figures 1 to 5.

Table 3: Pasting properties of *M. esculenta* free starch and starch/gum blends

Test	Peak Viscosity (RVU)	Trough Viscosity (RVU)	Breakdown (RVU)	Final Viscosity (RVU)	Setback (RVU)	Peak Time (mins)	Pasting Temp. (℃)
AME	464.33	157.00	307.33	202.67	45.67	3.33	73.45
BME	399.08	78.67	320.42	133.08	54.42	3.40	73.60
CME	409.42	95.17	314.25	155.25	60.08	3.47	73.55
DME	347.00	98.42	248.58	150.17	51.75	3.60	74.40
EME	376.58	115.58	261.00	187.83	72.25	3.67	76.00

AME: *M. esculenta* free starch i.e 100 % starch (without gum)
BME: *M. esculenta* starch/gum blend (3.0: 0.25)
CME: *M. esculenta* starch/gum blend (3.0: 0.50)
DME: *M. esculenta* starch/gum blend (3.0: 0.75)
EME: *M. esculenta* starch/gum blend (3.0: 1.00)

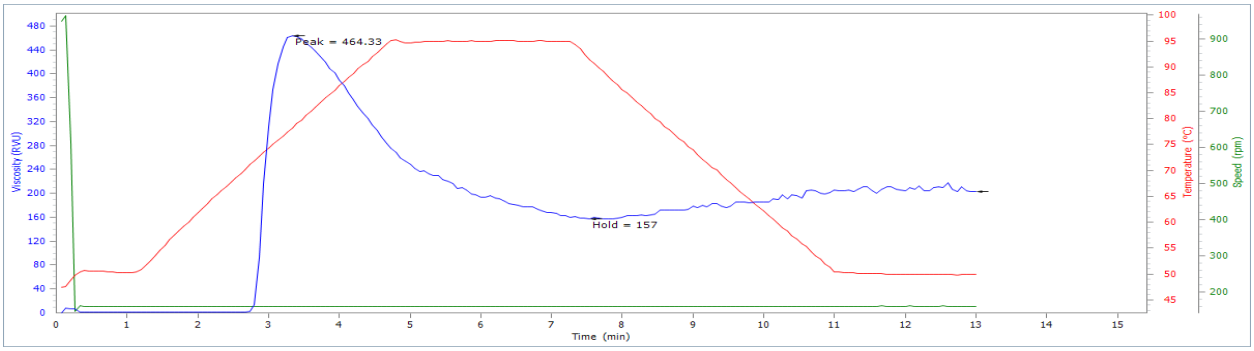

Figure 1: Viscosity profile of the unmodified cassava starch sample

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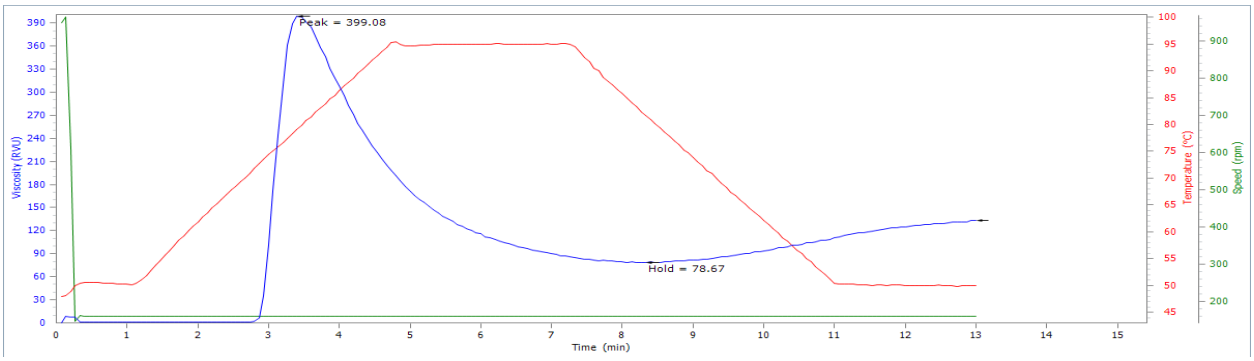

Figure 2: Viscosity profile of the cassava starch modified with 0.25 g of gum sample

