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A comparative study on physicochemical properties of rice and starch of white rice, black rice and black glutinous rice

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Abstract

Rice is a staple food for Indonesians and Asians in general. It is rich in starch, a component that can be developed as a texture agent, filler, or raw material for edible films, encapsulation, or other products. The characteristics of the starch produced will determine its functional properties. This study aimed to characterize the physicochemical properties of rice and starch of white rice, black rice, and black glutinous rice. In this study, rice was extracted using an alkaline method to obtain rice starch. The processing of rice into starch can change some of its characteristics. A comparative study was also conducted on rice starch. The results showed that the starch contents of white, black, and black glutinous rice were 85.48; 86.67; and 83.56% (db). Black glutinous rice contains more amylopectin than black and white rice. Resistant starch in the rice fractions was greater than the amount of resistant starch in the starch fractions. Black rice contained anthocyanins of 323.85 mg/100 g, while the anthocyanins in black glutinous rice reached 219.35 mg/100 g. Although in very small amounts, anthocyanins were detected in black rice and black glutinous rice starch fractions. The starch fraction has much lower antioxidant activity compared to that in the form of rice. It appears on all types of rice. The peak viscosities of the starch of white rice, black rice, and black glutinous rice were 3627, 5448, and 5001 cP with pasting temperatures of 79.10°C, 80.60°C, and 80.90°C. Physicochemical and pasting properties of the rice fraction and the starch fraction from white, black, and black glutinous rice provide complete information to be used as a basis for the manufacture of food products.

1. Introduction

Rice is a staple food for Indonesians and several other Asian countries, such as Malaysia, Thailand, Taiwan, the Philippines, and Singapore. It contains many carbohydrates that serve as a body's energy source. Apart from being a carbon source, several types of rice cannot be used as a staple food because of their rheological properties, for example, black glutinous rice and black rice. Black glutinous rice is more often used as a raw material for processed foods or snacks than as a staple food. Black glutinous rice (*Oryza sativa* var. glutinosa) has a sticky texture and contains anthocyanins (Thuengtung and Ogawa, 2020; Xiong *et al*., 2022). Unlike black glutinous rice, black rice has a hard texture so it is not commonly preferred as a staple food. Black rice is consumed because it contains anthocyanins, providing health benefits (Pratiwi and Purwestri, 2017).

Rice contains starch compounds composed of amylose and amylopectin, proteins, fats, minerals, vitamins, and pigments. Recently, research on pigmented rice began to be widely conducted in line with the fact that pigmented rice has a low glycemic index and is good for people who are on a diet (Juliano, 2016). The development of rice starch is also rapid because it can lower its glycemic index (Wahjuningsih *et al*., 2016) and develop it as a texture agent, edible film, filler, or

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encapsulation material. Processing rice into starch will cause physicochemical changes, which will also expand its use in the food sector.

Starch can be extracted from food sources using several methods, among which is a simple method proposed by Chavanon (2019). Rice starch is obtained by immersing the rice, crushing it using a grinding machine, and dissolving it with cold water. The insoluble fraction is considered rice starch. However, because there are non-starch fractions that may be insoluble in water, there is also a process of starch isolation using better methods, for example, the methods presented by Song *et al.* (2006), Zhang, *et al*. (2010) and Guo *et al.* (2015). Protein and fat fractions have been separated using these methods although the produced starch still contains little fat or protein. Starch isolation and purification techniques are likely to affect starch's characteristics and functional properties, especially if the starch is processed from different types of rice.

Much research related to rice has been carried out, but in-depth research on the physicochemical properties of native white rice, black rice, and black glutinous rice from Indonesia is still rare. Research related to the three types of rice focuses on the bioactive components (Anugrahati *et al*., 2017; Pradipta *et al*., 2020; Susiyanti *et al*., 2020; Suarti *et al*., 2021; Putri *et al*., 2022), or the physical and chemical properties of rice and not as starch and the use of rice as a food product apart from being a staple food (Darniadi *et al*., 2022). Information about the physicochemical properties of rice, especially rice starch and the pasting properties of rice starch, needs to be obtained to provide accurate information, especially for the development of rice-based food products, both pigmented and non-pigmented rice.

