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ABSTRACT

Rice has different varieties, with each variety possessing diverse physical and chemical characteristics. The objective of this study was to analyze the physicochemical properties of several Indonesian local rice varieties. The experiment was conducted from March to April 2017 at the Agriculture Applied Technology Laboratory of the Faculty of Agriculture, Universitas Sultan Ageng Tirtayasa and at the Laboratory of Food Analysis Services in the Department of Food and Technology, IPB University. Nine local rice varieties from several areas in Indonesia were used as samples, namely Jalahawara, Ciherang, Pandan Wangi, Rojolele, Sokan, Bendang Pulau, Batang Piaman, Cisantana and Sidrap. Their physicochemical characteristics were analyzed based on some criteria such as: physical quality (weight, length, width, form and percentage of chalkiness), chemical content, water content, ash content, fat content, protein content, carbohydrate content, crude fiber content, starch, amylose and amylopectin content. Data obtained were analyzed by one-way ANOVA using a Randomized Block Design. Jalahawara has the highest percentage of chalkiness. Based on the ratio of length and width, Sidrap and Ciherang were categorized as medium type and the others were oval/round. The heaviest and lightest based on the 1000-grain weight of rice were Ciherang and Bendang Pulau, respectively. The water content was about 2-4% for all samples. The highest and lowest amount of ash and fat content were found in Sidrap and Sokan, respectively. The highest and lowest amount of protein content were found in Batang Piaman and Sokan, respectively. The highest and lowest starch content were observed in Pandan Wangi and Ciherang. The content of amylose and amylopectin were the highest in Batang Piaman. The rice samples were categorized into two groups of low and medium levels of amylose. The low level of amylose were observed in Cisantana, Ciherang, Pandan Wangi and Sidrap, while the medium level of amylose were observed in Jalahawara, Sokan, Bendang Pulau, Batang Piaman and Rojolele.

Keywords: Indonesian local rice, physicochemical properties

INTRODUCTION

Food, a basic need of human beings, is a source of energy for humans to do their activities and survive in life. The quality of both husked and un-husked rice becomes the priority of rice cultivation which is related to consumer satisfaction. More than half of world population consumes rice as the main daily source of calories and protein (Tonini & Cabrera 2011; Rohit & Parmar 2011). Industrial development has affected the determination of rice taste and quality. A dominant factor in determining the taste of rice is amylose content in the rice (Setyowati & Kurniawati 2015).

Rice quality is a combination of its physical and chemical (physicochemical) characteristics particularly needed by consumers. Rice tastiness is closely related to rice quality and its complex physicochemical characteristics, namely amylose content, starch, gel consistency, gelatin temperature and protein level. Rice quality is also related to stickiness, sweetness, transparency and palatability.

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Palatability (good taste) is a characteristic of rice related to quality, determined by smell, appearance, taste and texture. In addition to genetic factors, such as those in the synthetic processing of starch and protein, rice quality is affected by environmental conditions, such as water availability, temperature, fertilizer utilization, drought and salinity stresses (Chen *et al.* 2012).

The physical and chemical properties of rice depend on the variety used (Rolando *et al.* 2013). Consumers have the right to information about physical characteristics and chemical content of consumable goods, including rice. Sitaresmi *et al.* (2013) stated that a large amount of germplasm of good quality local rice variety had been identified as vulnerable and tolerant to biotic and abiotic stresses. The Indonesian Agricultural Research and Development Agency had released tungro-resistant varieties, such as Tukad Unda, Tukad Petanu, Tukad Balian, Bondojudo, Kalimas, Inpari 7 Lanrang, Inpari 8 and Inpari 9 Elo (Suprihatno *et al.* 2009; Mejaya *et al.* 2014). These variety had not been fully adopted by farmers because of its limited seeds availability, undesirable taste and poor quality which affected the selling price (Muliadi *et al.* 2015). However, Ciherang varieties have advantages in terms of its productivity, tastiness, market segments and relatively early maturity. New superior varieties are difficult to develop and market, if they do not have the previously mentioned potential characteristics.

