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Characterization and classification of whole-grain rice based on rapid visco analyzer (RVA) pasting profile

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Abstract

Classification of whole grain rice using only amylose content is not practical to predict starch viscosity for end product recommendation. This study aims to characterize and categorize whole-grain rice based on pasting profile of Rapid Visco Analyzer (RVA). The rice cultivars showed a wide range of peak viscosity (89.98 to 280.95 RVU), hold viscosity (59.97 to 211.56 RVU), breakdown viscosity (-0.33 to 130.67 RVU), final viscosity (111.25 to 390.75 RVU), setback viscosity (-44.47 to 205.67 RVU) and pasting temperature (74.17 – 91.15°C). Stability ratio and final viscosity explained 68.8% of total variance in the RVA profiles. The rice cultivars could be grouped into high (>0.95), medium (0.65-0.95) and low (< 0.65) stability ratio, followed by high (>300 RVU), medium (140 – 250 RVU) and low (< 140 RVU) final viscosity. The classification could serve as a basis for effective rice selection according to functional properties of whole grain rice..

Introduction

Quality assessment of rice is increasingly essential since it is one of the most essential foods in the human diet. Rice quality is commonly defined as eating quality and cooked texture (Vasudeva *et al.*, 2000; Chung *et al.*, 2003). Rice is a readily available source of starch offering various starchy properties to be attach to food and non-food products (Liu, 2005). Pasting characteristic is an essential function of starch to give thickening and sizing effects in food and non-food applications.

Pasting is defined as the phenomenon following gelatinization, involving granular swelling, extrudation of the molecular components and, eventually, the total disruption of the starch granules (Atwell *et al.*, 1988; Meadows, 2002). Rapid Visco Analyzer (RVA) is a heating and cooling viscometer that provides information on the pasting properties, including peak viscosity (PV), trough/hold viscosity (HV), breakdown (BD), final viscosity (FV), setback (SB), pasting temperature (PT) and peak time (Wrigley *et al.*, 1996). Pasting properties of starch depend on the amylose content, lipid content, branch-chain length of the amylopectin, varieties of the starch and cropping environment (Jane, 2004; Bao *et al.*, 2006). Other co-occurrence of nutrients such as starch, protein and lipid are also affecting the pasting properties of rice (Yu *et al.*, 2010).

Whole-grain rice is the full rice grain with bran and embryo still intact (Juliano, 1990). It has higher amount of nutritional components such as vitamins, minerals and fiber than polished rice (Dinesh Babu *et al.*, 2009). The presence of these constituents could affect the pasting properties between whole-grain and milled rice flour (Reece and Blakeney, 1996; Hamaker, 1999). The fibrous fractions of whole-grain rice often show low hydration profile and strongly bonded structure, which restrict the swelling and dispersion of starch granules and therefore affect the viscosity during heating (Wang *et al.*, 1993; Daramola and Makanju, 2008). Nevertheless, pasting properties of whole-grain rice still receive little attention although it is widely consumed as whole-grain supplements in many food products. The selection of suitable rice cultivar becomes laborious especially when there is no significant different between amylose content to effectively reflect the pasting profiles (Lee *et al.*, 2012).

Sarawak has a large diversity of rice cultivars with a unique name, grain size, color, fragrance and texture. Over 1000 rice varieties are grown in small scale by the farmers all over Sarawak mainly for self-consumption (Teo, 2010a; Teo, 2010b). These

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traditional rice with wide array of rice traits provide an opportunity for researchers to study the quality variation among the varieties (Chee *et al*., 2009). The large collection of traditional rice provides rooms for breeders and manufacturers in selection of suitable cultivars for product improvement. Moreover, these traditional varieties offer higher nutritional quality than commercial varieties, especially in the whole-grain form.

Whole-grain rice is a good functional ingredient for food product development, but its quality is often inconsistent among rice cultivars with similar amylose content. Classification of rice cultivars based on the practical processability was more appropriate than the classical amylose classification (Lee *et al*., 2012). Hence, the purposes of the current study were to characterize the RVA pasting profile of whole grain rice and propose a classification using multivariate approach. This classification would be a reference for starch processability and end quality indicator for whole grain rice.

