Note

Functional and Pasting Properties of Locally Grown and Imported Exotic Rice Varieties of Malaysia

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In the present study, functional and pasting properties of 3 locally grown exotic rice varieties were compared with 3 popular imported rice varieties. Various parameters such as water and oil absorption capacities, gelation properties, pH, water activity, emulsion activity and stability, foaming capacity and pasting properties were evaluated. Results obtained showed significant differences in water absorption (3.82 – 10.86) and oil absorption capacities (2.18 – 6.37) with pH and aw varying between 6.07 – 6.45 and 0.62 – 0.68, respectively among various rice samples. Emulsifying activity (5.48%) and stability (98.3%), and foaming capacities (3.98%) were highest in glutinous rice. Significant differences were observed in pasting parameters of rice starch especially in relevance to peak time, peak viscosity, final viscosity (range 513 – 1077 cP) and setback. Results generated in this study pertinent to functional and pasting properties is envisaged to be useful in exploiting the potentiality of local rice grain varieties at international market levels to develop new rice based food products.

Keywords: functional properties, total starch content, pasting properties, exotic rice

Introduction

Rice (*Oryza sativa* L.) is one of the most extensively grown and consumed cereal crops, especially among the Asians (app. 95% of the residing production) (Bhattacharjee *et al.*, 2002; Ramesh *et al.*, 2009; Hasjima *et al.*, 2013). Depending on the growing regions, various popular dishes are prepared by utilizing rice in combination with other ingredients used in smaller percentages (Zhou *et al.*, 2002).

Determining the functional properties such as water and oil absorption capacities, emulsifying activity and stability, and foaming capacity of rice are highly significant as this can help in deciding whether the grains have promising usage in the food ingredient industry or not (Theerakulkait *et al.*, 2006; Marerat *et al.*, 2011). In addition, determining the pasting properties is essential as it can aid in deciding the cooking stability, water-

binding capacity and baking quality of starch.

As functional and pasting properties tends to play a pivotal role in determining the quality of rice or rice based food product, it is highly essential to provide details pertaining to these parameters, especially for the locally grown rice varieties. Apart from the physical, textural and gelatinization properties, starch components can also be an influential parameter in determining the quality of a rice product (Juliano, 1985; González *et al.*, 2004). Starch (encompassing nearly 90% on d.w.) is one of the principal components of rice grains that can have a significant influence on the texture of cooked grains (Iturriagaa *et al.*, 2010; Mutters and Thompson, 2009).

Above all, consumers' acceptance is very important in choosing the right variety of rice when quality criteria are set, it is highly important to identify and provide details on the positive aspects of

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local rice grain varieties. Hence, based on these facts, the present study was undertaken to evaluate the functional and pasting properties of different locally grown rice varieties and were compared with those of popular, imported rice varieties in order to provide baseline information's which are envisaged to be useful while developing new rice based food products or food formulations.

Materials and Methods

Materials In total, six popular rice varieties (local and imported) were purchased from the local supermarket (Penang, Malaysia). The local rice varieties were the White rice (medium grain type, grown in Kedah region of Malaysia), Bario rice (grown in the Bario region of Sabah, East Malaysia) and Brown rice variety (grown in Kedah region of Malaysia). Whereas, imported rice varieties used for comparison included: Black rice and glutinous rice (from Thailand) and Basmati rice (from Pakistan). Only whole rice grains which maintained 75% of its grain length and without any physical damage was selected for analysis. Rice samples were individually ground to a fine powder (30 mesh size) using a Waring blender (Panasonic MX-898M, Malaysia, packed in air tight plastic bags and were stored at 4°C for future usage).

Physical Properties

pH and water activity measurements The pH and water activity (aw) in rice samples were measured based on the method of Cuevas-Rodriguez *et al.* (2006). In brief, rice flour samples (10 g) were suspended individually in 200 mL of boiling distilled water and the resulting slurry obtained (after cooling) was centrifuged at room temperature (25 ± 1°C) in an orbital shaker (at 1500 rpm for 20 min.) (Janke and Kunkel model KS501 D. IKA-Labortechnik, Germany). The pH reading for flour samples were recorded using a pH meter (Mettler-Toledo, Switzerland).

