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Efficient processing of cassava starch: physicochemical characterization at different processing parameters

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Abstract

The aim of this study was to evaluate the physicochemical properties of cassava starch that was processed using different parameters (types of water, drying temperatures and milling sizes) to be added into the food products as an ingredient. Selected commercial cassava starch was used as a reference. Mineral water showed a significantly higher value ($p<0.05$) for the paste viscosity of cassava starch compared to the other types of water, but indicated no significant difference ($p>0.05$) with tap water for the swelling power, solubility and gel strength of cassava starch. The increase in the drying temperature significantly decreased ($p<0.05$) swelling power, paste viscosity and gel strength of cassava starch but significantly increased ($p<0.05$) its solubility. The increase in the milling size significantly increased ($p<0.05$) swelling power and solubility, paste viscosity and gel strength of cassava starch. For industrial benefits, the use of mineral water for starch processing, the lowest drying temperature of 70°C and the largest milling size of 63 µm shall be the best processing parameters to produce cassava starch with the highest swelling power which could act as a reliable expansion aid in food products. These parameters shall also be the best processing parameters to produce cassava starch with the highest paste viscosity which could function as a desirable food thickening or gelling agent, as well as the highest gel strength that could be applied as an excellent texture enhancer, binder, or coating for food products.

1. Introduction

Cassava, scientifically known as *Manihot Esculenta Cranz*, is a type of plant that is consumed across the world as one of the main sources of carbohydrates and as a staple food (Alves, 2001). The ability of cassava plants to survive and grow on lands with low water supply, fertilizers and agrochemical inputs allows easier, cost-effective cultivation and management (Okudoh *et al.*, 2014). Starch, which is a functional major component of cassava roots, is usually dried and ground into dry powder form to increase its shelf life and facilitate its uses for many applications (Falade and Akingbala, 2010). Various applications of starch in food production have made it a highly demanded raw material by consumers and manufacturers. Starch can be used as a thickening agent, gelling agent (Berski *et al.*, 2011), binder, texture enhancer (Beggs *et al.*, 1997; Pietrasik, 1999), crispiness enhancer and coating (Gaines *et al.*, 2000) in many edible and non-edible products. However, some problems may emerge on the end product of cassava starch manufacturing where the quality of cassava starch could be unfit for applications in food products that use cassava starch as an ingredient. The quality of starch could be determined by its physicochemical properties which represent the functionality of starch (Adebowale and Lawal, 2002). For instance, commercial cassava starch produced by a local starch manufacturer in Malaysia that was used as a reference in this experiment showed very low paste viscosity that could render it less suitable to be applied as thickener and gelling agent in food (Berski *et al.*, 2011) and very low gel strength that may hinder its capacity as a texture enhancer in food products like frozen surimi products (Liu *et al.*, 2014). These problems eventually may lead to fewer consumers' acceptance and loss of profits. For these reasons, the need to inquire into processing factors that may lower the quality of cassava starch has emerged so that these factors can be controlled or modified in order to meet the quality standards that are highly anticipated by consumers or manufacturers.

Potential involuntary changes of physicochemical properties of the cassava starch could be induced by processing factors such as types of water, drying temperature and milling size as proven from previous

