05 Functional and pasting characteristics of modified water yam flour (Diocorea alata)

By Rosida

Functional and pasting characteristics of modified water yam flour (*Diocorea alata*)

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Abstract

Autoclaving-cooling treatment was introduced in order to produce the physically modified water yam flour. Water yam (*Dioscorea alata*) tuber of three varieties (purple, yellow, and white) were autoclaved-cooled (3 cycles) prior to the determination of their functional and pasting properties of their flours. Autoclaving-cooling treatments resulted in a significant increase in crystallinity of the starches, swelling power, and water absorption capacity; whereas solubility and oil absorption capacity were lowered by autoclaving-cooling process. When compared to the native, and modified water yam flours showed lower peak viscosity, breakdown viscosity, final viscosity, pasting temperature and shorter pasting time, but the differences were insignificant (p>0.05). Low viscosities of the modified water yam flours make it suitable for a wide application in the food industry. The objective of this work is to study the effect of autoclaving-cooling treatments and the varieties of water yam on the pasting and functional properties of modified water yam flours.

Keywords: water yam, functional properties, pasting properties, autoclaving-cooling

Introduction

Water yam (*Dioscorea alata*) is irregular shape tuber with the outer skin is brown to black in color. The tuber flesh has white cream or light purple in color. *D. alata* is known as water yam, winged yam, greater yam or purple yam (Mudita, 2013). Usually water yam is processed before consumed by steaming, boiling, frying, or roasting.

The quality of tuber root products, such as yams, usually is determined by functional and pasting properties of their starch. These properties are important to know for industrial application purposes. Starch properties of yam influence the suitability for different products.

Starch affect textural qualities to the tubers and is also a dominant factor in determining the physicochemical, rheological, and textural characteristics of yam products (Baah, 2009).

The viscosity of starch paste is an important physical characteristic that determines its potential use in various foods. Likewise, pasting properties indicate what physical changes may be expected during the processing of starchy foods. This could also be able to modify the starches if necessary to suit product and processing demands (Yen *et al.,* 2009). Modified starch is made to improve the lack of natural starch properties from various sources of tuber roots. Starch modification is expected to produce starch properties which can be applied for certain food products and improve the product characteristics (Wuzburg, 1995).

Most of the starchy food, such as cereals, beans, and tuber roots are processed by heating with or without water addition before consumed. When starch is heating with excess water, starch will be gelatinized after hydration and then dissolved (Wursch, 1999). Heating and cooling of soluble starch will change the structure of starch from insoluble form into retrograded starch. Starch gelatinization and retrogradation play important roles in the quality and digestibility of the many resultant food products (Liu et al., 2005). The variations of such properties for the different yam flours studied could be of significance in the formulation of diets for diabetics and other health conscious individuals (Oke *et al.*, 2013).

Autoclaving process could hydrolyze the outer chain of amylose and amylopectin in crystalline area of starch granules (Mahadevamma *et al.*, 2003). Increasing the number of autoclaving-cooling cycles increased amylose and amylopectin hydrolyze and formed short chain amylose fractions. Increasing the amount of short-chain amylose fractions facilitates retrogradation and recrystallization that possibly happened during cooling. Amylose fraction bound each other by hydrogen bonds and formed double helices structure. Double helices structure bound each other and formed crystallite hence produced recrystallization of amylose fractions (Haralampu, 2000).

The research of Faridah (2011) used 3 cycle treatment (autoclaving at 121°C for 15 minutes and cooling at 4°C for 24 hours) on modified arrowroot starch. The process increased resistant starch content from 2.12% into 11.71% as well as increased in amylose and reducing sugar

The effect of autoclaving-cooling on water yam flour functional and pasting characteristics has not been investigated yet. Therefore, the objective of this study the effect was to evaluate the functional and pasting characteristics of modified water yam flours. In this research, three varieties of water yam tubers (purple, yellow and white) were autoclaved and cooled as many as three cycles prior to slicing, drying, milling and sieving, and the effect of the treatment on [7] functional and pasting properties of the flour were investigated.