For measuring water activity, five grams of each rice sample was tempered at 25°C using a Hydrometer Aqua Lab Model CX-2 (Decagon Devices Inc., Pullman, WA, USA), and after the headspace equilibrium was attained, and readings were taken. Measurements for both pH and aw were done in triplicates.

Functional Properties

Water and oil absorption capacity The water and oil absorption capacities (WAC and OAC) in rice samples were ascertained based on the method described by Beuchat (1977), with some minor modifications. Briefly, to 25 mL of distilled water or refined Sunflower oil (for OAC), a known weight of powdered rice samples (2.5 g) were added in centrifuge tubes (50 mL capacity). The contents in tubes were centrifuged (Centrifuge Model: Kubota 4000 Tokyo, Japan) for 15 minutes at 3500 g, and the mixture acquired was left standing at room temperature (25 ± 1°C) for 30 min. The residue obtained after centrifugation was weighed, followed by calculation of water and oil absorption capacities (WAC and OAC) using the following equation:

$$\text{WAC and OAC} = \frac{\text{Millilitres of water or oil absorbed (mL)}}{\text{Weight of dry sample (g)}}$$

.....Eq. 1

Foaming capacity The foaming capacity (FC) in rice samples were determined based on method reported by Narayana and Narasinga Rao (1982), with some modifications. Briefly, 100 mL of distilled water was mixed with 2.5% (w/v) of rice flour and was whipped thoroughly at low speed in a Waring blender (for 5 min.) and the foam volume formed after 30s was recorded. The percentage increase in foam volume after 30s was considered as foaming capacity. Finally, the foaming capacity (FC) in the rice samples was calculated by using the following formula:

$$\text{FC (\%)} = \frac{\text{Volume of increase in foam layer (mL)}}{\text{Original foam volume (mL)}} \times 100\%$$

.....Eq. 2

Least gelation capacity (LGC) Gelation properties of rice flour were performed based on method described by Coffman and Garcia (1977). In brief, suspensions were prepared by blending rice flour in distilled water (concentrations 2 to 20%). Further, each suspension (10 mL) were placed in clean test tubes, and heated in boiling water bath (for 1 h). Followed by this, samples were cooled (for 2 h) in an refrigerator at 4°C. The lowest concentration wherein samples did not slide (or fall down) easily (on inverting the test tube) was considered as least gelation concentration.

Emulsifying properties The emulsifying activity and emulsion stability (EA and ES) was achieved based on the method described by Sathe *et al.* (1982). Briefly, 7% (w/v) of rice flour suspension was dispersed in 100 mL of distilled water and the mixture was homogenized for 30s at 11000 rpm using a homogenizer (Polyton homogenizer, Kinematica, PT-1200 E, Switzerland). Further, 100 mL of sunflower refined oil was added to this and the mixture was again homogenized for 1 min. The emulsions obtained were centrifuged at 1200 g for 5 min in 50 mL graduated centrifuge tubes (Model: Kubota 4000 Tokyo, Japan). The volume of the remaining emulsion was measured and emulsifying activity (EA) was calculated using the following equation:

$$\text{EA (\%)} = \frac{\text{Vol. of emulsified layer (mL)}}{\text{Vol. of whole layer in centrifuge tube (mL)}} \times 100$$

.....Eq. 3

Emulsion stability was determined by heating the emulsions prepared by the same procedure described above at 80°C for 30 min. The emulsions obtained were cooled at room temperature and centrifuged at 1200 x g for 5 min. Emulsion stability was calculated using the following equation:

$$\text{ES (\%)} = \frac{\text{Volume of remaining emulsified layer}}{\text{Original emulsion volume (mL)}} \times 100$$

.....Eq. 4

Determination of total starch content Total starch (TS) was determined enzymatically according to the method described by Goni *et al.* (1996). Rice samples (30 mg) were dispersed in 6 mL of 2M potassium hydroxide (KOH) and were incubated for 30 min at room temperature to disperse all starch fractions. About 60 µl of amyloglucosidase (JREF 102 857, Boehringer) was added to hydrolyse the starch. The samples were then incubated at 60°C for 45 min in a controlled shaking water bath. After centrifugation (10 min, 3000 g), the supernatant obtained was collected, transferred into a volumetric flask (50 mL) and final volume was made up with distilled water. Different concentrations of standard solutions, anhydrous D-glucose (10 – 60 ppm) were prepared. Glucose oxidase/peroxidase assay (SERA-PAK Plus®, Bayer de México, S.A. de C.V., Edo, De México) was used to determine the glucose content. 1 mL glucose oxidase peroxidase (GOD-PAP) reagent was added into a part of diluted sample mixed with standard solution (0.1 mL) in their respective test tubes. Further, this was incubated in a water bath for 30 min (at 37°C), and the absorption was measured at 510 nm using UV-spectrophotometer (Shimadzu Co. Japan Model AA-6650). The GOD-PAP reagent was used as blank for zero adjustment of the spectrophotometer. Glucose concentration was converted to starch using a 0.9 factor.