This study aimed to identify the physicochemical properties of three types of rice, namely, white rice, black rice, and black glutinous rice, as well as the physicochemical properties of the starch produced by the three types of rice. The difference between white rice, black rice, and black glutinous rice lies in their pigment components and also in their amylose and amylopectin proportions. Differences in the composition of amylose and amylopectin will affect the modified starch (Shen *et al*., 2019). Modification of starch is conducted to obtain more stable characteristics that have wider use in the food sector. The results of this study are expected to be used as a basis for determining the utilization of starch for further processes, for example, for the development of resistant starch, modified starch, or edible film or to produce starch-based products (Slamet *et al*., 2019). The development of resistant starch from rice can also be carried out using a gluten-free composite flour design as conducted by Praseptiangga *et al*. (2022). This flour can be used as the main ingredient or as an additive in the design of a new product.

2. Materials and methods

2.1 Materials

The main samples used in this study were white rice (a local variety from Delanggu, Central Java Province, Indonesia), black rice, and black glutinous rice (local varieties from Wonogiri, Central Java Province, Indonesia). The chemicals used in the analysis were analytical-grade chemicals.

2.2 Starch isolation and purification

Rice starch was isolated based on the method published by Zhang *et al*. (2010). Rice (1 kg) was immersed in 0.3% NaOH solution for 24 hrs with a 3:1 ratio of the solution and rice. After that, the rice was ground in wet conditions along with the rice water and filtered using a 100-mesh sieve. The ground rice was then allowed to stand for 12 hrs at room temperature and the supernatant was removed. Next, 0.3% NaOH was added to the ground rice to maintain the total weight (4 kg). This procedure was repeated 4 times. The mixture was neutralized until the pH reached 7.0 by adding HCl solution. The mixture was then washed with water up to 5 times. After the supernatant was removed, the ground rice was centrifuged and dried in an oven at 40°C for 17 hrs. Finally, the dried starch was ground and sieved using a 100-mesh sieve.

2.3 Determination of antioxidant activity

DPPH [1,1-diphenyl-2-picrylhydrazyl radical-2,2-diphenyl-1-(2,4,6-trinitrophenyl) hydrazyl] radical scavenging activity (DPPH activity) was determined based on the method presented by Yamuangmorn *et al.* (2018) with slight modifications. A 0.1 g of rice flour sample was extracted using 10 mL of pure methanol. The extract was homogenized using a vortex mixer for 30 mins. After that, the resulting supernatant was separated by centrifugation at a speed of 4500 rpm for 10 mins and filtered using a 0.22 μm nylon filter. A total of 0.3 mL of the extract was reacted with 1.6 methanol and 0.5 mL of 0.1 mmol DPPH solution. The blank solution was a mixture of 0.3 mL of supernatant with 2.1 mL of methanol. The mixture was incubated in the dark at room temperature for 20 mins and then measured using a spectrophotometer at a wavelength of 517 nm. The percentage of radical scavenging activity using DPPH (%RSA DPPH) as a radical source of the sample and Trolox standard was calculated using the following formula:

$$\% \text{ RSA DPPH} = (AC - AS/AC) \times 100$$

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Where AC is the absorbance of the control and AS is the absorbance of the sample. Antioxidant activity based on the measurement of DPPH radicals was calculated using a calibration curve using Trolox with concentrations between 10-62 μg/mL (R^2 = 0.995).

2.4 Analysis methods

The moisture content of starch was determined thermogravimetrically (Association of the Analytical Chemists (AOAC), 2012), while crude protein was estimated by the micro-Kjeldahl method (N = 5.95) (AOAC, 2012). Crude fat was determined by extraction using hexane (Soxhlet extraction). Ash content was determined based on the thermogravimetric method (AOAC, 2012). Total sugar content was estimated using the Nelson-Somogyi method (AOAC, 2012) while the determination of crude fiber was based on the method presented by Englyst *et al*. (1996). Determination of resistant starch using a multienzyme system (AOAC, 2012).

2.5 Water holding capacity

Water holding capacity was determined based on the method presented by Chau *et al*. (1997). A gram of the sample was stirred in 10 mL of distilled water. The solution was then centrifuged at 2200 g for 30 mins. The supernatant volume was measured. Water holding capacity was measured based on the number of grams of water held by 1 g of sample.

