Experimental Studies of a Hybrid Peeling Process for Cassava (*Manihot esculenta crantz*) roots and its effects on Quality Characteristics of some products

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Abstract

Peeling is an essential unit operation prior to further processing of cassava. This study presents a experimental studies on functional and proximate parameters of *gari* and HQCF as affected by peeling methods and cassava cultivars. A newly developed abrasive peeling machine with the dual function of mechanical and mild chemical peeling of cassava roots by recycling of fruit water was used in the peeling process. Peeling of cassava by hands were used as control for this study. The peeling machine utilizes abrasive peeling surface inscribed with indented 0.12cm stainless steel of 77cm height with 245cm diameter, a concrete based cavity, fruit water recovery tank, water pump and the transmission system. The fruit water was used to soak the cassava tubers before peeling with the machine for 60 minutes. Improved cassava varieties: TMS 30572 and TME 419 were used. High quality cassava flour (HQCF) and *gari* were produced from the varieties with three different peeling methods: manual, mechanical and mechanical/chemical (hybrid). Results obtained from the HQCF produced from tubers that were peeled manually, mechanically and hybrid peeling using TMS 30572 and TME 419 cassava varieties were: moisture content (10.90–11.36% d.b.), crude protein (0.24–0.35%), carbohydrate content (88.24–88.86%) and ash content (0.09 – 0.30%) while results of values for bulk density, swelling capacity, WAC, solubility, LGC and pH were (0.55–0.68g/ml), (854.38– 862.38%), (122.5–152.5%), (6.00-6.80%), (5.00–6.67%) and (5.50–6.92) respectively. Cyanide content (1.98-4.04mg/kg) and OAC (128-144%). The *gari*'s proximate and functional compositions values were: moisture content (6.00– 6.86% d.b.), crude protein (1.32–1.59%), crude fat (0.30–0.52%), crude fibre (2.21–2.58%), CHO (88.02– 90.50%) and ash content (0.71–0.82%). The bulk density (0.560 – 0.675g/ml), swelling power (827–.38%), WAC (318.21–435.39%), cyanide content (1.92- 3.14mg/kg) and pH (4.35–5.00). HQCF and *gari* had proximate and functional properties that compared favorably with those of manual peeling of cassava for the products. The functional properties were well improved by the hybrid and mechanical peeling methods.

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Introduction

Cassava (*Manihot esculenta Crantz*) also known as *manioc* is an ancient tropical root crop belonging to a group of about 100 species of the genus *Manihot* (Howeler *et al*., 2013). It is one of the oldest root and tuber crops, used by humans to produce food, animal feed and beverages. It is currently produced in more than 100 countries and fulfils the daily caloric demands of millions of people living in tropical America, Africa, and Asia (Parma *et al*., 2017; Adegoke *et al*., 2020). Adegoke *et al* (2020) reckons the importance of cassava as a food security crop especially in Western, Central and Eastern Africa due to its ability to produce reasonable yields (~10 t/ha) in poor soils and with minimal inputs.

Parma *et al* (2017) and Lebot (2009) reported that cassava is a perennial shrub of the *Euphorbiaceae* (Dicotyledons) family that can grow for years and has lateral subterranean storage organs in the form of starchy roots. Nigeria is the largest producer of cassava in the world with production level estimated at 57,134,478 million tons per year (Uthman, 2011; FAOSTAT, 2016). This is a third more than the production in Brazil (The world's second largest cassava producer) and almost double the production of Indonesia and Thailand. Adegoke *et al*., (2020) reported that, until recently, cassava was primarily produced for food as it is consumed on daily basis in different forms and often times more than once a day in Nigeria.

According to Oriola and Raji (2013), cassava is presently the most important food crop in Nigeria from the point of view of both the area under cultivation and the tonnage produced due to the fact that, it has transformed greatly into high yielding cash crop, a foreign exchange earner, as well as a crop for world food security and industrialization. In line with above-mentioned report, there has been an unprecedented rise in the demand for cassava and its numerous products worldwide for both domestic and industrial applications (Adetunji and Quadri, 2011; Parma *et al*., 2019). The cultivation of cassava as a major staple crop has expanded significantly in Sub-Saharan Africa (SSA) and Asia in the twentieth-century. Today, Cassava supports the livelihood of over 300 million Africans (????).

Above facts suggests that opportunities abound in the area of cassava processing, but, these opportunities cannot be fully utilized using the traditional processing methods currently in use in the country which is generally adjudged as arduous in nature, labour intensive, time consuming and unsuitable for large scale production (Adetan *et al.*, 2003; Agbetoye, 2005; Quaye *et al.*, 2009; Olayanju *et al*., 2019). According to Njukwu *et al*., (2015), the major challenges confronting most developing countries, especially in Africa, is not what to produce but primarily how to process and preserve what is produced. Freshly harvested cassava roots start deteriorating almost immediately after harvest and can only last for few days due to its high moisture content of about 70% (Ngoddy, 1989 and Egbeocha *et al*., 2016) and in the light of this, cassava should be processed after harvesting due to its short shelf life (Reilly, 2003; Latif and Muller, 2015). The best form of preservation and reduction of post-harvest losses is immediate processing into various shelf stable products such as *gari*, chips, pellets, etc. Processing cassava into different products involves peeling and other operations. Most of these operations are still being done manually, and they are generally labour intensive, arduous in nature, time consuming and unsuitable for large scale production (Adetan *et al.*, 2003; Quaye *et al.*, 2009, and Olayanju *et al*., 2019).
Peeling which is limiting the complete mechanization of cassava processing is the first step for all cassava products processing such as flour, starch and *gari*. Because manual peeling is labour intensive (Jimoh and Olukunle, 2012), it is essential to mechanize the cassava peeling process.

Therefore, finding a way to increase the efficiency of mechanical peeling is very important and expedient.