Materials and Methods

Three varieties of water yams, purple (*Dioscorea alata L. var. purpurea*), yellow and white [53] water yam (*Dioscorea alata L.*) were obtained from local farmers in Tuban, East Java, Indonesia. Reagents were analytical grade, such as 96% ethanol, distilled water, diethyl eter, sulfuric acid (H_2SO_4), sodium hydroxide (NaOH), Nelson A/B, and Arsenomolybdat.

Preparation of modified flour

Modified method of Pratiwi (2008) was used for the preparation of modified water yam flour. Ninety to a hundred grams of whole yam tubers (without peeling) were weighed, placed in a 500 ml beaker and autoclaved for 15 min at 121°C. [16] After autoclaving, the samples were allowed to cool and stored for 24 h in a refrigerator (4°C). The autoclaving-cooling cycles were repeated up to 3 times. The treated samples were peeled, sliced, and dried in a cabinet drier at 60°C for 12 [7] h. The dried samples were milled into flour and sieved (80 mesh sizes) and [46] put in sealed bag and kept in covered plastic containers at 0°C for analysis.

Determination of Proximate Composition

For the determination of moisture, crude protein, crude fat and starch content using the AOAC methods (AOAC, 2005), and amylose content was determined using a colorimetric method by Juliano (1971).

Determination of Water and Oil Absorption Capacity

The water and oil absorption capacity method of Iwouha *et al*. (2004) was used. Water absorption capacity was calculated as follows:

$$\text{Water absorption capacity (ml/g)} = \frac{\text{10 ml filtrate volume (ml)}}{\text{Sample weight (g)}}$$

Oil absorption capacity was calculated as follows:

$$\text{Oil absorption capacity (ml/g)} = \frac{\text{10 ml oil volume (ml)}}{\text{Sample weight (g)}}$$

Determination of swelling power and solubility

The method described by Raina *et al*. (2006) was used. Swelling power and solubility were calculated as follows:

$$\text{Swelling power} = \frac{\text{Weight of sediment paste}}{\text{Sample weight}}$$

$$\text{Solubility} = \frac{\text{Weight of Soluble}}{\text{Sample weight}}$$

Determination of pasting characteristics

Pasting characteristics of yam flour were determined with a Rapid Visco Analyser (RVA Super 3, Newport Scientific Pty Ltd., Australia) by Newport Scientific (1998). Three grams [1](3 g) of flour was mixed in 25 ml of water in a sample canister. The sample was thoroughly mixed and fitted into the RVA as recommended by Newport Scientific (1998). With the use of the 12-min profile, [8]the slurry was heated from 50°C to 95°C with a holding time of 2 min. This was followed by cooling to 50°C with another 2 min holding time. Both the heating and cooling was at a constant rate of 11.25°C / min with constant shear at 160 rpm. [1]Corresponding values for peak viscosity, holding strength, breakdown, final viscosity, setback, pasting time, and pasting temperature from the pasting profile were read on a computer connected to the RVA.

Determination of Crystallinity [5](X-ray diffraction pattern)

The X-ray diffraction patterns of yam flour were obtained using an X-ray Diffractometer (X-Pert MPD, Japan). The instrument was [28]operated at 40 kV and 30 mA. Diffractographs were obtained from 4° (2Θ) to 40° (2Θ) at a scanning speed of 5°/min. Relative crystallinity was analyzed for control water yam flour and the modified flour from 3 cycle autoclaving-cooling treatment and calculated according to Frost *et al.* (2009).

Statistical analysis

This research used factorial experimental design with 3 varieties of water yam and 4 processing methods (0, 1, 2, 3 autoclaving-cooling cycles). All analyses, except XRD pattern, were carried out in duplicates. The mean and standard deviation of the data obtained were calculated. The data were evaluated for significant differences in their means with Analysis of Variance (ANOVA) (p=0.05). Differences between the means were separated using Duncan's Multiple Range Test (DMRT).