Indonesia possesses a very wide rice diversity comprising around 17,000 germplasm accessions including several wild varieties (Maulana *et al.* 2014). Indonesia is the centre of rice origin. Many places in Indonesia still have good potential sources of the local rice seeds. Each variety has different and unique characteristics, namely unique taste, color, nutrients and chemical composition (Yang *et al.* 2010). Hence, it is necessary to gather basic data related to the physicochemical properties of these local rice varieties, particularly related to plant cultivation processes that affects rice quality. The objective assessment of rice quality includes its physical and chemical characteristics, while the subjective assessment focuses on the individual and community preferences. The objective of this study was to analyze the physicochemical properties of several Indonesian local rice varieties.

MATERIALS AND METHODS

Plant Genetic Materials

Nine varieties of the Indonesian local rice were used as samples, namely Java varieties (Jalahawara, Ciherang, Pandan Wangi, Rojolele), Sumatra varieties (Sokan, Bendang Pulau, Batang Piaman) and Sulawesi varieties (Cisantana, Sidrap). The research was conducted from March to April 2017 at the Agriculture Applied Technology Laboratory of the Faculty of Agriculture, Universitas Sultan Ageng Tirtayasa and Food Analysis Laboratory, Department of Food Technology, IPB University.

Methodology

Milled rice grains from 9 local rice varieties from several places in Indonesia were used as research samples. Their quality was identified based on the following criteria: physical quality, water content, ash content, fat content, protein content, carbohydrate content, crude fiber content, starch, amylose and amylopectin content. The data acquired were then analyzed using the one-way analysis of variance (ANOVA) and a Randomized Block Design for all the physicochemical observations. The mean values were compared using Duncan's New Multiple Range Test (DNMRT) to confirm the differences among the varieties.

Physical Quality of Rice

Physical quality of rice was analyzed according to Utami *et al.* (2019). The weight of un-husked rice was measured by measuring the weight of 1,000 undamaged grains using analytical scales of each sample. Moreover, the length and width of 10 rice grains from each sample were measured by using calipers. The rice form was determined by the ratio of length and width of the rice grain. Furthermore, the percentage of chalkiness was obtained by observing at the opacity proportion of the endosperm.

Water and Ash Content

The water and ash content were analyzed using the gravimetric method (Longvah & Prasad 2020). For water content, it was measured by comparing the weight of rice before and after being heated. The difference is assumed as the decreased water content in the local rice after being heated at 105 °C, above the boiling point of water.

For ash content, an empty cup was heated in the oven and then cooled in the desiccator for 30 min. The cup was then filled with 5-gram rice of each sample. Each sample was weighed and then heated in the furnace at 550 °C for 2-3 h until it turned into ash. The cup was then cooled in the desiccator and weighed subsequently. The percentage of ash content was calculated as follows: ash content (%) = [ash weight (g)/sample weight (g)] × 100%.

Fat Content

The fat content was measured using soxhlet method (Sultana *et al.* 2018; Choi *et al.* 2015). The fat was extracted using the non-polar fat solvents (hexane). The solvent was then distilled and evaporated; the fat extract stayed in the tube and was measured as fat weight.

Protein Content

The protein content was measured using the Kjeldahl method (Wang *et al.* 2016), assuming that all Ns in the sample are protein. The observation process was done in three stages: first, destroying the sample in acid atmosphere to free the N from the sample then binding N in the form of ammonium sulfate, while C and H were oxidized into H_2O and CO_2; second, distilling the sample to break the ammonium sulfate into ammonia based on the different boiling points; third, titration was done to measure the N content in the sample (Legowo 2005).

Carbohydrate Analysis

Carbohydrate analysis was done using "by difference" method (Shakappa & Talari 2016). The following is the equation used in calculating carbohydrate levels: carbohydrate content (%) = 100% - (% water content + % ash content + % protein content + % fat content).

Analysis of Crude Fiber

Using the soxhlet method (Sultana *et al.* 2018; Choi *et al.* 2015), a 0.4 g of fat sample was extracted and then filtered with filter paper and wrapped. The filter washed with acid and alkali solvents (0.3 N NaOH and 1.5 N H_2SO_4) and placed in boiling water and was finally cleaned with distilled water. Afterwards, the filter was washed again with solvent and heated to reach its boiling point, and then put in the oven for 1 hour at 105 °C, and finally, the crude fiber content was calculated.