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researches. Different types of water may affect the physicochemical properties of starch due to the differences in mineral ion contents and concentrations which was proven to have remarkable effects on the properties of starch. The types of water generally used in starch processing are mineral water and household tap water. Mineral water, commonly known as hard water has a lot of dissolved ions, especially ions of calcium and magnesium (Gumashta *et al*., 2012). This water is abundant in nature and could be economical for manufacturers. Tap water is commonly used but could be costing more to manufacturers since the costs for water supplies and maintenance would be involved. Calcium ions, for instance, increase the swelling power of starch (Jiang *et al*., 2012) and viscosity of the starch paste (Jane, 1993; Samutsri and Suphantharika, 2012), while sodium ions decrease the swelling power of starch (Oosten, 1990; Hedayati *et al*., 2016) and viscosity of starch paste (Hedayati *et al*., 2016). Different drying temperatures were reported to have effects on the physicochemical properties of starch as well. Higher drying temperature reportedly causes lower swelling power and solubility of starch (Aviara *et al*., 2010; Akintunde and Tunde-Akintunde, 2013) and lower viscosity of starch paste (Alam and Hasnain, 2009). Besides that, different milling sizes also could influence the physicochemical properties of starch as smaller milling size reportedly causes lower swelling power (Noranizan *et al*., 2010), paste viscosity and gel strength (Hossen *et al*., 2011). Study on the effects of processing parameters on physicochemical properties of cassava starch seems to be scant. Thus, a need to investigate the influences of processing factors such as types of water, drying temperature and milling size on the changes in physicochemical properties of cassava starch such as swelling power, solubility, paste viscosity, and gel strength emerges as these changes may restrict the application of cassava starch in food production. Cassava starch manufacturing industry can benefit from this research through the knowledge for process modification in order to attain cassava starch with desirable qualities such as higher swelling power, paste viscosity, and gel strength which could be more applicable in the food industry.

The objective of our study was to investigate the effects of three processing parameters: different types of water, drying temperatures, and milling sizes on the physicochemical properties of cassava starch. The physicochemical properties of cassava starch evaluated were swelling power and solubility, paste viscosity, and gel strength.

2. Materials and methods

2.1 Raw materials

Cassava roots of *Manihot Esculenta Cranz* species with the same variety (peat cassava plants were grown in Banting, Selangor, Malaysia and harvested in April 2016) were obtained, peeled and washed with filtered clean water. Then, they were chopped into thin slices of 1 cm thickness (Oduro-Yeboah *et al.,* 2010) for further starch sample preparation. Cassava starch obtained from Bio Starch Industries Worldwide Sdn. Bhd., Malaysia was labeled as commercial starch (cassava roots were from the variety of clay-loam cassava plants grown in Perak, Malaysia, wholly processed using underground water from Section 51A, Petaling Jaya, Selangor, Malaysia). This commercial starch had particle size distribution of industrial starch at 0.29 μm based on particle size analysis carried out by Kim *et al.* (2004) and was used as a reference to the other cassava starch samples produced through different processing parameters.

The deionized water was obtained using Arium Pro DI Type 1 Ultrapure Water Quality Systems (Sartorius AG, Göttingen, Germany). The deionized water was selected as a controlled sample or a blank solution to be compared to the other types of water due to its very low mineral content (Mazurova *et al*., 2015). The tap water was obtained from food pilot plant of Universiti Kebangsaan Malaysia. Mineral water used was Spritzer mineral water from the underground source at Taiping, Perak, Malaysia. Tap water and underground mineral water were selected because they are abundant and generally used in food industries. Plus, selected commercial starch was also processed using 100% underground water.

2.2 Analytical measurement for different types of water

Analyses for pH value and mineral content were conducted on different types of water which were deionized water, tap water, and mineral water. The pH value of the water was determined by using a pH meter (Kulthanan *et al*., 2013). The analysis of the mineral content of water was carried out according to the method by Voica *et al*. (2013).

2.3 Preparation of cassava starch

Cassava starch extraction was carried out by means of sedimentation (Oduro-Yeboah *et al.*, 2010) with some modifications. Sliced cassava root was ground with tap water for 10 mins to obtain 1:2 cassava roots to water mixture (modification was made here by replacing tap water with deionized water and mineral water to yield three different types of water). The resulting semi-liquid starch slurry was filtered through cheesecloth to separate the pulp from semi-liquid starch milk collected in the filtrate. The rinsing process was repeated three times to ensure there was little or no starch in the semi-liquid pulp. Isolated starch milk was left for 15 hrs for sedimentation and then the supernatant liquid was poured out. The starch layer was visible as it deposited on the bottom. The starch layer was scraped off and dried in an oven for 7 hrs at 70°C (modification was made here by substituting the drying temperature of 70°C with 80°C, 90°C, 100°C to yield four different drying temperatures) and milled using a mortar and pestle. Milled starch was sifted using a sieve with 63 µm opening size (modification was made here by substituting the 63 µm sieve with 45 µm and 53 µm sieves to yield three different milling sizes) and then stored in clean labeled containers with the tight lid.