Results and Discussion

Chemical composition of modified water yam flour

Moisture content of the modified water yam flour ranged between 4.42and 5.36%. The moisture content of all flours was below 13%, which is good for maintaining flour quality. Moisture content between 4.40% and 5.86% have been reported by Harijono *et al.* (2013). The protein and fat content in modified flour were 3.59-5.69% and 0.18-0.46%, respectively. This composition is a key to achieve desirable product quality as well as nutrition value. Modified water yam flour had starch content ranged from 60.61% to 61.72%. Tuber crops such as yams are quite rich in starch, accounting for 60.42 to 77.56% (Wireko-Manu *et al.*, 2011) Starch contents influence the suitability of yam for different products (Baah *et al.*, 2009). Starch affects textural qualities to the tuber. Starch is also a dominant factor in determining the physicochemical, rheological, and textural characteristics of yam products.

Modified water yam flour had high amylose content ranging from 17.66% to 22.42%. Amylose content of yam is reported to be between 14-30% depending on the species, with 21-30% amylose for *D. alata*, 21-25 % for *D. rotundata* and 21-25% for *D. cayenensis* (Moorthy, 2002). Amylose is a major component of starch which influences pasting and retro-gradation behaviors (Zhenghong *et al.*, 2003) and impart definite characteristics to starch (Moorthy, 1994). Viscosity parameters during pasting are cooperatively controlled partly by 3 the properties of the swollen granules and the leached out soluble materials (mainly amylose) from the granules (Singh *et al.*, 2006).

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Water and Oil Absorption Capacity

Water and oil absorption capacity of water yam flour are shown in Figure 1a and 1b.

Native yellow water yam flours 64 had the highest water absorption capacity (3.35 ml/g), followed by white water yam (3.25 ml/g) and purple water yam (2.85 ml/g). It may be due to lower amylose content of yellow water yam than purple and white water yam. Increasing the amount of autoclaving-cooling cycle increased water absorption capacity. It is probably caused by starch damaged by heating process. Iwuoha (2004) reported that water absorption capacity of water yam in Nigeria was 1.77 g/mL which was higher than *D. rotundata* (1.74 g/mL) and *D. cayanensis* (1.76 g/mL). The [1] ability of starch to absorb water is an indication of its moisture stability that is very important for food industry (Adebowale [52] *et al.*, 2006).

The water absorption capacity of modified water yam flour was higher (3.05-4.05 ml/g) compared to native flour (2.85-3.25 ml/g). However, modified water yam flour had lower oil absorption capacity (0.6-0.9 ml/g) than those of the native flour (0.8-1.5 ml/g). Autoclaving-cooling process had increased water absorption but lowered oil absorption capacity. Water absorption capacity influenced produt viscosity and the properties of starch system (Richana and Sunarti, 2004). High water absorption capacity may assure product moisture stability (Adebowale *et al.*, 2006).

Native white water yam flour had the [61] highest oil absorption capacity (0.9-1.5 ml/g), followed by yellow water yam (0.9-1.3 ml/g) and purple water yam (0.6-0.8 ml/g). These observations [2] are in agreement with the previous results that reported by Harijono *et al.* (2013) which purple and yellow water yams had oil absorption capacity about 1.11 [25] ml/g and 0.96 ml/g, respectively. [25] Oil absorption capacity is higher than sweet potato flour (0.65 g/mL) (Adeleke and Odedeji, 2010).

Native purple water yam flour had the lowest [25] oil absorption capacity because of the highest fat content (0.60%). The mixture of fat and starch would affect physical properties of starch because fat content could form fat-amylose complex which restricted swelling of starch granule therefore the starch is difficult to gelatinize (Fennema, 1985).

Oil absorption capacity is decreased by autoclaving-cooling treatment. It might be caused by protein denaturation that make its nonpolar side open and be in the protein surface. Protein has both hydrophilic and hydrophobic properties and can interact with water in foods. Low water absorption capacity is related to low polar amino acids in flour, conversely low oil absorption capacity is related to high non polar amino acids. Carbohydrate is also reported to influence [60] water absorption capacity of foods. The high oil absorption capacity makes the flours suitable to enhancement flavor and mouth feel (Appiah *et al.*, 2011). While low oil absorption capacity is needed to produce fried products thus were not absorbed much oil while frying.