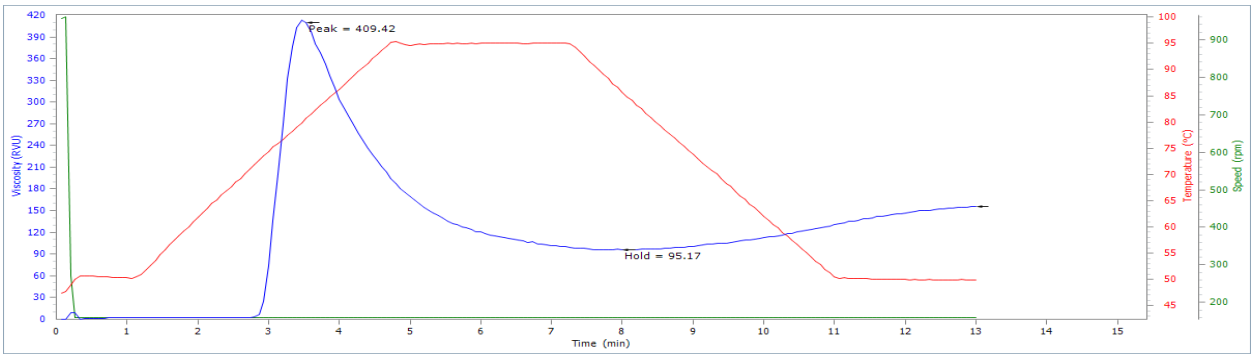

Figure 3: Viscosity profile of the cassava starch modified with 0.5 g of gum sample

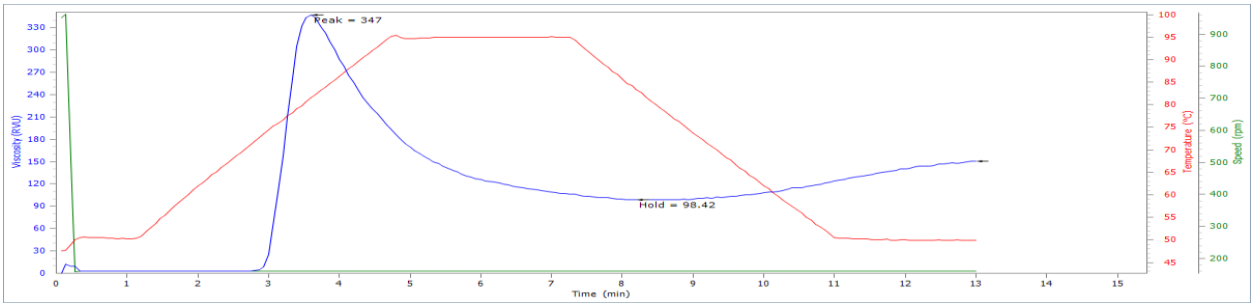

Figure 4: Viscosity profile of the cassava starch modified with 0.75 g of gum sample

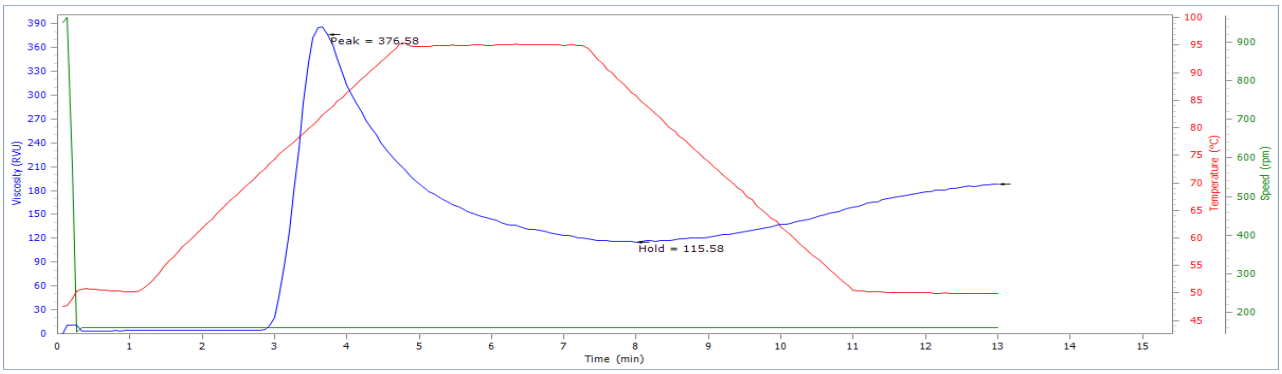

Figure 5: Viscosity profile of the cassava starch modified with 0.10 g of gum sample

The pasting properties obtained are a measure of the viscosity of starch suspension during the heating cycle which reflect the molecular events occurring in starch granules. Pasting properties

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varied significantly as the concentration of the gum increases. The pasting temperature of the starch ranges from 73.45 to 76.00 ^{o}C. The unmodified starch has the highest peak viscosity (464.33 RVU) while the starch with 0.75 g of gum has the lowest peak viscosity (347.00 RVU). According to Ghaisi *et al.* [36], increase in viscosity with temperature may be attributed to the removal of water from the exuded amylose by the granules as they swell. The high level of breakdown observed led to a reduced final viscosity for all the starches. The free starch presented the highest viscosity showing greater stability to staring and cooking. Miles *et al*. [37], related this fact to the aggregation or association of amylose molecules. The free starch presented low setback which can be related to the presence of amylose chain with high molecular weight [38]. There was reduction in peak viscosity of the physically modified starch (0.25 and 0.75 concentrations), similar trend was observed in the breakdown, final viscosity and setback of all the modified starches. These changes of pasting characteristics indicated that starch molecules have some degree of free association during hydrothermal treatment. James [17] reported similar findings in changes of pasting properties of heat-moisture treated potato starch.