The milling sizes of 45 µm, 53 µm, and 63 µm were selected because they complied with Codex Standard for Edible Cassava Flour by indicating particle size of flour starch lower than 600 µm (FAO and WHO, 2013). Selection of drying temperatures was based on some experimental reasons. Drying temperatures of 70°C and 80°C were chosen according to drying temperatures for starchy flour which had been used by Ajala *et al.* (2014), Njintang and Mbofung (2006), and Sanni and Jaji (2003). Drying temperatures of 90°C and 100°C were selected to investigate whether the drying temperatures higher than 80°C could have the benefit or harmful effect on the physicochemical properties of cassava starch apart from improving the efficiency of the drying process for cassava starch.

2.4 Swelling power and solubility

Swelling power and solubility of cassava starch sample had been determined using the method of Leach *et al.* (1959). The solution of 1% starch by weight/volume in distilled water was heated in a water bath shaker for 30 mins at 85°C. Water bath temperature of 85°C was selected because, at this heating temperature, starch began to thicken and became translucent (Shariffa *et al.*, 2017). Centrifuge tubes were covered with a plastic cover when heated to prevent water loss. After heating, the sample was centrifuged at 3000 rpm for 15 mins. The precipitated paste was separated from the supernatant and weighed (Wp). Both precipitated paste and supernatant were dried at 105°C for 24 hrs and subsequently weight of dry precipitated paste (Wps) and dried supernatant (Ws) were recorded. Swelling power is defined as the ratio of swollen starch after centrifugation to dry swollen starch. Solubility is defined as the percentage of dry soluble solids in the supernatant to the dry weight of the whole starch sample (Wo).

Swelling power = Wp/Wps (wet precipitated starch (g)/dry precipitated starch (g))

Solubility = (Ws/Wo) × 100% (soluble solids (g)/dry weight of whole starch sample (g))

2.5 Paste viscosity

Cassava starch solution was prepared based on the technique used by Reddy and Bhotmange (2014). The 2% starch solution was heated until it boiled at 100°C for 20 mins with even stirring and then cooled to room temperature (25°C) while continually stirred. The paste viscosity test of cassava starch solution was carried out based on the techniques proposed by Rohaya *et al.* (2013) and the readings were taken as Pascal-second (Pa.s) unit.

2.6 Gel strength

The gel strength analysis was carried out in accordance with the technique performed by Noranizan *et al*. (2010). About 10% by weight/volume of evenly stirred aqueous starch suspension was heated in a boiling water bath at 100°C while stirred continuously until the viscosity increased when the resulting starch paste reached 80°C. The hot starch paste was poured into plastic containers (4.5 cm diameter) to 3 cm height. Paraffin oil was immediately poured on the surface of this starch paste to prevent loss of moisture and then it was stored at room temperature (25±2°C) for 24 hrs. The resulting gel strength of cooled starch paste was measured using the Shimadzu AGS-J Texture Analyzer (Shimadzu Corp., Kyoto, Japan). Gel with its container was placed on the compression platform. A 20 mm diameter cylindrical ebonite probe (P10) was then driven at a constant speed (5 mm/s) into the gel for 10 mm depth. Trigger force was set at 5 g and the first peak was recorded as the gel strength. Reading was expressed in Newton (N) unit.

2.7 Statistical analysis

Values obtained from different processing parameters were expressed as mean with a standard deviation from triplicate determinations. Data were analyzed by analysis of variance using SPSS Statistics version 23. Differences between starch samples were considered significant at $p<0.05$.