[51] *Swelling Power and Solubility*

The swelling power of native and modified water yam flours measured from 50°C to 80°C at 10°C intervals and at three different varieties water yam is shown in Figure 2.

As shown in Figure 2, the degree of swelling of various flours was significantly different ($p<0.05$). Purple water yam flour had the least swelling power (2.21-4.49%) due to its highest amylose content (22.66%). Yellow and white water yam flour had similar swelling power (2.57-5.75%) and (2.58-5.82%), respectively because they have similar amylose content (17.59%) and (18.28%). Swelling power is influenced by amylose and amylopectin [50] content. The higher amylose content caused the lower swelling power. Since amylose molecule tended to be in parallel position, so its hydroxyl group bound freely and starch formed strong crystalline aggregate, thus restricted starch swelling (Rilley, 2006)

Beside that mucilage of yam (water soluble polysaccharides) also affected the swelling properties. According to Yen *et al.* (2009) the more mucus of yam caused in swelling power decreasing. The mucus of yam is water soluble polysaccharide which is bound to protein, while protein is the most compound and caused starch granule planted stiffly at protein matrix then confined water access and swelling power (Aprianita, 2010).

These observations [2] are in agreement with the previous results reported by Harijono *et al.,* (2012), that water yam had 3.0-6.0% of swelling power. But this value were lower than other tuber flour such as *D. rotundata* flour (5.48-8 [59] g/100 g) and sweet potato flour (6.01 g/100 g) (Srichuwong *et al.*, 2005).

It was found that the swelling power of all native yam flour was lower than those of modified flour. After autoclaving-cooling treatment, the swelling powers were increased as comparing with native yam flour. This was due to leaching of the straight chain amylose into the cooking medium. A similar increase in swelling power after heating treatment was reported for blanching (Harijono *et al*., 2013). Amylose was reported to restrict swelling and that starch granules show complete swelling after amylose has been leached out of the granules (Bhattacharya *et al*., 1999).

Starch is insoluble in water at room temperature; however if the temperature increased, starch could be swollen up to a certain degree (Wadchararat, 2006). As the temperature increased from 50°C to 80°C there was a progressive increase in swelling power of both native and modified water yam flours. These results are in agreement with the observations on increase in swelling power with temperature for purple and yellow water yam (Harijono *et al.,* 2013). When starch is heated with exceed amount of water, granule hydrate progressively, hydrogen bonds are ruptured resulting in crystalline regions being converted into amorphous regions and granules continue to imbibe water and swell (Ratnayake *et al*., 2002).

Another property related to swelling is solubility. Yellow water yam flour had the highest solubility (0.09-0.12%), followed by white and purple water yam flour, which had solubility about (0.10-0.11%) and

(0.07-0.08%), respectively (Figure 3). For native water yam flours, the solubility increased with decreasing amylose content due to restriction of the swelling capacity of the starch granules. The study revealed that autoclaving-cooling treatment lowered solubility of the flour. Increasing the amount of autoclaving-cooling cycle reduced the solubility of modified flour so this flour is suitable to be used as ingredient of food products.

Figure 3 showed the increasing temperature increased the solubility of all water yam flours, showing similar trend to swelling property. The raising in solubility with temperature may be due to increasing in mobility of the starch granules, which facilitated enhanced dispersion of starch molecules in water (Adebowale *et al.*, 2005).

Crystalinity Properties (X-Ray diffraction)

X-Ray diffraction was used to study the crystalline structure of native and modified water yam flours. In the diffraction spectra, purple water yam flour showed strong diffraction peaks at 14.0°, 17.0° and 23.0°(2θ); whereas yellow and white water yam flour showed diffraction peaks at 15.0°, 17.0°, 22.0° and 23.0°(2θ) (Figure 4). Thus, purple water yam flour had B-type while yellow and white water yam flour had A-type X-Ray diffraction pattern. These observations are in agreement with the previous results reported by Herawati (2009), that white water yam had A-type starch gelatinization pattern. The A-type pattern is signed by high maximum viscosity and sharp breakdown viscosity. So that, gelatinization profile of water yam is one category with tapioca, potato, sweet potato, sago, waxy yam and waxy barley starch.