Therefore, the objective of this research is to determine some quality parameters of *gari* (traditional product) and high quality cassava flour (industrial product) produced from the manual peeling, mechanical peeling and combined effects of soaking in fruit water using a newly developed hybrid peeling machine that combines mechanical and chemical peeling methods

Materials and methods

Adegoke *et al*., (2020), developed a hybrid cassava peeling machine with a variable speed (1600-2600 rpm) diesel engine of 7.331kW maximum power rating. The machine is as shown in Figure 2 and 3. The main features of the machine include peeling chamber, abrasive peeling surface or tool, supporting frame, hopper and the transmission system. High pressure water sprays from water sprinkler was sprayed on the roots during operation. After running for 20-25 minutes, the recycled water becomes 'fruit water'. All the known cassava cultivars contain varying concentrations of the cyanogenic glucosides, which are hydrolyzed to hydrogen cyanide (HCN) by endogenous linamarase when the tissue is damaged after running the machine for 20-25 minutes, the recycled water becomes hydrocyanic solution and this organic acid is referred to as 'fruit water' in this machine operation. Hydrogen cyanide is weakly acidic. It partially ionizes in water solution and the salts of the cyanide anion are known as hydrogen cyanide; a solution of hydrogen cyanide in water, this solution forms the cassava 'fruit water'.
The combined action of the high pressure water jets and abrasion of the tubers against the walls of the perforated stainless sheet wounded round the inner chamber of the machine and the roots against each other, removed the cassava skin. Mechanical peeling was performed using the above-mentioned peeling machine at a rotational speeds of 1600, 2100 and 2600 rpm and a peeling time of 5 minutes. In addition to the mechanical peeling process, fresh cassava tubers were immersed and soaked in cassava fruit water solution for 60 minutes respectively. The pH of the fresh water in the water tank that was continuously been recycled during the peeling operation would be adjusted by the hydrocyanic acid present in cassava tubers that was dissolving in the fresh water during the peeling operation after 20-30 minutes operation of the peeling machine. Hydrogen cyanide is weakly acidic. It partially ionizes in water solution and the acid of the cyanide anion are known as hydrogen cyanide; a solution of hydrogen cyanide in water, this solution forms the cassava 'fruit water'. The hydrocyanic acid solution was used to soak the cassava roots for one hour. A pH of 4.5 and a temperature of 40 °C of the immersion solution were chosen and maintained for all trials. Checks were carried out with pH meters/pH strips and Infrared thermometers to maintain the temperature and hydrogen ion concentration.

Processing of peeled cassava roots into HQCF

Freshly harvested cassava roots were weighed, peeled (manually, mechanically, soaked in fruit water and peeled manually, mechanically and with the hybrid peeling method). The method of Dziedzoave *et al.* (2006) was used**.** The peeled roots were washed with plenty of potable water to get rid of dirt and sand particles. The washed roots were then grated manually to obtain the mash. The wet mash was put in polyethylene sacks and the flaps were folded. The mash was dewatered using a hydraulic jack (32 ton capacity) to an approximate moisture of about 40% for about half an hour. Samples were then pulverized and spread on elevated stainless steel trays in a solar house

with backup heating (using biomass wood) operational at a temperature of 50 to 60^{o}C for 6 h. The dried grits were then hammer milled and packaged in a low density zip-lock polyethylene bag.

Processing of peeled cassava roots into gari

Freshly harvested cassava roots were weighed peeled (manually, mechanically, soaked in fruit water and peeled manually, mechanically and with the hybrid peeling method). The peeled roots were washed with plenty of potable water to get rid of dirt and sand particles. The washed roots were then grated mechanically to obtain the mash. The wet mash was put in polyethylene sacks and the flaps were folded. It was allowed to ferment for 3 days after which the fermented mash was dewatered. The dewatered mash from sacks were sieved and pulverized to remove large particles and spread out in trays before it was gari fried in a mechanical gari fryer (TOSMAT model, stainless steel frying pot, electrically operated on 3-phase, 1 Hp gear motor, heating source: (diesel fired), well-insulated body system with fiber and capacity of 500-750kg/shift), cooled and packaged in zip lock bags (IITA, 2013).

Moisture content determination

The moisture content of the samples was determined using the method described by AOAC (2010). Crucibles were cleaned and dried in an oven at 105^{0}C, cooled to room temperature in desiccators with dry silica gel for 40 min and weighed as (W_1). Five gram (5 g) of each sample was weighed into the crucible and the weight was recorded as (W_2), all the crucibles and their content were transferred into the Gallemkamp hot air oven at a temperature of 105^{0}C for 3 h. Thereafter the samples were cooled in the desiccators and weighed. The crucible sand the final weight were taken as (W_3). The percentage moisture content was calculated using the formula:

$$\% \text{ Moisture} = \frac{(W2-W3)}{(W2-W1)} \text{x } 100 \qquad (1)$$

Starch content determination

The starch content was determined by the method described by International Starch Institute, Denmark. The method is applicable to potato and cassava where starch determination by the hydrostatic method / under-water method (ISI, 2014).

Crude protein determination

The crude protein content determination was determined using micro Kjedhal method as described by AOAC (2010) which involved wet digestion, distillation, and titration. The crude protein content was determined by weighing 3 g of samples into a boiling tube that contained 25 ml concentrated sulfuric acid and one catalyst tablet containing 5 g K_2SO_4, 0.15 g $CuSO_4$ and 0.15 g TiO_2. Tubes were heated at about 400℃ temperature for digestion to occur. The digest was diluted with 100 ml distilled water, 10 ml of 40% NaOH, and 5 ml Na_2SO_3, anti-bumping agent was added, and then the sample was diluted with 10 ml of boric acid. The NH_4 content in the distillate was determined by titrating with 0.1 M standards HCl using a 25 ml burette. A blank was prepared without the sample. The nitrogen value obtained was multiplied by a conversion factor, and the result was expressed as the amount of crude protein.

$$Total\ gN\big(Nirogen\ (\%)\big) = \frac{14.1\ \times (sample\ titre\ -\ blank\ titre) \times N}{10\ \times sample\ weight} \qquad (2)$$

Where N = Normality of acid (0.1M)