Starch, Amylose and Amylopectin Contents

The starch content was analyzed according to the Luff Schoorl method (AOAC 1995), using reagent Luff Schoorl from 0.1 g of ground rice sample which was then measured by the titration process. The starch content was measured based on the difference between titration on the blank paper and sample titration. Sugar content was reduced after inversion (after hydrolysis using HCl 25%) inside the compound, which could be found in the table of standards. The starch content of the compound was calculated from the difference between the sugar content before and after inversion, then multiplied with 0.9.

Furthermore, the measurement of amylose content was conducted through iodometry based on the reaction between amylose and iodine compound which produced the blue color (Juliano & Villareal 1993). Each sample was taken from 100 mg of rice dissolved with 1 mL of 95% ethanol and 9 mL of NaOH 1 M and boiled for 10 min with water boiling at 95 °C until it turned into a gel. Then, 100 mL of water was added into the gel and stirred. Five mL of sample solvent was homogenized with 1 mL of acid acetate 1 N, 2 mL of iodine solvent 0.01 N (step by step) and aquadest, then heated at 30 °C for 20 min and measured with spectrophotometer UV-Vis in 620 nm wavelength.

Amylopectin content was calculated by reducing the starch content with amylose, as starch basically consists of amylose and amylopectin.

RESULTS AND DISCUSSION

Determining the Rice Physical Quality

Grain characteristics such as weight, length and width are prominent criteria in determining rice quality (Table 1). The width, length, and shape of rice grain affect the ease of the grinding process. Jalahawara has the highest percentage of chalkiness compared to other rice and has small grains with a less transparent appearance. On the other hand, although its nutrients disappear after cooking and do influence the food quality, rice with transparent grain are still preferred by consumers. Most rice consumers in principle, choose uniform and translucent grains (Xi *et al.* 2014). Rice consumers also prefer a product of satisfactory appearance even though most of the nutrients have disappeared (Abbas *et al.* 2011).

The genetic and environmental factors influenced the appearance of the rice grain which is assessed as the percentage of grain chalkiness. Chalkiness is an unwanted trait that negatively affects the milling, cooking, eating, and grain looks and that reflects the main concern in many producing areas of rice (Siebenmorgen *et al.* 2013). Nevame *et al.* (2018) stated that the happening of the chalkiness in rice is linked to both the genetic and environmental element, notably high temperature. The highest percentage of chalkiness was found in Jalahawara rice and the lowest in Pandan Wangi.

Based on its length, the local rice was classified into extra-long grain at >7 mm (Cisantana, Ciherang, Sidrap), long grain at 6.0-6.99 mm (Jalahawara, Sokan, Pandan Wangi, Rojolele) and medium grain at 5.5-5.99 mm (Bendang Pulau). Based on the ratio of length and width, Sidrap and Ciherang rice were included in the medium size category, while the other types were categorized as short grain rice with oval or round shaped. Most people in India prefer long grain, but people in South East Asia prefer medium grain (Jewell *et al.* 2011).

Furthermore, the heaviest 1000-grain weight was that of Ciherang variety, followed by Jalahawara rice, while the lightest weight was that of the Bendang Pulau rice. The weight of the 1000-grains of rice determined the amount of rice production. The weight of rice is affected by the environmental and atmospheric factors at the moment of grain harvesting. Patindol *et al.* (2015) said that the environmental elements (such as air temperature, atmospheric carbon dioxide, light, water, and soil nutrients) are important for plant growth and reproduction, Temperature is the most explored environmental aspect in relation to rice production and grain quality.