3. Results and discussion

3.1 Effect of different types of water on physicochemical properties of cassava starch

The pH value of different types of water was presented in Table 1 while the mineral contents of different types of water were shown in Table 2. When starch granules are heated in excess water, they swell due

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to water uptake and increase in size (Singh *et al.*, 2003). The deionized water showed the lowest swelling power of cassava starch compared to the other types of water, including commercial starch (Table 3), which could be due to its lowest pH (Table 1) that increases the amount of intermolecular bonding between the starch polymers and decreases the interaction of starch polymers with water, hence reduces ability of starch to swell (Hoover and Ratnayake, 2002). Besides that, the starch undergoes partial gelatinization in more alkaline condition and then increases the swelling power of starch compared to lower pH condition that is less alkaline (Adebowale and Lawal, 2005). The deionized water also showed the lowest swelling power of cassava starch compared to the other types of water due to its lowest calcium ions content (Table 2) that reduces water absorption by starch granules and inhibits their ability to swell (Jiang *et al.*, 2012). The commercial starch and cassava starch treated with both mineral water and tap water displayed higher swelling power and shall be more suitable to be applied as an expansion aid in food products comparison to cassava starch treated with deionized water. These starch samples could be fit for food products such as keropok lekor, Malaysian fluffy and chewy fish crackers that expand upon boiling and local thin fish crackers that expand upon hot deep frying due to entrapment of water molecules inside the swollen starch granules (Cheow *et al.*, 2004; Noranizan *et al.*, 2010). Furthermore, cassava starch with higher swelling power also forms a less hard texture of food by trapping more water in starch molecules (Muthia *et al.*, 2010).

Table 1. The pH value of different types of water

Type of water	pH value
Deionized	7.09±0.01^a
Tap	7.39±0.01^b
Mineral	7.50±0.02^c

The values are the average of triplicate analysis with ± SD. Mean values having different superscript in a column are significantly different (p<0.05).

The solubility of starch represents the percentage of leached amylose and amylopectin from starch granules when starch is heated above gelatinization temperature (Waterschoot *et al.*, 2014). The lowest solubility of cassava starch shown by deionized water compared to tap water and mineral water (Table 3) could be due to its lowest pH value (Table 1) that limits partial starch gelatinization, hence reduces swelling power and solubility of starch, unlike at higher pH (Adebowale and Lawal, 2005). This result opposed the finding reported by Builders *et al.* (2014), which stated that a pH condition which is higher than 7 reduces the solubility of tiger nut starch. The highest solubility of cassava starch treated with mineral water may indicate weakest bonding forces within starch granules (Aryee *et al.*, 2006) compared to the cassava starch samples treated with other types of water and commercial starch.

Table 2. The mineral content for different types of water

Type of mineral ion	Mineral content (ppm)		
	Deionized water	Tap water	Mineral water
Calcium	0.50±0.00^a	9.68±0.00^b	18.04±0.06^c
Magnesium	ND	1.18±0.01^a	3.42±0.01^b
Sodium	0.29±0.00^a	9.46±0.11^b	9.16±0.10^c
Potassium	0.11±0.00^a	4.66±0.05^b	2.83±0.03^c
Aluminum	ND	0.02±0.00^a	ND
Arsenic	ND	ND	ND
Barium	ND	0.02±0.00^a	ND
Boron	0.02±0.00^a	0.02±0.00^a	0.01±0.00^a
Chromium	ND	ND	ND
Iron	ND	0.07±0.00^a	0.13±0.01^b
Uranium	ND	ND	ND
Strontium	ND	0.03±0.00^a	0.11±0.00^a
Zinc	ND	0.01±0.00^a	ND
Antimony	ND	ND	ND

The values are the average of triplicate analysis with ± SD. Mean values having different superscript in a column are significantly different (p<0.05).