Therefore, *% crude protein = gN (%) × conversion factor (6.25)*

Crude fibre determination

The crude fibre content was determined using the method described by AOAC (2010). Approximately 3 g of sample was weighed and extracted with petroleum ether. It was allowed to boil in a diluted H_2SO_4 (under reflux condenser) for 40 minutes. Filter paper was placed in the funnel to trap the particles, this was washed with several portion of hot water. The insoluble material was then boiled in diluted NaOH for 30 minutes under same condition. The solution was filtered and washed in several portion of hot water; the sample was allowed to dry before being transferred quantitatively into a weighed crucible where it was dried in the oven at 105℃ to a constant weight. The content was weighed and then incinerated to ash inside a muffle furnace. The weight of the fibre was determined by difference and calculated as follow:

$$\%\ Crude\ fibre = \frac{W_2\ -\ W_1}{Weight\ of\ the\ sample}\ \times 100 \qquad (3)$$

Where,

W_2 =Weight of crucible + sample after washing, boiling and drying

W_1 = Weight of crucible + sample of ash

Crude fat determination

The crude fat content was determined by Soxhlet method (AOAC, 2010). Approximately 2 g of sample was placed in a fat free extraction thimble, plug lightly with cotton wool. The thimble was placed in the extractor and petroleum ether was added until it siphons over once. More petroleum ether was added until the barrel of extractor was two-third full. The condenser was replaced and all joints were securely tightened and the extractor placed on the boiling water bath. The solvent (petroleum ether) was heated, boiled vaporized and condensed into the reflux flask filled. Soon the sample in the thimble was covered with the solvent until the reflux flask filled up and siphoned over, carrying its oil extract down to the boiling flask. This process was allowed to go on repeatedly for 3 h before the defatted sample was removed, the solvent recovered and the oil extract was left in the flask. The flask (containing the oil extract) was dried in the oven at 100℃ for 1 hr to remove any residual solvent. It was cooled in desiccator and weighed. The weight of oil (fat) extract was determined by difference and calculated as follows:

$$\%\ Crude\ Fat\ Content = \frac{X\ -\ Y}{Z}\ \times 100 \qquad (4)$$

Where:

X = Weight of fat + flask

Y = Weight of flask

Z = Weight of sample (in grams)

Total ash determination

The ash content was determined using the method described by AOAC (2010). About 5 g sample was weighed into a previously ignited, cooled and weighed silica dish. The dish and its content was ignited first gently and then at 500 ̊C for 4 h in a muffle furnace. The dish and its content was cooled in a desiccator and reweighed. It was returned into the muffle furnace for 30 min, desiccated and reweighed until constant weight. The remaining residue inside the silica dish being the ash. Percentage ash content was calculated as follows:

$$\%\ Total\ Ash\ Content = \frac{Y_2\ -\ Y_1}{W}\ \times 100 \qquad (5)$$

Where:
Y_1 = *Weight of empty crucible*
Y_2 = *Weight of crucible + ash*
W = Weight of sample.

Carbohydrate determination

Total carbohydrate was determined by difference. An approximation was made by subtracting the measured crude protein, crude fibre, total ash, and moisture content from the total weight (Egunlety and Aworh, 1990), that is, available carbohydrate = 100 - (Weight in grams [protein + fat + water + ash + alcohol + dietary fibre] in 100 g of food)

pH determination

About 5 g of samples was suspended in deionized water for 5 min at a ratio of 1:5 (w/w) and pH measured using a digital pH meter (Orion Research Inc., Model 720A, USA) as reported by Sanni (1992).

Cyanogenic glucoside determination

Sample preparation for cyanogenic glucoside content

About 20 g of marcerated root samples were homogenized in 50 ml of 0.1M HCl for 3 min. The homogenate was filtered by vacuum and the resulting filtrate adjusted to pH 6.8 with base. This solution was then centrifuged at 500 rpm for 3 min. About 5 g of processed cassava products were made in the same way as from the cassava tuber except that 150 ml of 0.1M sodium phosphate buffer pH 6.8 was used in the extraction.

Preparation of alkaline picrate solution

About 25 g of anhydrous sodium carbonate and 5 g of anhydrous picric acid were added to 1- litre volumetric flask. The mixture was dissolved in a minimal amount of warm distilled water and the solution was made up to the mark with cold distilled water. The alkaline picrate method described by Ikediobi *et al*. (1980) and Olugboji (1987) was used.

Construction of a standard curve for cyanide assay using alkaline picrate method

A sample of potassium cyanide to be used as standard was first dried in the oven to constant weight. A stock solution was prepared by dissolving 8 mg of this salt in 100 ml of distilled water. This gives a concentration of 32 µg CN/ml. From this stock solution, a series of 10 ml-plastic stoppered test tubes containing from 32-64 µg of cyanide was set up. The volume of each was made up to 2 ml with distilled water and 4 ml of alkaline picrate was added and mixed. The resulting solution was incubated in a water bath at 95 °C for 5 minutes. Upon cooling to room temperature, the absorbance of the deep orange colour formed was read in a spectrophotometer at 490 nm. The absorbance at 490 nm was plotted against cyanide concentration.

Quantization of residual cyanide in the samples

About 0.5 ml of cassava or cassava product extract was incubated with 1.0ml of linamarase preparation containing 30 - 40 units of activity for 10 min at room temperature in a tall stoppered test tube. The volume of the incubation mixture was made up to 2ml with 0.2 M Na phosphate buffer of pH 6.8. At the end of the incubation period, 5ml of alkaline picrate were added and the resulting solution was incubated in a water bath at 95℃ for 5 min. Upon cooling to room temperature, the absorbance of the deep orange colour formed was read in a Spectrophotometer at 490 nm. The absorbance at 490 nm was plotted against cyanide concentration. The cyanide concentration was extrapolated from a standard curve previously prepared with potassium cyanide as standard and calculated using equation 6 (Onwuka, 2005).

$$mgHCN/kg = \frac{conc.obtained\ from\ curve\ in\ mg/l \times vol.of\ sample \times dilution\ factor\ (if\ any)}{Sample\ weight} \times 1000 \quad (6)$$

Determination of Functional properties

Bulk density (BD)