Table 1 Chalkiness, grain weight, length, width and the ratio of length/width of Indonesian rice varieties

No	Rice sample	% Chalkiness	1,000 - grains weight (g)	Length (cm)	Width (cm)	Ratio of length/width
1	Jalahawara	89 a	24.715 b	0.655d	0.255 f	2.57 d
2	Cisantana	25 f	19.575 f	0.769 a	0.261d	2.95 c
3	Ciherang	62 c	25.098 a	0.742 c	0.221 i	3.36 a
4	Sokan	35 e	16.890 h	0.617 g	0.254 g	2.43 e
5	Bendang Pulau	14 h	11.554 g	0.532 h	0.258 e	2.06 h
6	Batang Piaman	22 g	21.693 d	0.618 g	0.302 a	2.05 i
7	Pandan wangi	5 i	19.596 f	0.624 f	0.266 c	2.35 f
8	Rojolele	72 b	21.013 e	0.644 e	0.282 b	2.28 g
9	Sidrap	56 d	21.995 c	0.744 b	0.222 h	3.35 b

Note: Means with different letters inside a column are significantly different ($p < 0.05$, DMRT).

Figure 1 The appearance of Indonesian local rice grains

The opaque areas in the endosperm of the rice grains formed the starch and protein particles that break easily at grinding (Fig. 1). Compared to rice grains with transparent endosperm, their selling point is low. The different colors of rice are arranged genetically as a result of genetic differences of aleuron color, endosperm color and starch composition in the endosperm. White rice has white and transparent colors because it has only a little aleuron color and amylose content of about 20%. The outermost layer of the endosperm consists of aleurone cells and starch inside (Ishimaru *et al.* 2015). The aleurone layer accumulates lipids, while the starchy endosperms mainly accumulate starch. During the ripening stage, the degree of starch accumulation is known to be out of sync, depending on the location of the starchy endosperm.

Water Content

Based on the Indonesian National Standard No. 6128:2015 (BSN 2015), the maximum water content of premium rice is 14%, while that of medium rice is 15%. The water contents of the different rice varieties varied between 12% and 14%, and only Jalahawara had the water content of above 14% (Table 2); so almost all of the local rice samples are included under the category of premium rice. One of the benefits of water content standardization of the local rice is the prolonged rice storage time. If the rice has low water content, the development of microbes in the rice can be slowed down. Moreover, moisture also plays an important role in determining the rice quality (Tamrin *et al.* 2017). Water content affects the physical and chemical appearance of rice. If the water content is high then the rice will turn yellow with an unpleasant aroma and cannot be stored for a long period.

Table 2 Level of water, ash, fat, protein and carbohydrate contents of Indonesian local rice varieties

No	Rice sample	Water content (%)	Ash content (%)	Fat content (%)	Protein (%)	Carbohydrate (%)
1	Jalahawara	14.44 a	0.54 g	0.24 h	9.41 e	75.36 h
2	Cisantana	12.35 f	0.88 b	1.15 b	8.79 g	76.83 d
3	Ciherang	12.68 d	0.80 c	0.66 f	9.98 b	75.88 e
4	Sokan	13.01 c	0.45 i	0.21 i	7.32 i	79.01 a
5	Bendang Pulau	12.25 g	0.57 f	0.35 g	8.21 h	78.63 b
6	Batang Piaman	12.10 h	0.52 h	0.74 e	10.93 a	75.71 f
7	Pandan wangi	13.71 b	0.72 e	1.06 c	9.68 c	74.84 i
8	Rojolele	12.17 i	0.74 d	0.96 d	8.82 f	77.32 c
9	Sidrap	12.38 e	1.00 a	2.12 a	9.57 d	74.94 g

Note: Means with different letters inside a column are significantly different ($p < 0.05$, DMRT).

Ash Content

The lowest ash content was found in Sokan (0.45%), while the highest was in Sidrap (1.00%). Based on Indonesian National Standard No. 3549:2009 (BSN 2009), the maximum ash content of rice starch is 1%; hence, all the samples have fulfilled the Indonesian National Standard. Ash content is related to the mineral content of rice because when rice is heated until 1,000 °C, only the mineral is not oxidized. Ash content is also influenced by the environment where the rice grows. The composition of rice varieties differs according to the soil in which rice is grown, together with manuring (Abbas *et al.* 2011). The minerals most frequently found in rice husk ash are P, Mg, and K. In addition, it may consist of Ca, Cl, Na, Si and Fe. The minerals are distributed over the outer layer of the rice grain, and the concentration decreases as they move towards the internal part of the rice. Oko and Ugwu (2011), said that the mineral compositions in rice are: N (0.1-1.08%), P (0.52-0.54%), K (0.15-0.20%), Na (0.13-0.17%), Ca (0.07-0.11%) and Mg (0.19-0.26%).