Pasting Properties The Pasting properties of rice starch was determined using Rapid Visco Analyzer (RVA Model 4, Newport Scientific Inc., Warriewood, Australia). Briefly, 3.5 g of rice flour sample was weighed in an aluminium canister and deionized water was added. For the experiment, temperature-time conditions included a heating phase from 50 to 95°C at 4°C/min, a holding phase at 95°C for 3 min, a cooling phase from 95° to 50°C at the rate of 4°C/min and a holding phase at 50°C for 2 minutes. For the pasting curve, the measured parameters included: peak temperature, peak viscosity, breakdown, final viscosity, setback and peak time was obtained. Results were expressed in centipoise and minutes (for peak time).

Statistical analysis Statistical analysis of the generated data were subjected to one-way analysis of variance (ANOVA) and Tukey's HSD post-hoc test using SPSS software (SPSS version 17.0 SPSS Inc., Wacker Drive, Chicago, IL, USA), with the level of significance determined at $p < 0.05$.

Results and Discussion

Significance of rice varieties used in the present study In the present study, we used 6 popular rice varieties marketed in Malaysia. The white rice (medium grain type) is one of the milled rice types wherein the outer layers (husk, bran and germs) are removed. This rice is popular owing to its smooth flavour, and is believed to balance well with locally prepared sauces or curries. Additionally, the local white rice variety is considered to have long storage life, and this can be extended even further if the grains are stored air-tight. The brown rice (un-milled rice) variety used in this study, encompassed the whole kernel with its bran layer still

unremoved. The distinct characteristic feature differentiating brown from white rice is not only the colour, but also the milling process. Generally, in brown rice, the hull are removed but bran and the germ are retained. Brown rice is considered to have high fibre content, and is nutritious with mild 'nutty' flavour. Traditionally, this rice is considered more 'chewier' than white rice with a shorter shelf life owing to the presence of oil in the germ (causing rancidity). The 'Bario' rice used in the present study is considered to be an exotic variety with a unique taste and cooking quality. Cooked grain has a soft texture with a mild and delicate aroma and is longer compared to raw rice grain. Bario rice is grown at high altitudes (above 1000 m sea level) and has high market value as it is considered to be an organic produce, with no usage of chemical fertilizers or pesticides during its cultivation.

On the other hand, the imported rice varieties as that of glutinous rice (popular as sweet rice, origin of Thailand and Laos) is particularly preferred owing to its sticky and dense texture obtained on cooking. In addition, this rice is reported not to contain any gluten (Wanchana *et al.*, 2003). Glutinous rice are mainly used in stabilizing sauces or gravies (Juliano and Hicks, 1996). Apart from making sweet delicacies or desserts, this rice is also used by some of the Asian communities to prepare sushi and rice crackers. Black rice (popular as forbidden rice) is an unmilled rice (black husks are not removed, thus has increased nutritional value) and is considered as heirloom variety of rice cultivated in Asia. Black rice is rich in fibre and iron content, and is highly popular for preparing noodles, exotic desserts and sushi. Even though referred to as 'black rice', the colour of black rice is infact 'deep purple to burgundy' owing to its high anthocyanin content. Black rice is slightly sweet, has an unique taste with nut like flavour. Parallel to brown rice, even the black rice undergoes spoilage easily and has short storage life. It has been reported that consumption of black rice can lead to the prevention of cancer, heart problems, atherosclerosis, and infectious diseases (Barron, 2010). The last variety of rice used in this study was the 'Basmati' rice, which is characterized by its long and slender grain. This rice is cultivated mainly in India and Pakistan and encompasses an exquisite aroma that can be associated with the aging process (reduction in moisture content) (Wass, 2011). Compared to most of the rice varieties, Basmati rice has good cooking properties and has soft texture, distinct scent, and good cooked elongation ratio (Bligh, 2000; Arora *et al.*, 2007). Basmati rice is recommended for people suffering from diabetes as it is known to have a lower glycaemic index (British Dietetic Association, 2011).