This was determined using method of AOAC (2010). The sample (10 g) was weighed into a 50 ml graduated measuring cylinder. The cylinder was then tapped gently against the palm of the hand until a constant volume was obtained, and the bulk density (BD) was calculated.

$$\mathbf{BD} = \frac{\text{Weight of sample}}{\text{Volume of sample after tapping}} \quad (\mathbf{7})$$

Determination of water absorption capacity

The water absorption capacity of both samples was determined using modified method of Sosulski (1979). One gram of sample was stirred into 10 ml of distilled water in a centrifuge tube, after which the suspension was allowed to stand for 10 min and then centrifuged for 25 min at 2,500 rpm. The clear supernatant was decanted into a measuring cylinder, the adhering drops of water removed by inverting the tube and the tube weighed. Water absorption capacity was expressed as grams of water absorbed (or retained) per gram of sample as calculated as follows

$$\text{WAC} = \frac{\text{Final weight of X}-\text{Y}}{\text{Sample weight}} \text{ x } 100 \quad (\mathbf{8}).$$

Where Y = Final weight of sample and tube and X = Initial weight of sample and tube.

Determination of oil absorption capacity

The method of Lin *et al.* (1974) was used for the determination, with modification. One gram sample was added to 10 ml of groundnut oil in a centrifuged tube, stirred together and allowed to stand for 30 min at room temperature (30±2^{o}C). The sample was centrifuged at 2,500 rpm for 25 min. The clear supernatant was then decanted into a measuring cylinder, the adhering oil removed by inverting the tube and the tube was weighed. The weight of oil absorbed by 1.0g of flour was calculated and expressed as fat absorption capacity in percentage.

$$\text{OAC} = \frac{\text{Final weight of Y} - \text{X}}{\text{Sample weight}} \text{ x } 10 \quad (\mathbf{9})$$

Where Y = Final weight of sample and tube and X = Initial weight of sample and tube.

Least gelation concentration

The method of Coffman and Garcia (1977) was used for the determination. Test tubes containing suspensions of 2, 4, 6, 8 up to 20% (w/v) flour in 5 ml distilled was heated for 1 h in boiling water, followed by cooling for 2 h at 4^{o}C. The least gelation concentration was the one at which the sample does not fall down or slip when the test tube was inverted.

Statistical Analysis

Statistical analysis was carried out using SPSS 21.0 (SPSS Inc. NY) statistical software. Data obtained were subjected to analysis of variance (ANOVA) using the general linear model (multivariate).

Results and discussion

Functional Properties and Proximate Composition of HQCF

The functional properties of high quality cassava flour (HQCF) are presented in Tables 4.9 – 4.11 The packed bulk density for the high quality cassava flour was high having values of 0.55–0.68g/ml for the manually, mechanically and mechanical plus soaking in fruit water respectively for TMS 30572 variety and 0.6 – 0.64g/ml for the manually, mechanically and mechanical plus soaking in fruit water respectively for TME 419. Bulk density is the physical property of materials in dry mixes and it is an important parameter in determining product packaging requirements (Mohamed *et al.*, 2009). The advantage of HQCF with high bulk density is that it does take up too much space when distributing and decreases packaging cost. It also reduce the need for space per unit weight and overall packaging cost of food materials. The high HQCF density indicates that they can function as a good thickener in food products as well as their suitability for use in processed foods like seasoning and beverages. High bulk densities of the HQCF from TME 419 and TMS 30572 is desirable for wider use of dispersability and reduction of paste thickness. These results are similar to the reports of Udensi and Okaka (2000).

Water absorption capacity (WAC) and Oil absorption capacity is defined as the absorbed amount of water or fat per gram of flour. According to Butt *et al.* (2010), WAC and OAC values may include its protein content, carbohydrate and levels of dietary fibres. The protein have hydrophilic and hydrophobic properties to interact with water and oil in foods. WAC values of the HQCF samples indicate the hydrophilic capacity of the protein while the OAC indicate hydrophobic capacity of the protein. WAC and OAC were used to indicate protein ability in the food materials to prevent fluid loss from a product during processing and storage (Kiosseoglou *et al.*, 2011). The WAC values of HQCF from TME 419 and TMS 30572 was 122.5 – 152.5% in the two varieties for the different treatments. However, the mechanical plus chemical effects of soaking increased the WAC which was observed in the samples. The manually peeled and mechanically peeled HQCF samples had lower WAC 122.5 – 132.5% compared to the 147.5 – 152.5% in cassava tubers soaked in cassava fruit waters for 60 minutes. OAC values of HQCF from TME 419 and TMS 30572 were 125 – 144% in the manually peeled, mechanically peeled and mechanical and soaking in fruit water peeled cassava used in the processing of HQCF respectively. The manually peeled and mechanically peeled HQCF samples had lower WAC 125 – 140% compared to the 125 – 144% in cassava tubers soaked in cassava fruit waters for 60 minutes. These values indicate the functionality of the HQCF in bulking and consistency of products as well as baking applications

for WAC. The results are similar to similar trends observed in starch reported by Niba *et al*. (2001), while OAC affects the texture, mouth feel, flavor enhancement qualities, moisture reduction and fat loss of food products like comminuted meats, extenders or analogues and baked doughs according to Adebowale *et al.* (2005).

The swelling power of the HQCF from TME 419 and TMS 30572 determined at 100 degrees Celsius was 838.85 - 887.05 % for the different treatments of manually peeling, mechanically peeling and soaking in cassava fruit water cassava roots used in the processing of HQCF. The swelling power has been shown to be influenced by the amylose/amylopectin ratio in the residual starch in the flour and by the characteristics of amylose and amylopectin in terms of molecular weight distribution, degree of branching, length of branches and conformation of the molecules (Ratnayake *et al.,* 2002). The results agree with the positive correlation between high amylose content and swelling power. High swelling power could indicate that an ingredient can be applied to improve the characteristics of baked products from the flours. Solubility relates to the presence of soluble molecules in the flour (starch). The solubility of HQCF was 6.0 – 6.37 % for all the treatments (peeling methods and varieties) and similar to the values reported by Li *et al.* (2011). The difference in solubility could be attributed to the difference in structure and genetic mapping of the starch granules in the HQCF samples.