Modified water yam flours showed X-ray patterns similar to native flour in all varieties, so diffraction patterns were not changed after autoclaving-cooling treatment.

A-type X-Ray diffraction pattern is showed strong diffraction peaks at 15.0°, 17.0°, 20.0° and 23.0°(2θ) while B-type diffraction pattern had strong diffraction peaks at 17.0° and 23.0°(2θ) (Srichuwong *et al*., 2005). Native and modified purple water yam flour had crystallinity degree about 9.25% and 11.47%, respectively. In yellow and white water yam varieties, autoclaving-cooling treatment increased the crystallinity degree. Native yellow and white water yam flours had about 12.94% and 14.98% of crystallinity degree, and the values increased after autoclaving-cooling process into 16.26% and 18.07%. Autoclaving-cooling treatment slightly attacked amorphous region that raised crystallinity degree and did not change type of X-ray pattern of the flours. The increase of crystallinity degree was attributed to the cleavage of amylose chains in the amorphous region which allows crystalline lamellae region of amylopectin to give more crystalline structure with a sharper X- ray pattern (Wang *et al.*, 2001).

[35]

Pasting Properties

The pasting data of native and modified water yam flours are presented in Table 1. The pasting properties varied with water yam varieties and autoclaving-cooling treatment. Pasting temperature of different native water yam flours ranged from 78.2 to 87.3°C, whereas modified water yam flours had lower pasting temperature ranging from 74.2 to 78°C. [34] Pasting properties are representative of the intensity of changes that occur during starch modification (Guerra Dias *et al.*, 2011). Water yam flour started to gelatinize at high temperature (74.25-87.0°C). These observations are in agreement with the previous result that reported by Perez and Larez (2005) that the initial starch gelatinization temperature ranged from 67.75 to 81.40°C.

The pasting time provides an indication of the minimum time required to cook a given sample. The study showed there are [7] no significant difference ($p>0.05$) existed in the pasting time of the flour samples. However modified water yam flour required less time for cooking than the native flours.

The study showed that modified purple water yam flours do not undergo gelatinization process since the starch is ruptured by autoclaving-cooling process so pasting temperature cannot be detected. Thus the purple water yam variety is not suitable to process by autoclaving-cooling.

Higher peak viscosities were observed in the native water yam flour (128.29 RVU in purple water yam, 106.42 RVU in yellow water yam and 113.58 RVU in white water yam. The modified water yam flours had lower peak viscosities (ranging from 53.75 to 113.51 RVU) than the native flours indicating low starch contents in the modified flours. Reduction in the starch contents of the modified flours may be due to the formation of retrograded starch. Peak viscosity reflects the ability of starch granules to swell freely before their physical breakdown. The lower peak viscosities of test samples may be as a result of the relatively lower swelling power obtained (Figure 2). Low swelling power, low starch content, and high dietary fiber contents were reported to have influenced peak viscosity in *D. alata* varieties (Baah, 2009). Peak viscosity relates with product quality hence differences observed among the samples studied may influence their performance in product development. According to Srichuwong *et al.* (2006), water yam had peak viscosity about 2715 cP/226.25 RVU at 85.1°C. This value is similar to *Ganyong* and lesser yam.

The most commonly used parameter to determine starch-based samples quality is final viscosity, it indicates starch/flour ability to form a gel after cooking. Final viscosity is the viscosity after cooling cooked paste to 50°C (Wireko-manu *et al.*, 2011).