Physical Properties: pH and a_w In Figure 1 (A, B), the values obtained for pH and water activity are depicted. The pH values of rice flour varied significantly between 6.07 to 6.45. Based on the results obtained, it could be stated that the rice samples to low acidic food. The organic acids present in rice were minor constituents as compared to starch and protein content. It has been reported that the organic acids (such as fatty acids, amino acids and

Fig. 1. A, pH and aw of rice varieties; B, Water and Oil Absorption capacity of rice varieties, C, Emulsifying activity of rice varieties; D, Emulsifying stability of rice varieties. Values are mean $\pm$ standard deviation, same letter superscripted in the same column are not significantly different from each other at $p < 0.05$.

phytic acids) to have been formed during storage of rice owing to deterioration of lipids, carbohydrates and proteinaceous compounds (MoniQa, 2012). Also, these metabolically active compounds have been regarded to be good indicators of quality (Houston *et al.*, 1963). In addition, pH or the acidic nature of rice grain can influence colour changes, and can be correlated to poor eating qualities when acidity increases in rice grains.

Water activity (aw) is an important criterion which is based on Raoult's law of colligative properties (p/p_0) and is explained as the relative vapour pressure of the solute above a sample divided by the vapour pressure of pure water (determined at the same temperature). Water activity can influence the microbial quality and overall safety as rice grains are generally exposed to varied range of temperatures from pre-harvest upto post-harvest stages (Noorlidah *et al.*, 2000). As microbial growth can be controlled and reduced by monitoring the water activity levels it is very important to provide details on this parameter in relevance to rice grain. In the present study, water activity range for all rice samples was between 0.62 – 0.68. Growth of majority of the spoilage microorganisms can be inhibited if the water activity is below 0.9, and at 0.6 all microbial growths can be completely eliminated (FAO, 1998). This is because water is made unavailable due to its

tight-knitted bonds.

Functional properties

Water and oil absorption capacity (WAC and OAC) Water plays a significant role in bringing about a range of significant changes during gelatinization of starch as well as it influences other functional properties. Determining WAC is important as it assists in the formulation of various food products such as bread and soups (Oshodi and Adeladun, 1993; Bhat *et al.*, 2008). Results obtained for the WAC and OAC for the different rice varieties evaluated in the present study are shown in Figure 1B. Accordingly, WAC ranged between 3.82 – 10.86 mL/g. White rice had the lowest water absorption capacity while black rice had the highest. The differences observed in WAC can be attributed to the starch composition namely the amylose/amylopectin ratio (Sage V foods, 2000). It is reported that low WAC corresponds to high amylose contents of rice (Williams *et al.*, 2002; Ihegwuagu *et al.*, 2009).

OAC measures the capability of proteins to physically bind fat by capillary gravitation. In the present study, the range recorded for OAC was between 2.18 – 6.37 mL/g. OAC for brown rice was significantly high compared to all other local and imported varieties. OAC can influence not only the oil retention in a food

product, but can also determine the level of flavour retention and 'mouth-feel' (Fasoyiro *et al.*, 2010). The differences in OAC has been attributed to the variations in the amylose/amylopectin ratio as well as their chain length distribution (Perez *et al.*, 2002; Lawal *et al.*, 2004).

Foaming capacity Foaming activity is considered to be an assessment on the capability of a liquid to form foam after aeration (Khuwijitjaru *et al.*, 2007). The surface active effects of protein can help in the formation of foam by lowering the surface tension at the 'water-air' interfaces (Guan *et al.*, 2007). In addition, foam capacity can be formed exclusively if the aqueous phase allows protein to solubilise as well as unfold to surround the gas or the air droplets with a strong layer of protein (Tang *et al.*, 2002). In the present study, foaming capacity of rice samples ranged between 0.97 to 3.96%. The lowest foaming capacity was recorded in white and basmati rice, whereas glutinous rice exhibited highest foaming capacity. Recently, Islam *et al.* (2012) have reported on foaming capacity of brown rice flour, which was four times higher than our observation. This difference can be attributed to the variation in molecular flexibility as indicated by Sengupta and Damodaran (1998). Rice with acceptable foaming capacity possesses high potential to be incorporated in various baked products (*e.g.* rice cakes and bread) (Akubor *et al.*, 2000; Bhat *et al.*, 2008).