The proximate composition of the various HQCF samples from manually peeled, mechanically peeled and mechanical plus chemical peeling are presented in Tables 4.7 – 4.9. The moisture contents ranged from 9.9 – 11.36%. The HQCF from TMS 30572 manually peeled cassava roots had the highest level of moisture content while the lowest was in HQCF from TME 419 manually peeled cassava roots. All the samples moisture content results conform to NIS standard of 12% maximum moisture content for HQCF. The samples had excellent moisture content a key indicator that the products will keep very well under storage. Moisture content of 12 % maximum is recommended for storage of by Standard Organisation of Nigeria (Sanni *et al*., 2005).

The HQCF samples from the two varieties and three methods had good proximate compositions; the various HQCF products had protein, fat, carbohydrate and ash contents that compared favourably well with HQCF from that of manually peeled cassava. The study has also shown that through modifications of traditional method of peeling, the physical and technological properties of HQCF, such as swelling index, bulk density and water absorption capacity, could be well improved.

The pH values obtained for the HQCF from the two varieties of TMS 30572 and TME 419 cassava subjected to manual peeling, mechanical peeling and mechanical plus chemical peeling method are shown in Tables 4.7 – 4.9. The HQCF samples from TME 419 cassava roots pH ranged from 5.95 – 6.92 while HQCF samples from TMS 30572 cassava roots pH ranged from 5.50 – 6.86 for the different peeling methods, that is, manual peeling, mechanical peeling and mechanical + chemical peeling methods. HQCF from manually peeled roots have pH range of 6.86 – 6.92, mechanically peeled roots had 6.55 – 6.70 and the soaking in fruit water before peeling had 5.50 – 5.95 values. All the values conform to the Standard Organisation of Nigeria (Sanni *et al*., 2005) and Standard Organization of Nigeria (NIS) (2005) of pH values of 5.5 – 7.0 for HQCF. The pH of HQCF is also a function of the extent of fermentation. The lower the pH, the better will be the keeping quality of HQCF and its overall acceptability for its industrial usage. There was a significant ($p<0.05$) difference among the samples in terms of hydrogen cyanide (HCN) content (Tables 4.7 – 4.9). The residual cyanide (HCN) in the samples were generally lower than the NIS

standard of 10 mg/kg. HQCF from manually peeled roots have HCN range of 2.94 – 2.98 mg/kg, mechanically peeled roots had 3.98 – 4.04 mg/kg and the soaking in fruit water before peeling had 1.98 – 2.04 mg/kg values. All the values conform to the Standard Organization of Nigeria (Sanni *et al*., 2005) and Standard Organization of Nigeria (NIS) (2005) of HCN values of 10 mg/kg for HQCF.

Functional Properties and Proximate Composition of *gari*

The proximate composition of the various gari from manually peeled, mechanically peeled and mechanical plus chemical peeling are presented in Tables 4.12 – 4.14. The moisture contents ranged from 6.30 – 7.00 %. The gari from manual peeling had moisture content values 6.30 – 6.80 % for TMS 30572 and TME 419 respectively. The gari from the combination of mechanical and chemical peeling by soaking the cassava before peeling in cassava fruit water had the moisture content values of 6.51 – 7.00 %. The gari from the mechanical peeling of the cassava before processing the roots into gari had moisture content of 6.00 – 6.86 for the two varieties of cassava used (TME 419 and TMS 30572). The highest level of moisture content was recorded in the gari from the combination of mechanical and chemical peeling by soaking the cassava before peeling in cassava fruit water while the lowest was observed in gari from the mechanical peeling of cassava. There was no significant difference ($p<0.05$) among the gari samples and an increase in the level of moisture content was not noticed the gari samples. This variation can be attributed to the difference in the production methods. The low moisture content recorded gari could be attributed to the effective peeling process which removed the sub cutaneous layer of the peels and less fibrous nature of the peeled roots which would make moisture removal during roasting more easier hence, shorter roasting time requirement to obtain the same level of dryness. Moisture content of 10% is recommended for storage of gari by Standard Organisation of Nigeria (Sanni *et al*., 2005). All the gari samples processed have good moisture contents and meets the NIS standard and shows that the gari will be very crispy and would store longer.

Gari produced from the three methods had good proximate compositions; the various gari products had protein, fat, carbohydrate and ash contents that compared favourably well with gari from that of manually peeled cassava. The study has also shown that through modifications of traditional method, the physical and technological properties of gari, such as swelling index, bulk density and water absorption capacity, could be well improved.

The crude fibre contents of the gari samples ranged from 2.21 to 2.58 % for all the processing methods and the two varieties. The gari from the mechanical peeling of the cassava before processing the roots into gari had crude fibre values of 2.40 – 2.58 % for the two varieties of cassava used (TME 419 and TMS 30572). The gari from mechanical peeling method had the highest crude fibre content while that of manual peeling had the lowest value. The samples, however, did not differ significantly ($p>0.05$). Though the expected increase in the level of crude fibre contents of the gari samples are close to those recorded by Kure *et al.*, (2012). The deviation from the expected trend might be as a result of the difference in the production method. Crude fibre through its water absorption capacity has been found to aid bowel movement and aid digestion (Abu *et al*., 2006) and therefore significant in diet. The protein contents of the gari samples differed significantly ($p<0.05$) and ranged from 1.32 to 1.59%. However, Ojo and Akande (2013) and Kure *et al*., (2012) reported protein contents of 1.27–2.38% and 2.56–3.07%, respectively for gari samples in their research work. These are fairly similar to the values obtained in this study. The crude fat contents of the various gari samples ranged from 0.30 to 0.42%, and

differed significantly among the samples ($p<0.05$). Gari from mechanical peeling method only had the crude fat content 0.40 – 0.52 % for the two varieties of TME 419 and TMS 30572 respectively and had the highest fat contents respectively. These values were lower compared with the 1.08 – 2.11% reported by (Ojo and Akande, 2013). The variation in the level of fat content could be attributed to the effect of the different production methods on the gari samples.