Fat Content

The fat content varied from 0.21% to 2.12%. The large amount of fats (above 0.5%) was found in Cisantana, Ciherang, Batang Piaman, Pandan Wangi, Rojolele and Sidrap rice. The study results differed from that of Tarigan and Kusbiantoro (2011), which recorded a fat content between 0.2-0.3%. The amount of fat content in rice is influenced by the environment where the rice plant grows. Kang *et al.* (2011) stated that the main component of fatty acid in rice was oleic acid (18:1), linoleate (18:2), and palmitate (16:0), and the composition of those three components reaches 90% of the total fatty acid in rice.

Protein content

The lowest protein content was observed in Sokan (7.32%) and the highest in Batang Piaman (10.93%). The highest amount of amino acids found in the rice protein were aspartate and glutamate, while the acids with the smallest amount were cysteine and tryptophan (Kang *et al.* 2011). Protein content has a close relationship with palatability or taste quality rice (Song *et al.* 2012). Protein also supports rice texture by making the barrier which results in less leaching of rice component during the cooking process. Variation in protein content causes differences in the viscosity of rice paste due to its effect on the expansion of starch granules and on the character of its stiffness. Protein plays an important role in rice quality based on a water-producing agent that occurs during cooking rice and that increases the stickiness of cooked rice.

Carbohydrate Content

Carbohydrate was the most abundant nutrient in all the samples. The lowest (74.84%) was found in Pandan Wangi and the highest (79.01%) in Sokan. Carbohydrate content in rice is mostly in the form of starch, consisting of amylose and amylopectin. Fiber is also found in rice, including hemicellulose (food fiber) and lignin (crude fiber). The shape and size of starch granules are affected by the source and the condition around the growing zone (Omar *et al.* 2016).

Fiber Content

Adequate amounts of dietary fiber are also found in rice grains (Aune *et al.* 2011), thus rendering rice a healthy food (Thomas *et al.* 2015). The crude fiber content varied from 8.91% to 24.51% among the rice varieties. The crude fiber content is influenced by the variety of rice. Fiber is a plant component and a type of carbohydrate. Fiber is not a nutrient and cannot be digested by the human system. Based on its structural characteristics, fiber consists of two kinds, food fiber, and crude fiber. Food fiber cannot be digested by amylose enzyme, while crude fiber can be hydrolyzed by acid and strong alkaline such as cellulose, hemicellulose, and lignin.

Starch, Amylose and Amylopectin Content

The starch content in the rice sample largely contributed (72.92% to 88.18%) to its dry weight (Table 3). Starch is composed of amylose and amylopectin (Bertoft 2017). Starch is one kind of carbohydrate in plants that functions as an energy reserve. Starch in rice and other seeds is the major carbohydrate, so that the amount of starch is more prominent than other kinds of carbohydrate. The histochemical investigation of the caryopsis indicated that starch was mainly accumulated in the endosperm (Yu *et al.* 2014). Amyloplasts in endosperm contained many starch granules that were spherical during the early stages but turns polyhedric at the later stages. Structurally, the starch arrangement of monosaccharide units is like glucose. Glucose molecules are bonded with each other, producing two kinds of starch, amylose and amylopectin. Amylose has a linear chain structure bound by α-(1,4)-D-glycoside bonds, while amylopectin has a branching structure linked by α-(1,6)-D-glycoside bonds that comprise around 4% to 5% of the total weight.