Least gelation capacity (LGC) The concentration required for developing of a 'self-supporting' gel is known as LGC. According to Boye *et al.* (2010), LGC is considered as a significant index of gelling capacity. Overall, a better gelling capacity is indicated by a lower LGC. Results of LGC are presented in Table 1. In the present study, Bario rice was able to form a better gel at lower concentration (8%), followed by white and basmati rice (at 10%), black and brown rice (at 12%) and glutinous (at 14%). According to Ikpeeme *et al.* (2010), compared to other cereal flour such as wheat flour, rice has similar least gelation capacity. The observed differences in LGC can be related to the presence of varied levels of proteins, carbohydrates and lipid in the various rice samples (Sathe *et al.*, 1982; Kaur *et al.*, 2007; Yeom *et al.*, 2009).

Emulsifying activity and Emulsion stability (EA and ES) Results on the EA and ES of different rice varieties investigated in the present study are shown in Figure 1 (C, D). Results indicated that glutinous rice to have considerably high EA when compared to white rice, which can be attributed to the presence of high protein content. However, there was not much difference in the ES among

all the rice samples investigated. It has been reported that cell wall (endosperm) of milled rice to encompass large amounts of pectin substances, which are good emulsifying and stabilizing agents (FAO, 1992). Additionally, Panyam and Kilara (1996) have reported macro peptides to provide higher ES, while micro peptides can reduce the ES.

Results on emulsion properties are important, as they are closely associated with protein solubility and protein surface hydrophobicity, which can prevent and eliminate any bonding between lipid and protein components found in rice grain (Damodaran, 1996; Travis *et al.*, 2000). The results of this study clearly indicates the possible usage of rice in various food industries as binders due to its excellent emulsion stability, thus capable of holding all the ingredients together (Toriyama *et al.*, 2005).

Total starch content and pasting properties In this study, among the different rice varieties, black rice had the lowest total starch content followed by glutinous rice. Whereas, white rice had highest total starch content, which can be attributed to the retrogradation of amylose molecules (Adu-Kwarteng *et al.*, 2003). On heating starch in presence of water, physico-chemical changes occur in the molecule that include breaking of hydrogen bonds. This allows water to enter the granule leading the granule to swell and rupture. After this, crystallinity is disoriented and amylose leaching occurs from the grain. It is reported that certain distinct features can affect granule swelling integrity with relation to rigidity of gelatinized starch granules (Sandhya and Bhattacharya, 1989; Suh *et al.*, 2004). The swollen granules as well as leached amylose are reported to contribute to their pasting properties (Morris, 1990).

Results on pasting properties of different rice starches evaluated in the present study are summarized in Table 2. The pasting temperature (onset of the rise in viscosity) for rice samples ranged from 62.1 to 78.3°C with the lowest being recorded for black rice and the highest for white rice. The peak time ranged from 5.3 to 9.2 min. Earlier, Sompong *et al.* (2011) have reported that rice with high amylose content to have a peak time above 8 min. In addition, starch with a short peak time has been reported to swell up and disintegrate more (Tsakama *et al.*, 2010).

The maximum viscosity obtained by gelatinized starch during heating in water is known as peak viscosity (PV). PV signifies the water binding capacity of a starch granule (Shimelis *et al.*, 2006).

Table 1. Foaming capacity and least gelation Capacity of rice varieties investigated in the present study

Parameter	Rice varieties					
	White	Brown	Bario	Black	Glutinous	Basmati
Foaming Capacity	0.97	2.97	1.98	1.98	3.96	0.97
LGC (%)	10	12	8	12	14	10

LGC, Least Gelation Capacity. Values are mean of three independent replicates (n = 3). (The statistical differences were not shown, hence not highlighted).

Fig. 2. Total starch content of rice varieties evaluated in the present study. Values are mean $\pm$ standard deviation, same letter superscripted in the same column are not significantly different from each other at $p < 0.05$.