The ash content of the gari samples ranged from 0.71 to 0.82 % and differed significantly ($p<0.05$). The gari from TME 419 had the total ash content values of 0.71 to 0.79 % across the different processing methods while the gari from TMS 30572 had total ash content values of 0.76 to 0.82 %. The manually peeled cassava produced gari with ash content values of 0.79 to 0.82 % being the highest across the two varieties while the mechanically peeled roots produced gari with lowest ash content values of 0.73 to 0.76 % across the two varieties of TME 419 and TMS 30572. These values fall within the range of values (0.12-0.48%) and (1.40–1.82%) reported by Ojo and Akande (2013), Ajala *et al*., (2008) and Kure *et al*., (2008) respectively. Ash content is a representation of mineral content in food. Therefore, the gari will be a good source of minerals which are essential in many biochemical reactions of the body.

The values obtained for the pH are shown in Tables 4.10 to 4.12. There was a significant difference ($p<0.05$) in the pH values obtained for the gari samples (Tables 4.10 to 4.12). The values ranged from 4.35 to 5.00. These were within the range of values (4.42–5.98) reported by Sanni *et al*., (2005) for gari samples. The pH of gari is also a function of the extent of fermentation. The lower the pH, the better will be the keeping quality of gari. The gari from manually peeled cassava had the pH range of 4.98 to 5.00 across the two varieties of TMS 30572 and TME 419; the gari from mechanical plus chemical peeling had pH values of 4.35 to 4.82 and the gari from the mechanical peeling of the cassava varieties of TME 419 and TMS 30572 had the values of 4.53 to 4.90.

There was no significant ($p>0.05$) difference among the gari samples in terms of hydrogen cyanide (HCN) content (Tables 4.10 to 4.12). Gari from the combined effect of mechanical and chemical peeling had the highest HCN content while that of manual peeling had the lowest. Tables 4.12 to 4.14 show the HCN contents of the various gari samples. The highest level of HCN obtained for gari from the combined effect of mechanical and chemical peeling could be attributed to the high content in the raw cassava root due to soaking in the cassava fruit water. Sweet cultivars of cassava can produce as little as 20 mg of HCN per kg of fresh roots, while bitter ones may produce more than 50 times as much (Ihekeoronye and Ngoddy, 1985). The value obtained would be far less than what was in the raw cassava root as a result of the detoxification brought about by fermentation (Odunfa, 1985), tissue disintegration (Hahn *et al*., 1987), dewatering, roasting, etc., in the course of production. All the gari samples are within the HCN specification standard for gari samples of NIS standard of 10 mg/kg. The physical and technological properties of gari samples are shown in Tables 4.12 to 4.14.The swelling index of the samples ranged from 827.00 to 864.38%, with gari from the mechanical peeling had the highest swelling power while that of manual peeling had the lowest. Tables 4.12 to 4.14 show the swelling power of the various gari samples. The highest level of swelling power obtained for gari from the combined effect of mechanical and chemical peeling could be attributed to the high content in the raw cassava root due to soaking in the cassava fruit water. These values agreed with those (301–430%) reported by Ojo and Akande (2013) and Karim *et al*. (2016). The high values can be attributed to the dryness of the gari samples as indicated by the low moisture content (6.30 – 6.80%). Swelling index indicates the ability of the gari to swell and this is influenced by the quantity and starch components (amylose and amylopectin) present in the gari. Swelling index has been reported and

shown to give a greater volume and more feeling of satiety per unit weight of gari to a consumer and a swelling index of at least 3.0 (300%) was recommended to be preferred by consumers (Almazan, 1992; Karim *et al*., 2016 and Akingbala, 2005).