2.6 Swelling power

Swelling power was determined based on the method presented by Leach *et al*. (1959). A total of 0.5 g of the sample was dissolved in distilled water, followed by a heating process at 60°C and 95°C for 30 mins in boiling water. The solution was then cooled and centrifuged at 5,000 rpm for 15 mins. At this stage, the supernatant was removed and then weighed. Swelling power is the ratio between the wet sediment's weight and the dry sample's weight. The swelling power is equal to the sediment's weight divided by the dry sample's weight.

2.7 Pasting properties

The pasting properties of starch were determined using the method proposed by Polesi and Sarmento (2011) by employing Rapid Visco Analyzer (RVA), Perten RVA 4500. For analysis purposes, 2 g of the sample was dissolved in 25 mL of distilled water. Parameters measured included pasting temperature, peak viscosity, breakdown viscosity, final viscosity, and setback viscosity.

2.8 SEM analysis

The surface microstructure of starch granules and the granule size were analyzed by SEM using Jeol JSM 6510 LA Scanning Electron Microscope (SEM) with the method described by Ratnaningsih *et al*. (2020).

2.9 Statistical analysis

All analyzes were repeated 3 times. After that, the data were processed using one-way ANOVA to determine the significant difference between treatments. Duncan's multiple range test (DMRT) ($P<0.05$) was used as a further analytical procedure if there was a significant difference between treatments. The analysis process employed IBM SPSS version 20.

3. Results and discussion

3.1 Chemical properties

The main components in rice are water, minerals, fat, protein, and carbohydrates. The moisture content of white rice, black rice, and black glutinous rice, as well as the moisture content of the starch they produced, were significantly different in the statistical test with a significance level of 5% (Table 1). With this significant difference in moisture content, other data were displayed in the form of dry-weight basis or simply dry basis (db). The starch moisture content is lower than the rice moisture content, probably because there are components or macromolecular complexes that help bind water in rice. The moisture content of the rice ranged from 11.70-12.47%, while the starch's moisture content was in the range of 9.08-11.17%. Murdifin *et al*. (2015) also reported similar results, who obtained the results of pigmented rice moisture content in the range of 11.33-13.32%.

The starch still contained fat and protein fractions. The smallest fat content and the highest protein content were found in black rice starch. Similar results were also presented by Guo *et al*. (2015) who stated that starch produced through extraction still contains several proteins, fats, and minerals. The protein contents of white rice, black rice, and black glutinous rice were 1.52, 1.81, and 1.44% (db), respectively. The alkali method in starch extraction effectively reduces rice starch's protein and fat content. This alkaline method has been reported to be more effective in reducing protein content during starch extraction compared to extraction using enzymes or wet milling (Junejo *et al*., 2022). The protein content of the three starches was different. The lowest content was found in black glutinous rice starch. This is thought to be related to the amylopectin content in black glutinous rice, which is 70.24%, the highest compared to white rice or black rice. The black glutinous rice protein

Table 1. Chemical properties of rice and rice starch.

Items	Rice/Starch Variety					
	WR	BR	BGR	WRS	BRS	BGS
Moisture content	11.70±0.06^{d}	12.47±0.00^{f}	12.27±0.06^{e}	9.80±0.11^{b}	11.17±0.16^{c}	9.08±0.49^{a}
Ash (%db)	0.41±0.02^{a}	1.78±0.02^{b}	1.90±0.05^{c}	1.90±0.08^{c}	2.29±0.08^{d}	2.41±0.02^{e}
Fat (%db)	0.32±0.02^{b}	3.67±0.17^{c}	4.91±0.01^{d}	0.13±0.02^{a}	0.01±0.00^{a}	0.11±0.01^{a}
Crude fiber (%db)	0.14±0.01^{b}	2.34±0.21^{d}	1.75±0.14^{b}	0.00±0.00^{a}	0.00±0.00^{a}	0.00±0.00^{a}
Protein (%db)	8.81±0.16^{c}	9.04±0.22^{d}	11.65±0.03^{e}	1.52±0.05^{a}	1.81±0.04^{b}	1.44±0.05^{a}
Starch (%db)	85.48±0.06^{c}	86.67±0.26^{d}	83.56±0.08^{b}	91.80±0.10^{f}	91.28±0.40^{e}	83.02±0.43^{a}
Amylose (%db)	21.32±0.47^{c}	21.41±0.47^{c}	13.32±0.09^{a}	30.38±0.94^{d}	30.87±0.19^{d}	17.30±0.30^{b}
Amylopectin (%db)	64.16±0.45^{c}	65.27±0.65^{d}	70.24±0.07^{e}	61.42±0.86^{b}	60.42±0.53^{a}	65.72±0.25^{d}
Resistant Starch (%db)	1.22±0.01^{d}	1.87±0.01^{f}	1.81±0.00^{e}	0.55±0.00^{a}	0.83±0.00^{c}	0.62±0.00^{b}
Anthocyanin	0.00±0.00^{a}	323.85±11.80^{d}	219.35±1.88^{c}	0.00±0.00^{a}	16.26±0.36^{b}	16.02±0.22$_{b}$
TPC (mg GAE/g)	0.07±0.00^{d}	0.83±0.00$_{f}$	0.72±0.00^{e}	0.03±0.00^{a}	0.04±0.00^{c}	0.03±0.00^{b}
Antioxidant activity DPPH (%)	26.26±0.08^{d}	56.84±0.08^{f}	49.57±0.08^{e}	18.18±0.15^{a}	24.71±0.15^{c}	22.89±0.15^{b}
Water Holding Capacity (%)				81.32±0.87^{a}	81.48±1.38^{a}	107.55±0.38^{b}
Swelling Power (%)				2712.78±6.10^{b}	2087.42±23.66^{a}	2982.37±21.91^{c}