The higher values obtained for final viscosities as compared to the peak viscosities (Table 1) are due to high degree of association between starch-water and their high ability to re-crystallize. The final viscosities of the water yam flours decreased after autoclaving and cooling treatment (75.83-169.42 RVU). [49] The final viscosities of the modified flours were higher than the peak viscosity which indicating their high resistance to shear stress during cooking and cooling. [22] The final viscosity of starch gels is affected by starch retro-gradation. Previous data indicate the retro-gradation properties of flours differed by plant sources (Liu [57] *et al.*, 2005). Aprianita (2010) reported that the interaction of mucus and starch caused low viscosity. The [69] final viscosity of flour is affected by protein content which could bind water so that water availability is decreased. The less water absorbed by starch because of protein content hampered gelatinization processed and lowered final viscosity.

The modified water yam flour showed setback viscosities (43.82-72.08 RVU) which were higher than those of native flour (30.5-56.87 RVU). Native purple water yam had the highest setback viscosity (56.87 RVU) than yellow and white water yam, about (49.33 RVU) and (30.5 RVU), respectively. It might be purple water yam had higher amylose content than other varieties.

The higher setback observed for modified water yam flours than native flour in this study suggested that the flours were relatively unstable when cooked and have a higher [56] tendency to undergo retro-gradation during freeze/thaw cycles. Retro-gradation of starch paste is considerable practical significance since it affects textural changes that occur in starchy foods. Generally the tendency of yam starch paste to retrograde is a limiting factor for its use in food industries. Baah (2009) reported that yam starch had high setback viscosity and tended to undergo retro-gradation within cooling process compared to other root and tuber crops. High maximum viscosity and undergo retro-gradation process fast are the important properties which are needed to make non-wheat noodle (Tam *et al.,* 2004).

Conclusion

Modification by autoclaving-cooling at three varieties of water yams caused significant changes in functional and pasting properties. Varieties of water yams and autoclaving-cooling treatment resulted in an increase in crystallinity of the starches. Autoclaving and cooling did not affect on solubility but resulted in significant effect on swelling power. Modified water yam flours showed lower peak viscosity, and pasting temperature, and shorter pasting time than those of native ones.

Autoclaving-cooling process improved the functional properties of the flour. Low viscosities of the modified flour are suitable for a wide application in the food industry. Modified white water yam flour had better pasting and functional properties than other varieties, such as swelling power, water absorption capacity and oil absorption capacity.

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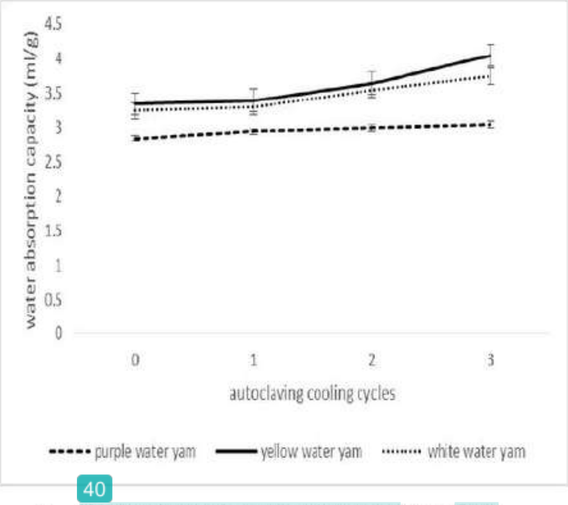
Table 1. Pasting data of purple, yellow and white water yam flour at different autoclaving-cooling cycles