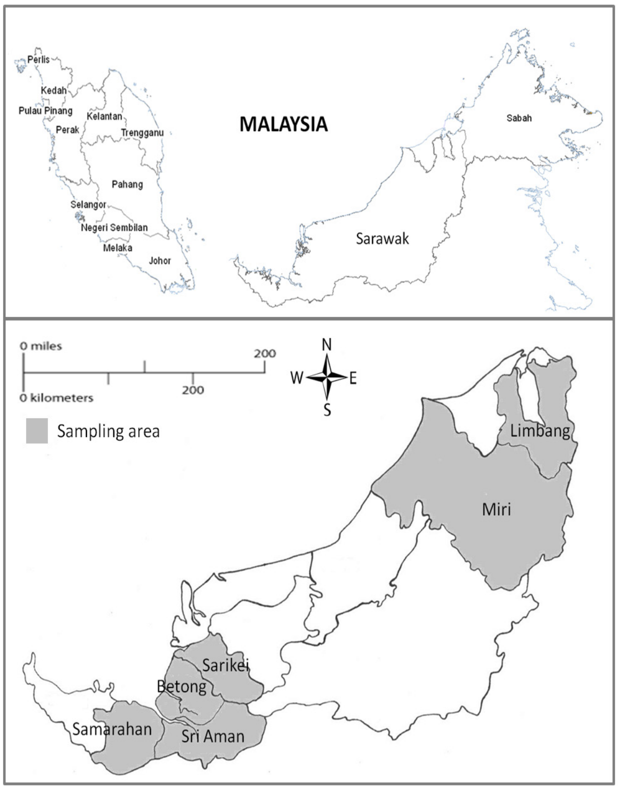

Figure 1. The sampling areas of 72 rice cultivars in Sarawak, Malaysia

Materials and Methods

Samples preparation

A total of seventy-two rice cultivars were collected from local farmers in Sarawak, Malaysia (Figure 1). Paddy were dehulled by hand and ground into rice flour in a blender and later pass through 125 µm sieve. The samples were later mixed well to ensure homogeneity.

Analysis of pasting properties

A Perten Rapid Visco Analyzer (RVA, Newport Scientific, Australia) was used to record and analyze the pasting properties of the rice flours. Rice flour suspension was prepared by adding 3.00 ± 0.01 g of the flour directly into a metal RVA canister containing 25 ml of distilled water. Paddle was jog up and down to remove any lump that formed. The pasting profile was recorded in triplicate under a constant shear rate (160 rpm) with heating and cooling cycles of 50°C to 95°C for 13 min (AACC, 2000). Peak viscosity (PV), trough/hold viscosity (HV), breakdown (BD), final viscosity (FV), setback (SB), pasting temperature (PT) and peak time were recorded from the RVA curve. Stability ratio was the ratio of hold viscosity to peak viscosity and setback ratio was the ratio of final viscosity to hold viscosity.

Statistical analysis

Data were analyzed using Analysis of Variance (ANOVA) to test for differences among the seventy-two rice cultivars between sampling areas, followed by Duncan's Multiple Range Test (DMRT) procedure at 5% significance level. The principal components in the RVA profile were identified from principal component analysis, followed by cluster analysis using Euclidean-distance average linkage technique.

Results and Discussion

Pasting profile of rice cultivars

All RVA pasting parameters were significantly different ($p < 0.05$) among the rice cultivars. Wide range of peak viscosity, hold viscosity, breakdown viscosity, final viscosity, setback viscosity and pasting temperature were shown in the rice collection.