Table 2. Pasting Properties of rice varieties investigated in the present study ($n = 3 \pm \text{S.D.}$)

Rice samples	Pasting Temperature ($^{\circ}\text{C}$)	Peak time (min)	Peak Viscosity (cP)	Breakdown (cP)	Final Viscosity (cP)	Setback (cP)
White	73.5 ± 0.23^c	9.2 ± 0.14^f	729 ± 0.32^e	345 ± 0.11^d	1077 ± 0.21^e	561 ± 0.76^e
Brown	64.2 ± 0.14^b	5.3 ± 0.13^a	298 ± 0.27^a	127 ± 0.34^a	513 ± 0.23^a	281 ± 0.16^c
Bario	78.3 ± 0.24^d	8.1 ± 0.1^e	339 ± 0.65^b	246 ± 0.24^b	589 ± 0.71^b	351 ± 0.32^d
Black	62.1 ± 0.32^a	6.2 ± 0.2^b	435 ± 0.89^c	215 ± 0.43^b	618 ± 0.13^c	212 ± 0.14^a
Glutinous	63.8 ± 0.1^{ab}	6.9 ± 0.09^c	413 ± 0.21^c	202 ± 0.09^c	598 ± 0.14^b	264 ± 0.19^b
Basmati	72.5 ± 0.12^c	7.2 ± 0.09^d	662 ± 0.34^d	354 ± 0.43^d	813 ± 0.32^d	296 ± 0.31^c

Values are mean $\pm$ standard deviation, $p < 0.05$). Same letter superscripted in the same column are not significantly different from each other at $p < 0.05$.

In the present study, PV was recorded to be highest in white rice 729 cP and lowest in brown rice 298 cP.

Breakdown viscosity, which is a measure of disintegrated cooked starch granules (Agu *et al.*, 2006), ranged from 127 to 354 cP with the lowest being for brown rice and the highest being Basmati rice. BC occurs when swollen starch granules are disrupted leading to amylose leaching during the holding phase at 95°C under shear. High values of BV indicates lesser breakdown of starch and is rather more inferior in handling heating and shear stress during cooking process (Adebawale *et al.*, 2005).

Re-association of starch molecules occurs when the mixture is cooled, consequently forming a gel leading to enhanced viscosity known (as the final viscosity). Final viscosity (FV) is commonly used as a quality parameter to measure the strength of a gel formed on cooling (Cornejo-Villegas *et al.*, 2010). The range obtained for FV from this study was 513 to 1077 cP. The rapid increase in FV could be attributed due to the amylose chains attaining an ordered arrangement (Flores-Farias *et al.*, 2000).

Setback, which is associated with the retrogradation and consistency of a gel formed by starch molecules, can provide valuable informations especially when high amylose starches are

retrograded (Karim *et al.*, 2000). In other words, setback can be considered as the measure of recrystallization attained by gelatinized starch while cooling. Results of the present study showed that setback was highest in white rice, followed by Bario, Basmati, brown, glutinous and black rice. According to Mutters *et al.* (2009), rice with low amylose content can have a low setback.

With regard to the results obtained for pasting properties, except for the glutinous rice, all other rice varieties showed significantly higher pasting properties. The differences observed in pasting properties of starch can be attributed to variations in amylose and lipid contents as well as the differences in the amylopectin structure such as chain length, degree of polymerization, etc (Wang *et al.*, 2001; Gupta *et al.*, 2009). According to Simi and Abraham (2008), dissimilarity between the two factors in amylopectin structure can influence gel viscosity, consistency and gel strength. Additionally, the size of starch granules can influence pasting properties. It has been reported that gelatinization to be slower in smaller starch granules owing to the formation of extra molecular bonds (Chen *et al.*, 2003). According to Zhou *et al.* (2002), higher temperature is required for gelatinization when internal molecular structures are stronger.

Conclusions

Investigations conducted on six different rice varieties (local and imported in Malaysia) indicated differences in the functional and pasting properties. The functional properties of rice varieties showed significant differences in water and oil absorption capacity, with less significant difference in emulsion stability. The percentage of starch content varied significantly with the lowest starch yield obtained from black rice and the highest from white rice. The peak time, peak viscosity, final viscosity and setback were highest in black rice, which can be attributed to their high amylose content. Overall, from the results obtained, understanding the functional and pasting properties of local rice varieties is expected to aid in the development of new rice based food products.

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