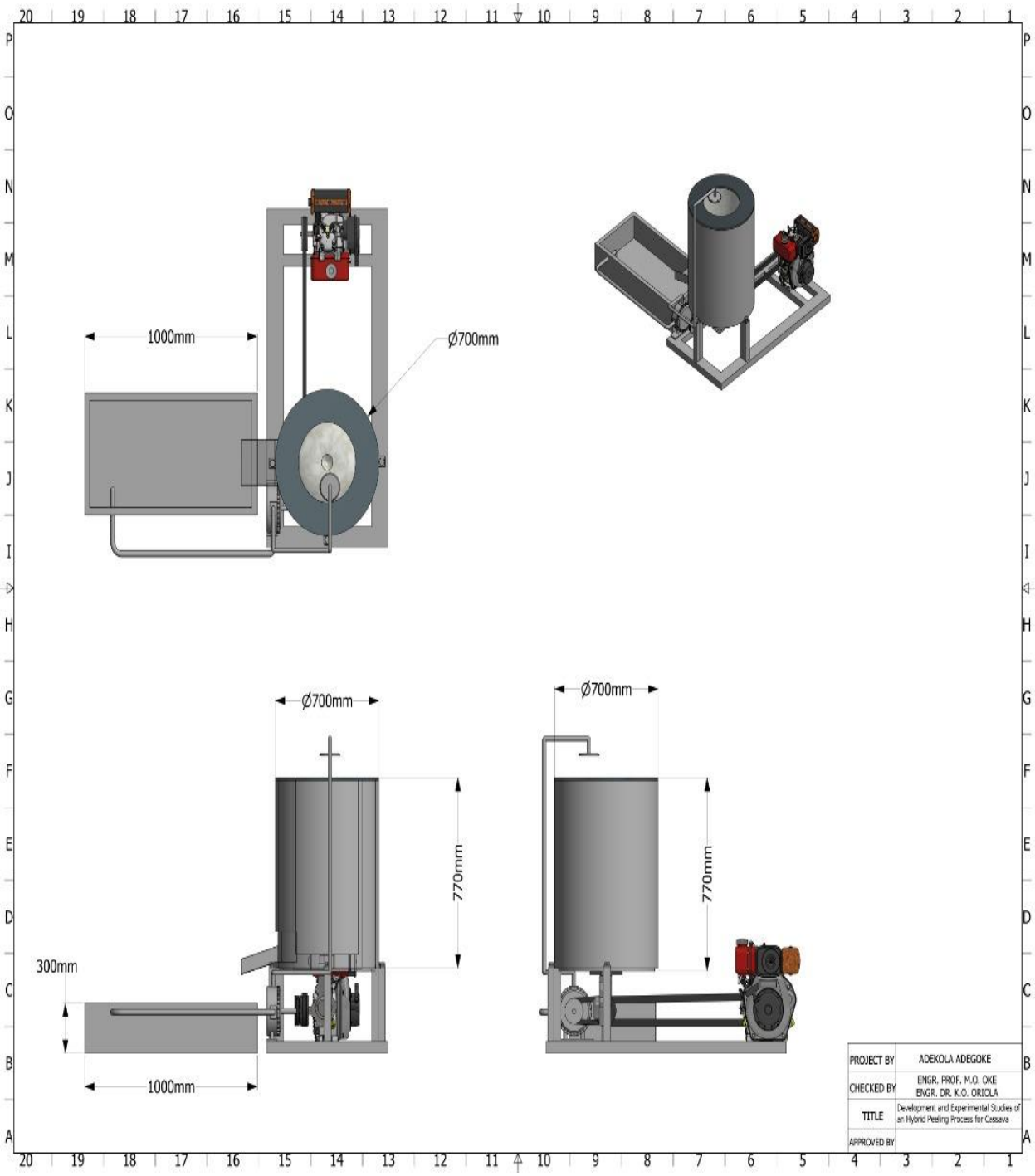

Figure 2: Isometric views of the peeling machines as described by Adegoke *et al.,* (2020)

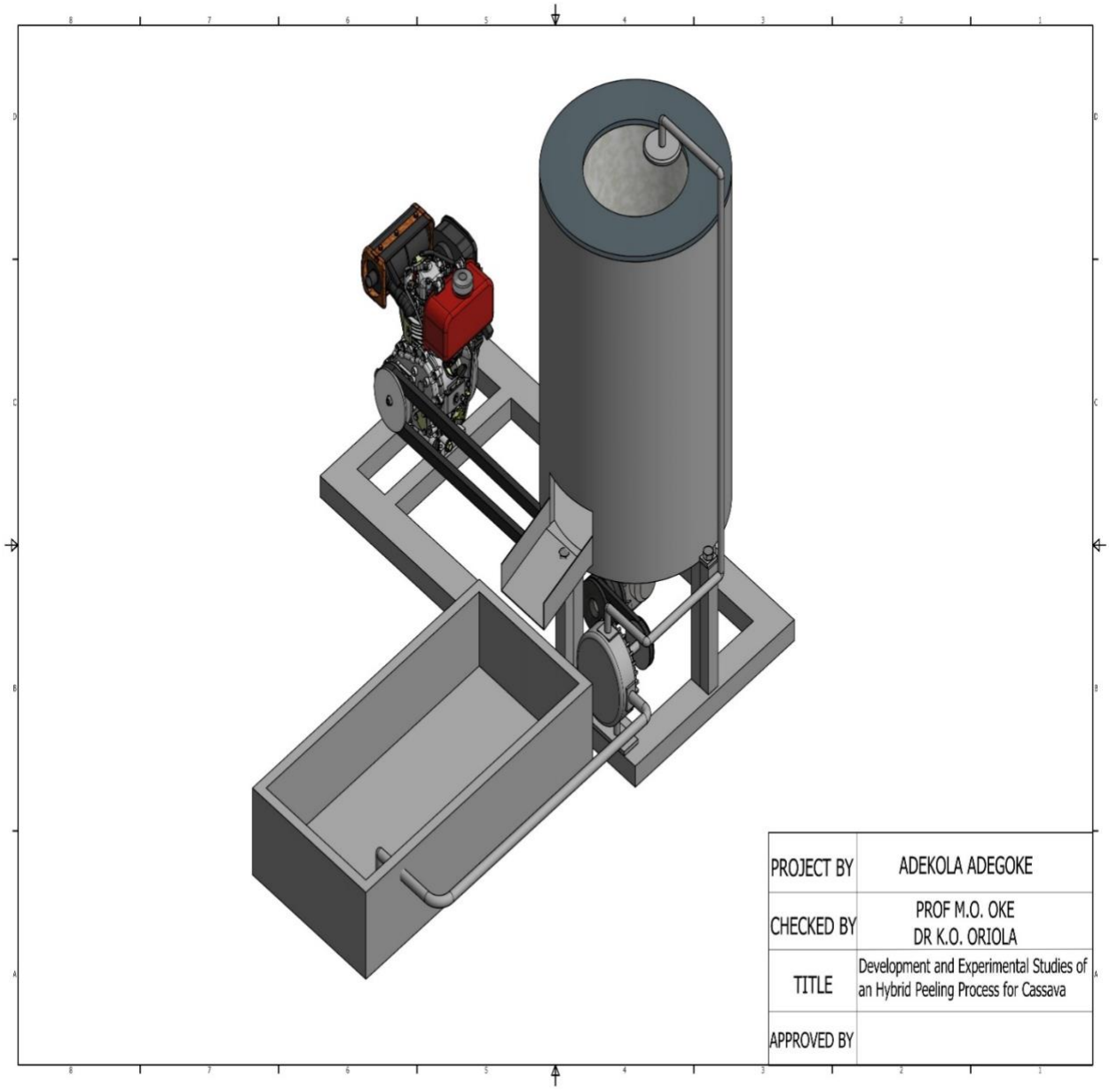

Figure 3: The 3 Dimensional drawing of the developed machine by Adegoke *et al.,* (2020)

(a) The peeler with fruit water **(b) Cassava fruit water used in soaking roots**

(b) Peeled roots after soaking in fruit water (d) Peels retained on the strainer

(a) Dressed peeled cassava roots after soaking in fruit water

Figure 4: Picture of the machine, peeled root and the peels for mechanical and chemical peeling

Table 1: Proximate Composition and Some Functional Properties of HQCF from manually peeled Cassava roots