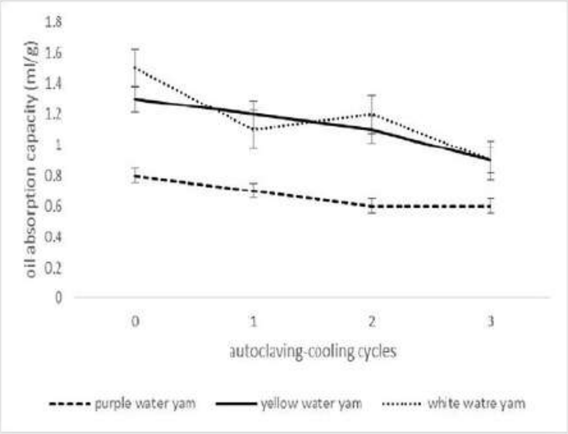
Treatment		Peak Visc. (RVU)	Final Visc. (RVU)	Setback (RVU)	Pasting Time (min)	Pasting temp (°C)
Variety of water yam	Number of autoclaving cooling cycle					
Purple	0	128.29^{a}	173.71^{a}	56.87^{a}	7.00^{a}	81.50
	1	108.50^{a}	105.87^{a}	43.92^{a}	6.46^{a}	-*
	2	15.33^{a}	32.63^{a}	20.79^{a}	6.96^{a}	-*
	3	12.92^{a}	18.38^{a}	11.92^{a}	6.96^{a}	-*
Yellow	0	106.42^{a}	168.42^{a}	49.33^{a}	7.00^{a}	78.20
	1	98.50^{a}	143.17^{a}	50.50^{a}	6.93^{a}	78.00
	2	88.83^{a}	141.75^{a}	51.50^{a}	6.27^{a}	76.60
	3	82.50^{a}	75.83^{a}	51.75^{a}	7.00^{a}	74.20
White	0	113.58^{a}	141.58^{a}	30.50^{a}	5.87^{a}	87.30
	1	104.33^{a}	169.42^{a}	48.58^{a}	6.60^{a}	76.65
	2	104.50^{a}	164.42^{a}	69.58^{a}	6.93^{a}	76.65
	3	53.75^{a}	115.67^{a}	72.08^{a}	7.00^{a}	75.10

*the values cannot be detected so other value of the flour is not included in statistical analysis

** the values with different superscripts in the same column are significantly different at $p<0.05$

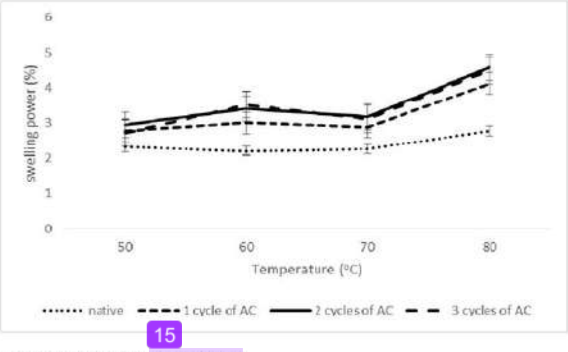


a. Water absorption capacity water yam flour

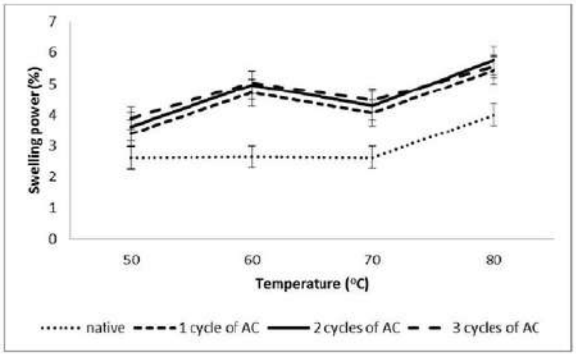


b. Oil absorption capacity water yam flour

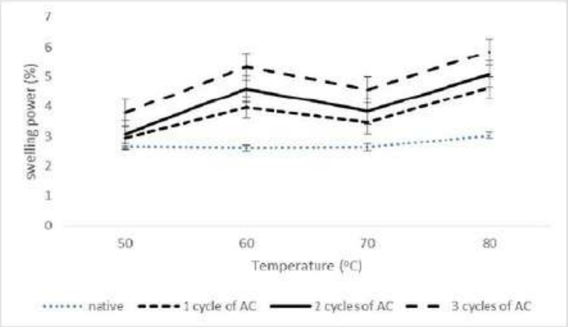
Figure 1. (a) Water absorption capacity (ml/g) and (b) Oil absorption capacity (ml/g) of purple, yellow and white water yam flour at different autoclaving-cooling cycles