Values are presented as mean±SD. Values with different superscripts within the same row are statistically significantly different according to DMRT ($p<0.05$). WR: white rice, BR: black rice, BGR: black glutinous rice, WRS: white rice starch, BRS: black rice starch, BGS: black glutinous rice starch.

decreased more than white rice or black rice. Pratepha *et al*. (2005) stated that rice with high amylopectin content will experience greater disintegration when exposed to alkali when compared to rice with low amylopectin content. Ash contents were also detected in the starch produced and were in the range of 1.90-2.41% (db). The minerals found in rice include P, K, Na, Ca, Cl, Fe, Mg, and several other minerals (Huang *et al*., 2020). Crude fiber can no longer be discovered in the starch component produced. The ash content of the results of this study increased after the alkaline process. This was different from other studies as conveyed by Zhang *et al*. (2010). Further studies need to be carried out to examine this. The crude fiber content in rice ranged from 1.14-2.34% (db) with the highest crude fiber content being in black rice, followed by black glutinous rice and white rice. According to Sadimantara *et al.* (2019), the crude fiber content of brown rice is 2.52% (wet basis, wb) or equivalent to 2.77% (db). The crude fiber content was lower than rice from Malaysia, Thailand, and Pakistan (Thomas *et al*., 2013), i.e. between 7.17-8.47%.

The starch content of white rice, black rice, and black glutinous rice ranged from 83.56-86.67% with amylose content between 13.32-21.41%. This result was slightly different from Saragih *et al*. (2019) who stated that the starch content of the local varieties of rice in North and East Kalimantan ranged from 71.75-78.49%. Chay *et al*. (2017) reported that black glutinous rice from Cambodia contained 86.69% starch. The starch content of the rice depended on the variety. Based on the amylose content, rice is classified as moderate amylose rice if the amylose content ranges from 20 to 24% and considered low-grade amylose rice if the amylose is between 10 and 20% (Haryadi, 2006). Based on that, black glutinous rice is low-grade amylose, but white rice and black rice are moderate amylose.

Black glutinous rice starch contained more amylopectin than black rice and white rice, as shown in Table 1. The amylose content in black glutinous rice starch was quite high, however, this starch still has the same properties as other glutinous rice starches, namely being sticky because the amylopectin content was still quite high. White rice and black rice are classified as low -amylopectin rice. Susiyanti *et al.* (2020) stated that most white rice (other than glutinous rice) has an amylose content between 17.74 and 24.61%. The highest level of resistant starch was discovered in black rice starch, followed by white rice starch and black glutinous rice starch. Itthivadhanapong and Sangnark (2016) reported that the amylose content of black glutinous rice flour was 4.82% with a water adsorption index (WAI) of 2.66 and a water solubility index of 4.32%.