Table 3. Swelling power, solubility, paste viscosity and gel strength of cassava starch processed with different types of water

Type of water	Swelling power (g/g)	Solubility (%)	Paste viscosity (Pa.s)	Gel strength (N)
Deionized	22.44±0.81^a	12.79±0.55^a	0.42±0.01^a	0.77±0.05^a
Tap	25.64±0.37^b	18.63±0.55^b	1.04±0.03^b	0.85±0.02^b
Mineral	26.29±0.34^b	19.25±1.51^b	1.17±0.07^c	0.87±0.01^b
Commercial starch	25.37±0.61^b	13.30±1.26^a	0.23±0.03^d	0.48±0.02^c

The values are the average of triplicate analysis with ± SD. Mean values having different superscript in a column are significantly different (p<0.05).

The lowest paste viscosity shown by cassava starch treated with deionized water compared to the other types of water (Table 3) could be due to its lowest calcium ions content (Table 2) that could reduce the absorption of water into the starch granules and inhibit the formation of intramolecular cross-linkage effects on the starch polymer chains (Jane, 1993; Samutsri and Suphantharika, 2012). Sodium ions can compete with starch to bind water and cause electrostatic interactions between starch and sodium ions (Oosten, 1990; Samutsri and Suphantharika, 2012) and therefore, led to lower paste viscosity of cassava starch treated with tap water compared to mineral water. Viscosity shown by starch paste may contribute to its role as a thickening agent or gelling agent in food products (Berski *et al.*, 2011). Cassava starch treated with mineral water and tap water could be promoted as the thickening and gelling agents in food (Berski *et al.*, 2011) especially in sauce products that require high stability during storage (Sikora *et al.*, 2007), instead of selected commercial starch and also

Table 4. Swelling power, solubility, paste viscosity and gel strength of cassava starch with different drying temperatures

Drying temperature (°C)	Swelling power (g/g)	Solubility (%)	Paste viscosity (Pa.s)	Gel strength (N)
70	24.57±0.56[a]	13.87±0.38[a]	0.98±0.00[a]	0.45±0.03[a]
80	22.03±0.43[b]	15.49±0.38[b]	0.82±0.01[b]	0.34±0.01[b]
90	21.95±0.37[b]	18.18±0.42[c]	0.66±0.02[c]	0.30±0.01[bc]
100	21.17±0.09[b]	18.81±0.42[c]	0.45±0.01[d]	0.27±0.02[c]
Commercial starch	25.37±0.61[a]	13.30±1.26[a]	0.23±0.03[e]	0.48±0.02[a]

The values are the average of triplicate analysis with ± SD. Mean values having different superscript in a column are significantly different ($p<0.05$).

cassava starch treated with deionized water. The commercial starch showed the lowest paste viscosity compared to those starch samples treated with all three types of water, so it is not suitable to be applied as a thickener or gelling agent.

When cooked starch paste undergoes the cooling process, leached amylose and amylopectin re-associate to form the irreversible starch gel (Lu *et al.*, 2007). The lowest gel strength of cassava starch shown by deionized water compared to tap water and mineral water (Table 3) could be due to lower calcium ions content (Table 2) that could reduce interaction between the molecules of starch and thereby, weaken starch gel (Hedayati *et al.*, 2016). Cassava starch treated with tap water and mineral water could be ideal to be applied as food coating, binder (Gaines *et al.*, 2000), texture enhancer, and chewiness enhancer for various food products, such as sausages and surimi products (Beggs *et al.*, 1997; Pietrasik, 1999) instead of cassava starch treated with deionized water and selected commercial starch. The commercial starch displayed the lowest gel strength compared to those cassava starch samples treated with all three types of water, and hence, its application in food shall be discouraged.

Although selected commercial starch was processed using underground water, it indicated very low paste viscosity and gel strength compared to the sample of cassava starch processed with mineral water, which was obtained from the underground source too. This possibly could be due to treatment with different kinds of underground water and other possible processing factors, such as probably unfit drying temperature used for commercial starch (Akintunde and Tunde-Akintunde, 2013; Mustafa Kamal *et al.*, 2017) and its very small milling size of 0.29 μm (Hossen *et al.*, 2011). By modifying the milling size or drying temperature, the commercial starch manufacturer could enhance the quality of its cassava starch so that higher paste viscosity and gel strength of starch can be obtained.