Morphological Properties

The morphological properties of *M. esculenta* free starch granules is shown in Figure 6 while that of the modified starch granules is shown in Figure 7.

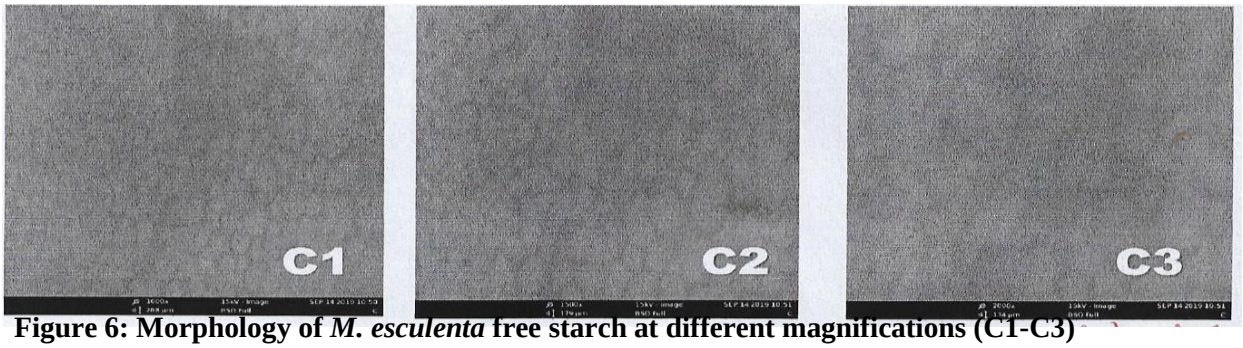

Figure 6: Morphology of *M. esculenta* free starch at different magnifications (C1-C3)

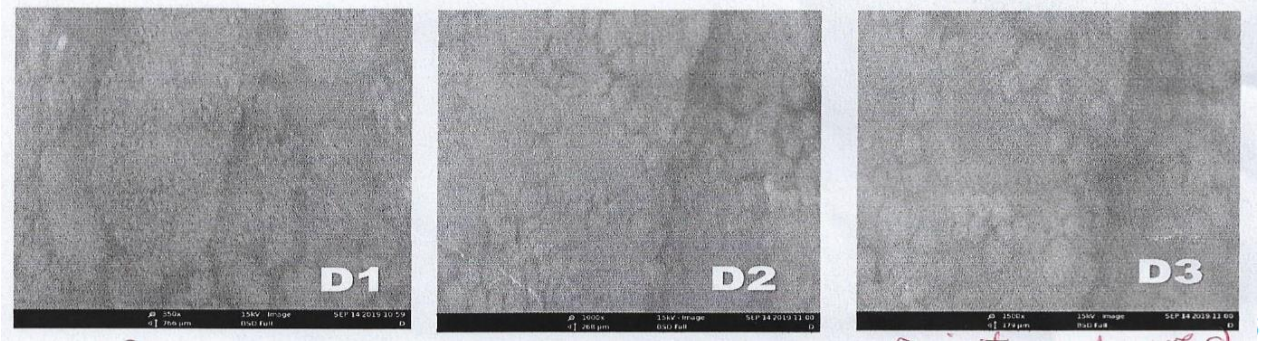

Figure 7: Morphology of *M. esculenta* starch modified with *T. mantaly* gum at different magnifications (D1-D3)

Scanning electron microscopy (SEM) was used to observe the shape and surface characteristics of the free starch and the modified starch for comparison of size and morphology. The microscopy was obtained at 500, 1000 and 1500 X magnifications. The *M. esculenta* free starch showed asymmetric and irregular shaped granules with primarily ellipsoid and oval shapes. The modified starch showed oval, truncated and spherical granules. These variations in morphology of the granules could be attributed to the modification with *T. mantaly* gum as well as the biological origins of both the *M. esculenta* starch and the gums. It has been reported that the morphology of starch granules also depends on the biochemistry of the chloroplasts or amyloplasts as well as plant morphology [39]. Moreover, several factors can affect the granule properties such as temperature, storage and cultural practices [40]. The cassava starch granules showed similar morphology with the one reported by Hernandez-Medina *et al.* [41].

CONCLUSION

Blending of *M. esculenta* starch with *T. mantaly* gum (hydrocolloid) modified the starch properties and functionalities such as significant decrease in peak and trough viscosities through strong network formation with starch granules. The starch-gum blend could afford typical applications in food industries as emulsifiers, thickeners, stabilizers or gelling agents. The objective of the starch modification with *T. mentaly* gum has been realized which was to alter the physical and (maybe) chemical characteristics of the native *M. esculenta* starch to improve its functional characteristics and pasting properties for specific food and industrial applications.

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