3.2 Antioxidant activity

Black rice and black glutinous rice contain anthocyanins, while white rice does not. This happens because black glutinous rice and black rice have anthocyanin pigments while white rice does not. Rahim *et al.* (2016) stated that the main pigment component in black glutinous rice is anthocyanin which is dominated by cyanidin-3-O-glycoside glycosides. The same was found in black rice (Zhu *et al*., 2018). The process of isolation and purification of starch by the method proposed by Zhang *et al*. (2010) still leaves anthocyanins in the produced starch. Toontom and Tudpor (2022) also reported that the process of immersing black glutinous rice flour with acidified methanol for 15 days still left anthocyanins, total phenols, and antioxidant activity. Isolation and purification of glutinous rice starch involve an immersion process using strong acids and bases, which can cause anthocyanin damage. Anthocyanins are stable at a pH below 3.0 (Oancea, 2021).

The antioxidant activity of each sample expressed in % radical scavenging activity (%RSA DPPH) using DPPH as the radical source was presented in Table 1. The highest antioxidant activity was found in black rice, black glutinous rice, and white rice, respectively. Although it does not contain a pigment component, white rice also still displays antioxidant activity. This happens because white rice has a TPC of 0.07 GAE mg/g (70 GAE µg/g). Min *et al*. (2012) reported that white rice has a TPC of 0.06 GAE mg/g while Chay *et al*. (2017) reported that non-pigmented glutinous rice had a TPC of 134 GAE µg/g (0.134 GAE mg/g). The total phenolic content was correlated with grain color and grain size (Shen *et al*., 2009). This result was supported by the TPC analysis, which shows that each sample contains a phenol component. Based on a review conducted by Lin *et al.* (2016), the phenol component has antioxidant activity. In addition, Murdifin *et al.* (2015) also reported that the higher the phenol content, the higher the antioxidant activity.

3.3 Water holding capacity and swelling power

The water holding capacity (WHC) of white rice starch and black rice starch was lower than that of black glutinous rice starch. The capacity of starch to hold water is influenced by the amount of amylopectin. The higher the amylopectin content is, the higher the WHC becomes. As shown in Table 1, black glutinous rice starch, which has the highest amylopectin (65.72%), also has the highest water-holding capacity (107.55%) when compared to white rice starch (81.32%) and black rice starch (81.48%). Starch's swelling power is also influenced by amylopectin levels, more precisely the amylose/amylopectin ratio. This result was consistent with studies about composite flour using two different materials (Praseptiangga *et al*., 2022).

When the proportion of flour with high amylose content is increased, the swelling power of the composite flour will also decrease. However, this study found a different finding: white rice starch, black rice starch, and black glutinous rice starch had significantly different swelling power. Moreover, white rice starch's swelling power was greater than black rice starch. The white rice used as a sample in this study was Delanggu rice, which was sold in the market and is usually used as a staple food. This type of rice was milled twice to produce well-cooked rice and that water can penetrate the rice seeds properly (Hendrawan *et al*., 2016). Unlike white rice, black rice is only milled once. It is because if black rice is milled twice, the pigment components contained in the aleurone layer of rice seeds will also be removed, and physically, the rice will turn white and slightly brownish, and consumers tend to dislike it. In addition, people buy and consume black rice because they want to get the benefits of anthocyanins for their health (Hasnelly *et al*., 2020). The presence of pigment compounds may also affect the ability of water to interact with the starch granules. Starch with high amylopectin content tends to have a higher swelling power value (Ardhiyanti and Indrasari. 2021).

3.4 Pasting properties

During the gelatinization process, the starch granules lose their crystallinity, absorb water, and expand and some components (amylose) are released. The difference in gel properties will be noticeable when the gels are heated. The changes that occur when the starch solution is heated and stirred (shear force) are referred to as pasting properties (Fredriksson *et al*., 1998; Charles *et al*., 2005).

Starch isolated using alkali will have a lower peak viscosity (PV) than that isolated without alkali. Research by Zhong *et al*. (2009) which used 0.1% and 0.4% alkalis, showed that the greater the alkali concentration, the lower the PV obtained. The decrease in PV was due to removing the lipid fraction from the starch granules. The higher the concentration of alkali used, the greater the lipid that can be transferred will be. The absence of lipids will facilitate water to enter the starch granules. Significant effects can be discovered in low-amylopectin starch, whereas in high-amylopectin starch, the absence of lipids will reduce PV but not significantly. Therefore, it is better to use only moderate concentrations of alkali.