a.Purple water yam flour

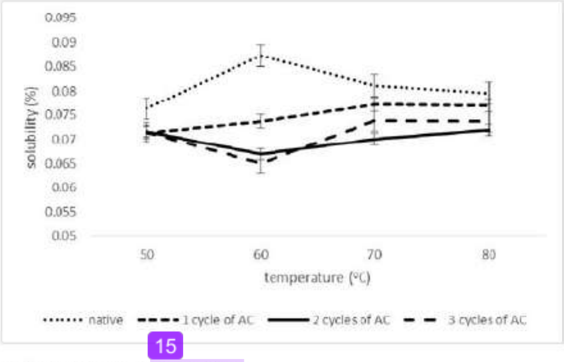


b.Yellow water yam flour

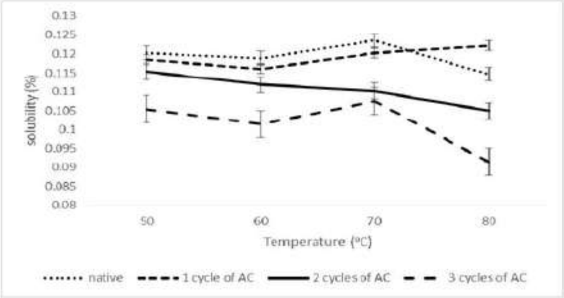


c.White water yam flour

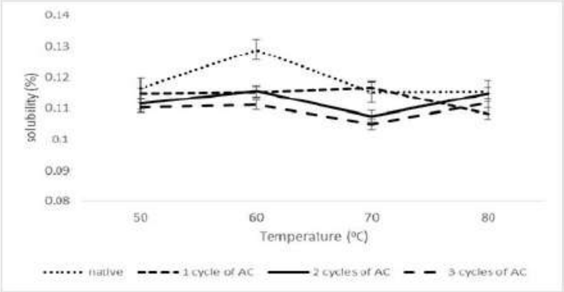
Figure 2. Swelling power (%) of (a) purple, (b) yellow and (c) white water yam flour at different autoclaving-cooling cycles (AC) and different temperature



a.Purple water yam flour



b.Yellow water yam flour



c.White water yam flour

Figure 3. Solubility (%) of (a) purple, (b) yellow, and (c) white water yam flour at different autoclaving-cooling cycles (AC) and different temperature

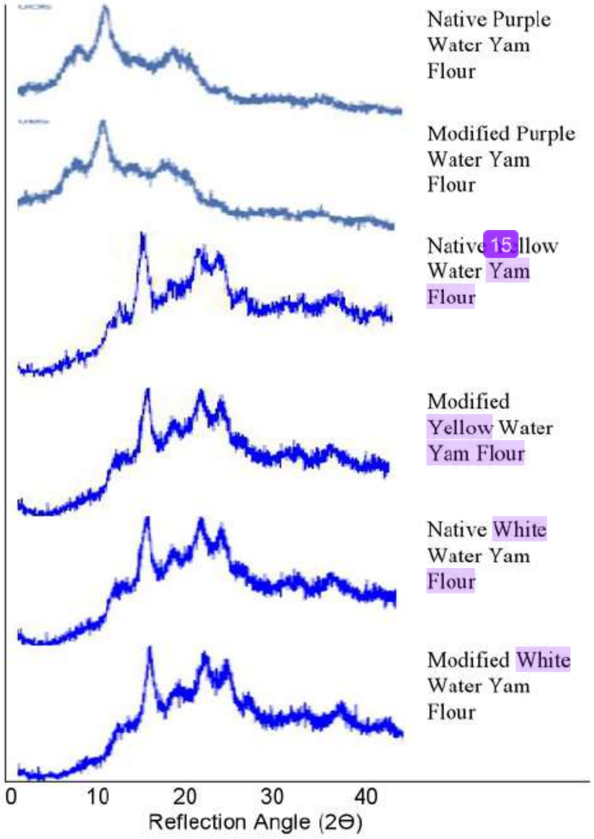


Figure 4. The diffraction spectra of native and modified water yam flour

(after 3 autoclaving-cooling cycles)

05 Functional and pasting characteristics of modified water yam flour (Diocorea alata)

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