The starch content varied depending on the rice variety and the environment where the rice grew. The highest amount of starch was found in Pandan Wangi (88.18%), and the lowest was in Ciherang (72.92%). The amylose content was around 17% to 24%, and amylopectin was around 54% to 70%. The ratio of amylose/amylopectin is stated only in amylose content because amylopectin can be obtained from the reduction of starch by amylose. The ratio of amylose/amylopectin determines the texture of rice, whether hard or not, getting hard easily or not, sticky or not. The smaller the content of amylose or the higher the content of amylopectin, the stickier the rice will be. For example, when sticky or glutinous rice is cooked, physically it is really sticky because the amylose content is very low, around 1% to 2% (in waxy/glutinous rice). However, the amylopectin is very high. This study showed that the rice samples were not glutinous.

Non-sticky rice are classified into 4 groups based on its amylose content: 1) rice with high amylose content (25% to 33%); 2) rice with medium amylose content (20% to 25%); 3) rice with low amylose content (9% to 20%); and 4) rice with very low amylose content (2% to 9%) (Masniawati *et al.* 2018). Based on this classification, the rice samples in this study belonged to 2 groups; that is rice with low amylose content for Cisantana, Ciherang, Pandan Wangi and Sidrap rice; and rice with medium amylose content for Jalahawara, Sokan, Bendang Pulau, Batang Piaman and Rojolele. Comparison between those two groups of starch (amylose and amylopectin) determines the color of rice (transparent or not) and also the texture of rice (sticky, soft, hard or really hard). Sticky rice is dominated with amylopectin so that it is really sticky, while hard rice (‘*pera’* rice) has an amylose content of more than 25% resulting in the seeds of rice not sticking to each other when they are well cooked.

The main component of rice is starch, while the minor components are protein (4.5% to 10%) and fat (0.5%). Amylose content determines the physicochemical characteristics of rice starch. Starch granule which has high amylose is strong and stiff and will result in hard rice (‘*pera’* rice). On the other hand, if the starch granule is soft, it can result in soft and tasty rice when it is well cooked (Li *et al.* 2017).

Table 3 Amounts of crude fiber, starch, amylose and amylopectin

No	Rice sample	Crude fiber content (%)	Starch (%)	Amylose (%)	Amylose criteria	Amylopectin (%)
1	Jalahawara	11.65 d	78.88 e	20.89 e	Medium	57.99 e
2	Cisantana	24.51 a	77.39 g	18.31 h	Low	59.07 d
3	Ciherang	18.67 b	72.92 i	18.48 g	Low	54.44 i
4	Sokan	12.62 c	85.90 c	23.29 b	Medium	62.61 c
5	Bendang Pulau	8.91 h	87.39 b	23.19 c	Medium	64.20 b
6	Batang Piaman	9.39 g	79.25 d	24.61 a	Medium	54.63 h
7	Pandan wangi	9.53 f	88.18 a	17.74 i	Low	70.45 a
8	Rojolele	9.72 e	77.67 f	21.78 d	Medium	55.90 g
9	Sidrap	11.73 d	76.74 h	19.30 f	Low	57.44 f

Note: Means inside a column with different letters are significantly different ($p < 0.05$, DMRT).

CONCLUSION

The Jalahawara variety was moderately transparent and had a high percentage of chalkiness compared to other varieties. The ratio of the length to width of rice grain for Sidrap and Ciherang varieties were considered medium-sized, and the other types as short/oval/round size. Ciherang is the heaviest rice based on the 1,000-grain weight, and the lightest rice was Bendang Pulau. The water content in the sample of the rice was between 12-14%. The lowest ash content was found in Sokan (0.45%) and the highest was in Sidrap (1.00%). The fat content varied from 0.21% (Sokan) to 2.12% (Sidrap). The lowest protein content was found in Sokan (7.32%), and the highest fat content was in Batang Piaman (10.93%). The highest starch content was observed in Pandan Wangi (88.18%), and the lowest is in Ciherang (72.92%). Amylose content among the varieties was around 17% to 24%, and amylopectin was around 54% to 70%. The studied local rice varieties were not sticky rice. The amylose content categorised the rice varieties into two; the first group included the varieties with low amylose content (Cisantana, Ciherang, Pandan Wangi, and Sidrap); and, the second group included those varieties with medium amylose content (Jalahawara, Sokan, Bendang Pulau, Batang Piaman, and Rojolele).

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