Peak, hold and final viscosity

Peak viscosity was the highest viscosity achieved during heating at 95°C. The variation of peak viscosity often associated with the swelling power of starch and the rate of disruption of the starch granules (Corke *et al*., 1997). "Siam" from Miri had the highest peak viscosity (280.95 RVU) among the rice cultivars, where the granules swelled slowly, and the disruption was countered by other granules continuing to swell and therefore a flatter initial decreased (Figure 2). On the other hand, "Udang Halus" from Sri Aman had low peak viscosity (89.98 RVU) where the starches hydrated and swelled rapidly and resulted in a quick peak (Figure 2). The starch granules were disrupted

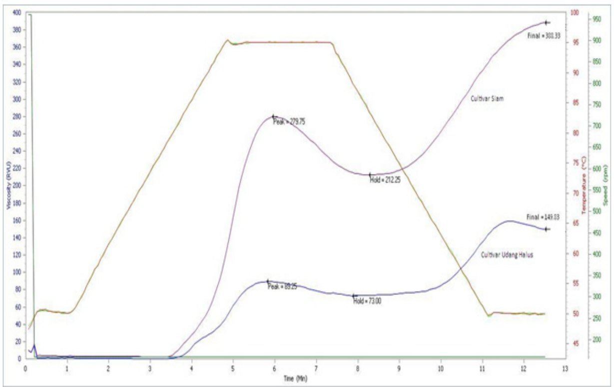

Figure 2. RVA profile for cultivar Siam and Udang Halus

by shearing forces and no remaining unswollen granules to counter the decrease in viscosity.

Hold viscosity was the lowest viscosity achieved during heating at 95°C. Hold viscosity measure the viscosity when the swelled starch granules were disrupted upon shearing and heating. "Lemak" and "Siam" showed the lowest (59.97 RVU) to highest (211.56 RVU) hold viscosity, reflecting different susceptibility of starch breakdown upon shearing and heating. Starch granules became increasingly susceptible to shear disintegration when swelled, especially in starches with lower amylose content (Kaur *et al.*, 2007).

Final viscosity was the paste viscosity upon cooling at 50°C. The starch granules experienced restructuring of starch molecules and retrograded. Final viscosity measured the ability of the starch to form viscous paste after cooking and cooling. "Siam" from Miri showed the highest final viscosity (390.75 RVU) among cultivars, indicating that "Siam" was suitable as a thickening agent in food application. The abundance of amylopectin in glutinous rice gave unique physical and chemical properties such as low pasting temperature and low final viscosity (111.25 RVU), as recorded in "Pulut Mas" collected from Miri (Jane, 2004; Surojanametakul, Tungtrakul, and Varanyanond 2006).

Breakdown viscosity and stability ratio

The paste stability of the rice flours could be expressed by either breakdown viscosity or stability ratio. Breakdown viscosity was defined as the difference between peak and hold viscosity, while stability ratio was the ratio of viscosity at the onset of cooling to the peak viscosity before cooling. The paste stability explained the hydration, starch swelling power and shear resistance of starch paste during heating. Low breakdown viscosity and high stability ratio often associated with low hydration and swelling power, and high shear resistance (Corke *et al*., 1997). "Minyak" from Limbang was susceptible to destruction from shear stress due to the highest breakdown viscosity (130.67 RVU) among all cultivars. Meanwhile, "Seratus" from Limbang with a negative breakdown viscosity (-0.03 RVU), gave a very stable starch paste and this might be partially due to some further starch swelling. Comparatively, rice cultivars from northern areas showed higher stability ratio than southern areas, but no significant differences in breakdown viscosity between the areas (Table 1).

Setback viscosity and setback ratio

Setback viscosity and setback ratio indicated starch retrogradation tendency after gelatinization and cooling at 50°C. Setback viscosity was calculated by subtracting peak viscosity from final viscosity, while setback ratio was the ratio of final viscosity over holding viscosity. The viscosity changes while cooling were mainly due to amylose molecular re-association, and low setback viscosity and setback ratio indicated a low rate of starch retrogradation. Low setback viscosity was found in "Minyak" (-44.47 RVU) from Limbang, "Pulut Mas" from Miri (-20.42 RVU) and "Bajong Wangi" from Samarahan (-3.42 RVU). Nevertheless, "Bandul" in Limbang showed the highest setback viscosity (205.67 RVU) connoted the highest water holding capacity within rice starch (Daramola and Makanju 2008). "Pulut Mas" gave the lowest setback ratio (1.28), and could be a good thickener and stabilizer for food processing industries (Corke *et al*., 1997). The setback viscosity was not determined by harvesting areas, but setback ratio was lower in rice cultivars from northern areas than southern areas (Table 1).