Pasting temperature (PT) is defined as the minimum temperature for the gelatinization process or the minimum heat required for the gelatinization process. The PT of white rice starch was lower than those of black rice starch and black glutinous rice starch. Amylose can increase the rigidity and cohesiveness of starch granules (Wang *et al*., 2020). This causes white rice starch with lower amylose than black rice starch to have a lower pasting temperature than black rice starch. The long amylose chains can cross the crystallization and the amorphous zone to support the starch structure and make it more compact. However, although black glutinous rice starch has lower amylose than the two, it has almost the same pasting temperature as black rice

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starch. Based on previous studies which stated that the amylose chain could affect the pasting temperature (Wang *et al*., 2020), further research is needed to examine the amylose chain structure of black glutinous rice starch. Amylose content has a positive relationship with pasting temperature but has a negative relationship with PV (Jang *et al*., 2016). Ardhiyanti and Indrasari (2021) said that based on Pearson's correlation coefficient, the amylose content of starch was not associated with PV. Their experiments showed a tendency that starch with low amylose will have higher PV. Black glutinous rice starch had the lowest amylose content and the lowest PV compared to white rice starch and black rice starch. Meanwhile, black rice starch, which contains approximately the same amount of amylose as white rice starch, had a much higher PV than white rice starch. Black rice starch and black glutinous rice starch had PV values of 5448 and 5001 cP, respectively, while the PV of white rice starch was only 3627 cP. From Figure 1 it can be seen that the characteristics of the viscosity changes of black rice starch and black glutinous rice starch are similar. Both also have a similar peak time. There may be other causes such as the structure of the amylose chain, as previously mentioned, which affect the PV.

Breakdown viscosity (BV) is defined as the viscosity at which the gel (paste) begins to release the water trapped in the starch granules under shear stress. The breakdown viscosity of white rice starch was the highest compared to those of black rice starch and finally, black glutinous rice starch. Breakdown viscosity is related to the palatability (eating quality) of starch (Ardhiyanti and Indrasari, 2021) and can be interpreted as the level of speed at which the gel disintegrates. Heat and shear force make starch with low amylose content more easily disintegrated. Starch with low BV has better stability during the cooking process and usually produces a firmer texture. This firm characteristic can also be indicated by the high value of through viscosity (TV). The setback viscosity (SB) of starch with high amylose content is higher; therefore, starch with high amylose retrograde faster than starch with high amylopectin (Ardhiyanti and Indrasari, 2021). A similar result was also discovered in white rice starch, which had a higher amylose content than black rice starch and black glutinous rice starch. The cooking quality of starch depends on PT, PV, and BV, while eating quality is influenced by BV, TV, and FV. A high final viscosity will give the rice a crunchy texture, while BV that is too high tends to make the rice tender. Low SV and low FV indicate that rice tends to maintain its tenderness.

Several research results indicate that the levels of amylose and amylopectin affect the pasting properties of the starch produced. However, from the results presented in Table 2, the pasting properties of black rice starch tend to be almost similar to those of black glutinous rice starch. This is a new finding and the factors that affect the pasting properties of rice starch need to be studied further. The chart of pasting properties of starch is presented in Figure 1.

3.5 SEM analysis

Figure 2 displays SEM photographs of white rice starch (A), black rice starch (B), and black glutinous rice starch (C). The starch structure is a polyhedron with visible angles, and the starch granule size is about 5 μm. If it is observed, white rice starch granules are more varied in size. Some granules have a size of 1 μm. Lindeboom *et al*. (2004) said that rice has a small and very small granule size. The granule size is considered very small if it has a size < 5 μm and is considered small if it has a size of 5-10 μm. The granule size will affect the starch composition, gelatinization and pasting properties, enzyme susceptibility, crystallinity, swelling, and solubility. From Figure 2, it can also be seen that, in general, black rice starch and black glutinous rice starch have granule sizes that are generally almost the same size and larger when compared to white rice starch granule sizes. It is suspected that this may be one of the reasons that the PT of black rice starch and glutinous rice starch is similar and larger than white rice starch. This is in accordance with Goering and DeHaas's (1972) statement that the larger the granule size, the higher the PT is.

The surface of the starch granules looks smooth and even. The same results were also obtained from SEM photographs of the structure of starch produced in a study conducted by Miao *et al*. (2009) and da Silva *et al.* (2020), which that the structure of rice starch is

Table 2. Pasting properties of white rice, black rice, and black glutinous rice starches.