Parameters	TMS 30572	TME 419
Moisture content (%)	10.90[a]	11.36[b]
Dry Matter (%)	90.91[a]	88.16[b]
Crude Fat (%)	0.00[a]	0.00[a]
Crude Protein (%)	0.27[a]	0.31[b]
Crude Fibre (%)	0.00[a]	0.00[a]
Total Ash (%)	0.09[b]	0.09[b]
Total Carbohydrate (%)	88.74[a]	88.24[ab]
Cyanide (mg/kg)	2.44[a]	2.98[b]
pH	6.92[a]	6.86[b]
Bulk Density (g/ml)	0.55[a]	0.60[ab]
OAC (%)	128.00[b]	134.00[c]
LGC (%)	5.00[d]	6.37[e]
WAC (%)	132.50[b]	122.50[c]
Swelling power (%)	862.38[b]	838.85[c]
Solubility (%)	6.37[ab]	6.28[a]

Means across the row with the same superscripts are not significantly different from one another ($p<0.05$)

Table 2: Proximate Composition and Some Functional Properties of HQCF from mechanical + soaking in fruit water (60 min) peeled Cassava roots

Parameters	TMS 30572	TME 419
Moisture content (%)	10.80[a]	11.00[ab]
Dry Matter (%)	89.11[a]	90.20[b]
Crude Fat (%)	0.00[a]	0.00[a]
Crude Protein (%)	0.24[a]	0.35[b]
Crude Fibre(%)	0.00[a]	0.00[a]
Total Ash (%)	0.10[a]	0.20[ab]
Total Carbohydrate (%)	88.86[a]	88.45[b]
Cyanide(mg/kg)	2.04[a]	1.98[b]
pH	5.96[b]	5.50[c]
Bulk Density (g/ml)	0.61[a]	0.64[b]
OAC (%)	125.00[a]	144.00[a]
LGC (%)	4.00[a]	6.67[b]
WAC (%)	152.50[a]	147.50[b]
Swelling power (%)	854.38[a]	887.05[b]
Solubility (%)	6.00[a]	6.28[b]

Means across the row with the same superscripts are not significantly different from one another ($p<0.05$)

Table 3: Proximate Composition and Some Functional Properties of HQCF from mechanical peeled Cassava roots

Parameters	TMS 30572	TME 419
Moisture content (%)	9.90[a]	10.00[b]
Dry Matter (%)	90.91[a]	88.16[b]
Crude Fat (%)	0.00[a]	0.00[a]
Crude Protein (%)	0.27[a]	0.31[b]
Crude Fibre (%)	0.00[a]	0.00[a]
Total Ash (%)	0.30[a]	0.09[b]
Total Carbohydrate (%)	89.60[a]	89.60[a]
Cyanide(mg/kg)	4.04[a]	3.98[b]
pH	6.55[a]	6.70[b]
Bulk Density (g/ml)	0.68[a]	0.60[c]
OAC (%)	138.00[b]	140.00[c]
LGC (%)	5.00[a]	6.11[c]
WAC (%)	132.50[b]	122.50[c]
Swelling power (%)	860.00[a]	857.85[b]
Solubility (%)	6.80[a]	6.28[c]

Means across the row with the same superscripts are not significantly different from one another ($p<0.05$)

Table 4: Proximate Composition and Some Functional Properties of *gari* from manually peeled Cassava roots

Parameters	TMS 30572	TME 419
Moisture content (%)	6.80[a]	6.36[b]
Crude Protein (%)	1.59[a]	1.52[c]
Crude Fat (%)	0.32[a]	0.30[ab]
Crude Fibre (%)	2.43[a]	2.51[b]
Total Ash (%)	0.79[a]	0.82[ab]
Total Carbohydrate (%)	90.50[a]	88.49[b]
Cyanide (mg/kg)	2.14[a]	1.92[b]
pH	5.00[a]	4.98[ab]
PBD (g/ml)	0.62[a]	0.60[ab]
WAC (%)	425.30[a]	320.22[b]
Swelling power (%)	863.80[a]	827.00[b]
Solubility (%)	7.58[b]	6.02[c]

Means across the row with the same superscripts are not significantly different from one another ($p<0.05$)

Table 5: Proximate Composition and Some Functional Properties of gari from mechanical + soaking in fruit water (60 min.) peeled Cassava roots

Parameters	TMS 30572	TME 419
Moisture content (%)	7.00[a]	6.51[b]
Crude Protein (%)	1.52[a]	1.42[ab]
Crude Fat (%)	0.42[a]	0.31[b]
Crude Fibre (%)	2.33[a]	2.21[a]
Total Ash (%)	0.71[a]	0.80[b]
Total Carbohydrate (%)	88.02[a]	88.75[a]
Cyanide(mg/kg)	3.14[a]	2.92[b]
pH	4.35[a]	4.82[b]
PBD (g/ml)	0.675[a]	0.560 [a]
WAC (%)	430.39 [a]	320.21 [b]
Swelling power (%)	860.38 [a]	830.55 [b]
Solubility (%)	6.50 [a]	6.25 [a]

Means across the row with the same superscripts are not significantly different from one another ($p<0.05$)

Table 6: Proximate Composition and Some Functional Properties of gari from mechanical peeled Cassava roots

Parameters	TMS 30572	TME 419
Moisture content (%)	6.00 [a]	6.86 [b]
Crude Protein (%)	1.55 [a]	1.32 [ab]
Crude Fat (%)	0.52 [a]	0.40 [b]
Crude Fibre (%)	2.40 [a]	2.58 [a]
Total Ash (%)	0.73 [a]	0.76 [a]
Total Carbohydrate %	88.80 [a]	88.08 [b]
Cyanide(mg/kg)	2.60 [a]	1.98 [a]
pH	4.69 [a]	4.53 [b]
PBD (g/ml)	0.675 [a]	0.599 [b]
WAC (%)	435.39 [a]	318.21 [b]
Swelling power (%)	864.38 [a]	837.85 [a]
Solubility (%)	6.57 [a]	6.22 [ab]

Means across the row with the same superscripts are not significantly different from one another ($p<0.05$)

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