3.2 Effect of different drying temperatures on physicochemical properties of cassava starch

The highest swelling power of cassava starch shown by the lowest drying temperature of 70°C compared to higher drying temperatures (Table 4) could be due to more loss of crystalline structure of starch, amylose leaching and rearrangement of molecules in starch granules caused by higher drying temperatures (Chung *et al.*, 2000). Both commercial starch and cassava starch dried at 70°C may have the good potential to be applied as an expansion aid in food products due to their high swelling power (Cheow *et al.*, 2004; Noranizan *et al.*, 2010) compared to those treated with other higher drying temperatures.

Cassava starch dried at the lowest temperature of 70°C displayed the lowest solubility compared to higher drying temperatures (Table 4), which may be due to loss of granular structure and crystallinity of starch at higher drying temperatures that allow easier leaching of starch molecules out of the starch granules (Li *et al.*, 2014). The commercial starch showed very low solubility that did not differ significantly ($p>0.05$) from cassava starch dried at 70°C, which could be due to possibly improper drying temperature for commercial starch (Akintunde and Tunde-Akintunde, 2013; Mustafa Kamal *et al.*, 2017) or due to the breakdown of starch granules on the starch molecules from the grinding process to obtain its very small milling size of 0.29 μm (Hossen *et al.*, 2011).

Higher drying temperatures caused lower paste viscosity of cassava starch (Table 4) because higher drying temperatures can cause more broken hydrogen bonds in starch granules (Aviara *et al.*, 2010) and lead to more losses of granular structure that render starch to be less viscous (Alam and Hasnain, 2009). The cassava starch dried at the lowest drying temperature of 70°C showed the highest paste viscosity and could be ideal to be applied as a thickening agent compared to those dried higher temperatures. The commercial starch shall not be suitable as a thickening agent due to its very low paste viscosity of starch. Since the drying temperature of commercial cassava starch was undetermined, modification can be made by the commercial starch manufacturer by reducing the drying temperature presently used so that higher paste viscosity of starch can be achieved.

The highest gel strength was indicated by cassava starch dried at 70°C compared to the other higher drying

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temperatures (Table 4). This could be due to the fact that higher drying temperatures cause more soluble substances to leach out of starch granules, including water. The starch dried at very high temperature already lost the soluble substances and produced more dilute gel when being heated in water (Noranizan *et al.*, 2010). Higher drying temperatures also caused the breakdown of starch granules and reduced its ability to hold water. Thus, lower gel strength of starch was produced (Wang, 1997). The cassava starch dried at 70°C and also commercial starch could have the good capacity to be applied as food coating (Gaines *et al.*, 2000), binder and texture enhancer (Beggs *et al.*, 1997; Pietrasik, 1999) in food products due to higher gel strength compared to the other cassava starch treated with higher drying temperatures.

3.3 Effect of different milling sizes on physicochemical properties of cassava starch

The lowest swelling power indicated by cassava starch with the smallest milling size of 45 µm compared to larger milling sizes (Table 5) could be due to the grinding process which caused the breakdown of starch polymer chains into smaller fragments and eventually reduced the ability of starch to absorb water and swell (Hossen *et al.*, 2011). The grinding process to obtain smaller milling size also reduced the swelling power of cassava starch due to loss of solids into the supernatant that minimized the ability of starch to absorb water (Kerr *et al.*, 2000). Compared to cassava starch samples with the larger milling sizes of 53 µm and 63 µm, commercial starch and cassava starch with milling size of 45 µm are not suitable for use as an expansion aid and volume enhancer in food products.