Variety	Peak (PV), cP	Trough (TV), cP	Break Down (BD), cP	Final Visc. (FV), cP	Set Back (SB)	Peak Time (Min)	Pasting Temp (°C)
White rice starch	3627.00	1961.00	1666.00	5103.00	3142.00	8.87	79.10
Black rice starch	5448.00	1635.00	3813.00	3185.00	1550.00	7.93	80.60
Black glutinous starch	5001.00	1522.00	3479.00	2993.00	1471.00	7.93	80.90

Pasting temperature (PT): temperature indicating an initial increase in viscosity, Peak viscosity (PV): maximum viscosity during the heating cycle, Final viscosity (FV): final viscosity at 50°C, Breakdown viscosity (BD): PV minus FV at 95°C, Setback viscosity (SB): FV minus FV at 95°C.

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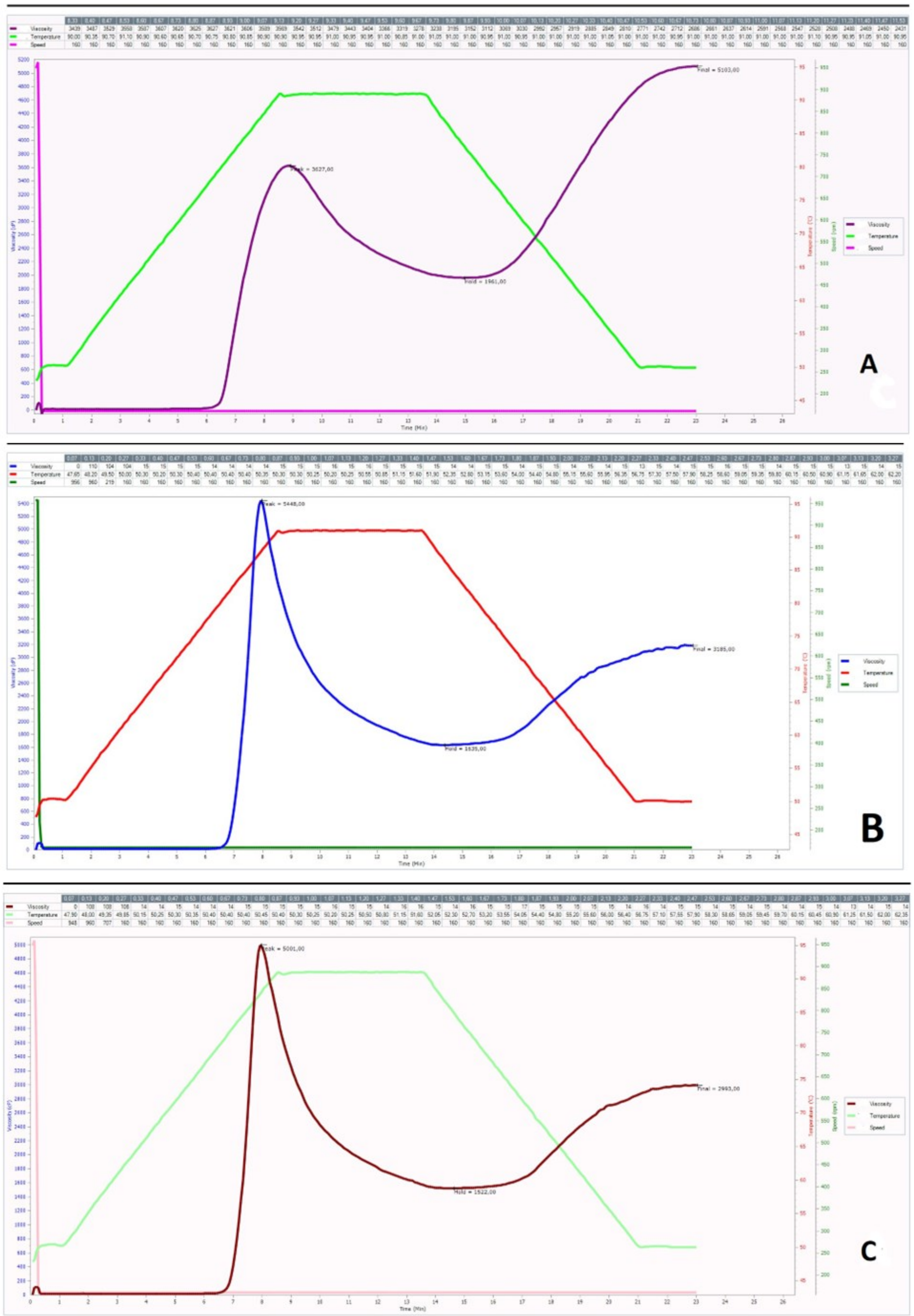

Figure 1. Pasting properties of starch: A. White rice starch, B. Black rice starch and C. Black glutinous rice starch.

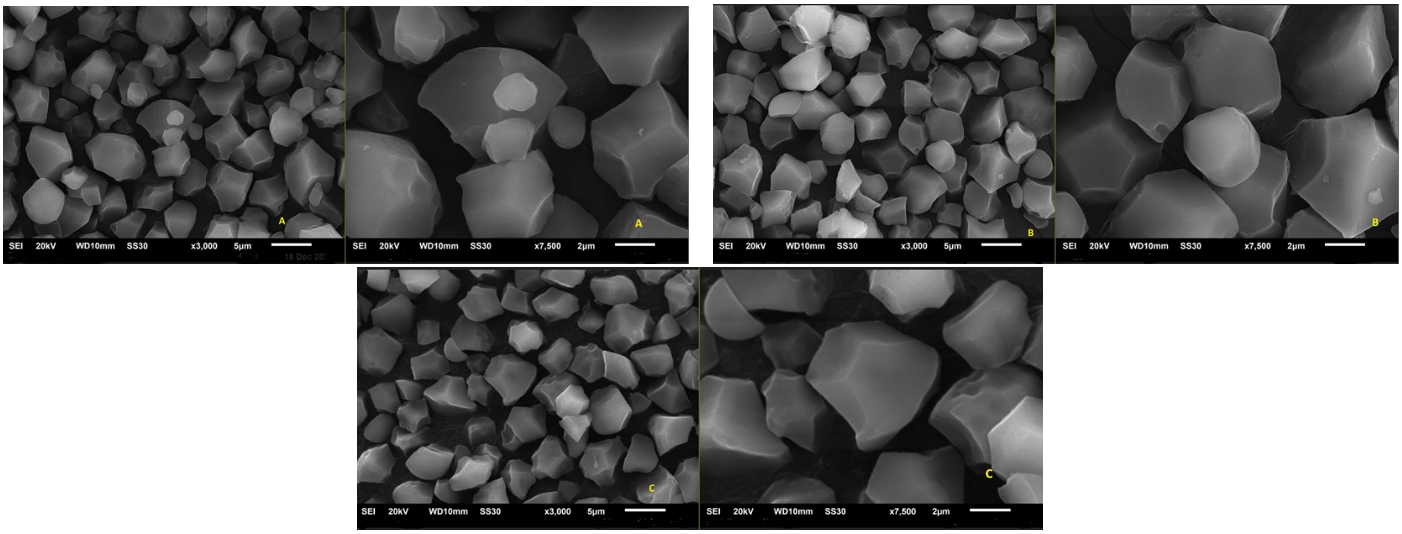

Figure 2. Scanning electron micrograph (SEM) of starch: A. White rice starch, B. Black rice starch and C. Black glutinous rice starch.

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polyhedral in shape with an irregular shape and visible sharp angles. This morphological form is slightly different from the breadfruit starch's morphology, as Rahayu *et al*. (2021) presented. Breadfruit starch has a spherical and polyhedron shape with a blunt angle. In addition, Ratnaningsih *et al*. (2020) reported that native cowpea starch has a smooth surface and spherical shape.

4. Conclusion

White rice, black rice, and black glutinous rice have different physicochemical characteristics. Black rice has greater starch and resistant starch than other rice. The resistant starch and fiber content in the rice fraction was higher than those in the starch fraction. Anthocyanins can be found in the black rice starch and black glutinous rice starch fraction, although in very small amounts. White rice starch also has total phenols. This causes the three types of starch to still have antioxidant activity. The peak viscosity of black rice starch was similar to that of black glutinous rice starch, and both had significant differences when compared to the peak viscosity of white rice starch. Similar to the pasting temperature, black rice starch and black glutinous rice starch require a higher temperature to undergo gelatinization. PT of each starch shows a fairly high temperature (> 70°C) indicating that all starches can be processed at high temperatures. Starches with high amylose, such as white rice starch or black rice starch, tend to be harder when processed and harden easily when cold. Such starch can be used as a filler.

Conflict of interest

The authors declare no conflict of interest.

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