Table 5. Swelling power, solubility, paste viscosity and gel strength of cassava starch with different milling sizes

Milling size (µm)	Swelling power (g/g)	Solubility (%)	Paste viscosity (Pa.s)	Gel strength (N)
45	27.6±0.42[a]	20.20±1.50[a]	0.82±0.01[a]	0.78±0.01[a]
53	32.21±0.57[b]	22.29±1.39[a]	0.86±0.01[b]	0.84±0.03[b]
63	33.47 ±1.95[b]	25.48±0.51[b]	0.90±0.01[b]	0.94±0.02[c]
Commercial	25.37±0.61[a]	13.30±1.26[c]	0.23±0.03[c]	0.48±0.02[d]

The values are the average of triplicate analysis with ± SD. Mean values having different superscript in a column are significantly different ($p<0.05$).

Cassava starch with the largest milling size of 63 µm showed the highest solubility compared to the other lower milling sizes and commercial starch (Table 5). This could be due to higher swelling power of the starch granules that allowed more starch molecules to be leached out of the granules and thereby increased the solubility of the starch molecules (Srichuwong *et al.*, 2005). The lowest solubility that was shown by commercial starch may indicate the least leaching of the starch molecule from granules, which could be due to its very low swelling power.

The lowest paste viscosity exhibited by cassava starch with the lowest milling size of 45 µm compared to those with larger milling sizes (Table 5) could be due to breakdown of starch granules into smaller fragments during grinding that prevented water from being completely absorbed by the starch and reduced the paste viscosity of starch (Hossen *et al.*, 2011). The commercial starch exhibited the lowest paste viscosity than all other milling sizes of cassava starch, which could be due to its smallest milling size (0.29 µm), hence rendered it the least ideal starch to be applied as a thickening agent in food. The use of larger milling sizes of cassava starch of 53 µm and 63 µm as thickening agents could be promoted owing to their higher paste viscosity compared to the milling size of 45 µm and commercial starch.

According to Table 5, the larger the milling size of cassava starch, the higher its gel strength. This is because dry grinding caused the breakdown of the starch polymer chains and reduced the retrogradation ability of starch and finally reduced its gel strength (Ahmad *et al.*, 2016). Thus, cassava starch with the largest milling size (63 µm) will be suitable as food binder and texture enhancer in food. The commercial starch showed the lowest gel strength due to its very small milling size of 0.29 µm and thereby could be unfit for food application.

Compared to cassava starch samples with larger milling sizes such as 53 µm and 63 µm, the commercial starch showed very low swelling power, paste viscosity and gel strength (Table 5), which may restrict its application in food products and cause loss of profits to the commercial starch manufacturer. It is recommended that the commercial starch manufacturer could use larger milling size in order to obtain better qualities of commercial cassava starch in terms of swelling power, paste viscosity, and gel strength.

4. Conclusion

Mineral water showed a significantly higher value ($p<0.05$) for paste viscosity of cassava starch compared to the other types of water, but showed no significant difference ($p>0.05$) with tap water for the swelling power, solubility and gel strength of cassava starch. The rise in the drying temperature significantly reduced ($p<0.05$) swelling power, gel strength and paste viscosity of cassava starch, but significantly increased ($p<0.05$) its solubility. Increasing the milling size significantly increased ($p<0.05$) swelling power and solubility, gel strength and paste viscosity of cassava starch. For industrial advantages, the best processing parameters to produce cassava starch with the highest swelling power are the use of mineral water for cassava starch processing, the lowest drying temperature of 70°C and the largest milling size of 63 µm, which could act as an excellent expansion aid in food products. These parameters shall also be the best processing parameters for producing cassava starch with the highest paste viscosity that could function as a decent food thickening and gelling agent, as well as the highest gel strength that could be used as an excellent texture enhancer, binder, or coating in food products. A more extensive research to clarify the effects of different concentration for single types of mineral ions, such as calcium, magnesium, potassium, and sodium, on the physicochemical properties of cassava starch is suggested as different types and concentrations of mineral ions may show distinct effects on the physicochemical properties of cassava starch, such as swelling power, paste viscosity, and gel strength.

Conflict of Interest

Authors declare no conflict of interest.

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