Pasting temperature

Initial rise in viscosity occurred when starch granules and proteins began to absorb water and swelled as the temperature increased gradually (Crosbie and Ross, 2007). The temperature at this point, known as the pasting temperature, was associated with gelatinisation properties of the starch source. The higher pasting temperature indicated the resistance potential against swelling in the ingredient, which could be correlated to the amount of amylose and amylopectin in the rice cultivars. "Sia" in Samarahan showed the highest pasting temperature (91.15°C) in contrast to those waxy rice cultivars such as "Pulut Mas" in Miri (74.17°C). However, cropping area was not a significant determinant for pasting temperature among rice cultivars.

Table 1. RVA profiles of whole-grain rice collected from different sampling areas

Divisions	*n*	Peak Viscosity	Hold Viscosity	Breakdown	Final viscosity	Setback	Pasting temperature	Stability Ratio	Setback Ratio
Southern area									
Samarahan	5	157.89 ab	87.77 a	70.12 a	232.48 a	74.59a	84.99 a	0.57 a	2.66d
Sri Aman	6	166.04 ab	89.52 a	69.42 a	259.05 a	92.92a	82.47 a	0.60 a	2.65d
Betong	4	175.6 ab	96.87 a	69.01 a	249.87 a	74.27a	83.11 a	0.60 a	2.34cd
Sarikei	4	149.93 a	106.6 a	60.47 a	201.25 a	51.25a	83.40 a	0.61 a	2.28bc
Northern area									
Miri	24	184.43 ab	141.75 b	49.99 a	277.50 a	93.08a	84.50 a	0.76 b	1.97ab
Limbang	29	193.46 b	145.32 b	48.16 a	267.45 a	74.15a	85.03 a	0.77 b	1.84a

Values followed by different alphabets within column are significantly different at $p < 0.05$.

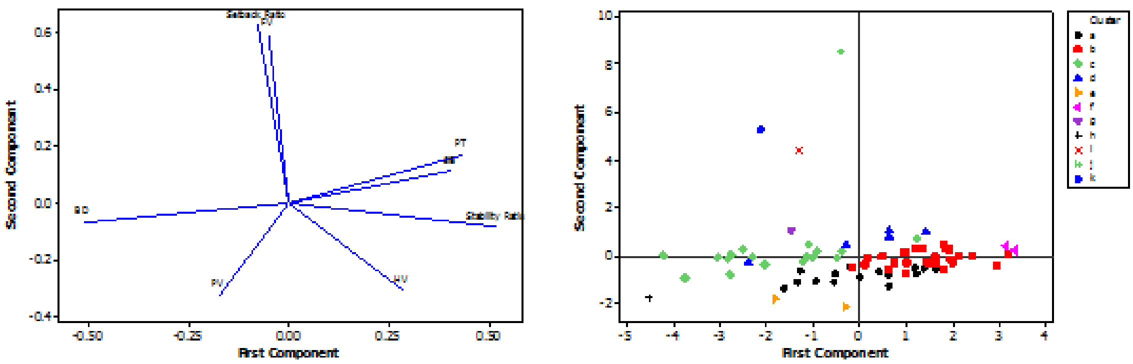

Figure 3. Factor loading and score plots of principal component analysis. Cluster "a - k" indicates rice cultivars clustered based on stability ratio, and final viscosity. PV: peak viscosity, HV: hold viscosity, BD: breakdown viscosity, FV: final viscosity, SB: setback viscosity, PT: pasting temperature

Classification of rice cultivars based on pasting profile

In the principal component analysis, the factor loading and score plots of first two principal components (PC1 and PC2) explained a total variance of 68.0% of pasting properties in the rice cultivars (Figure 3). Stability ratio was the major contributor to the separation along PC1, whereas final viscosity was responsible for the separation along PC2. Majority of the rice cultivars showed wide variation in stability ratio but exhibits narrow range of final viscosity. The rice cultivars were discriminated into 11 clusters based on principal components with Eigen values more than 1.0. These rice cultivars in cluster could be classified into three main pasting types by stability ratio, consisting of three sub-types by final viscosity (Table 2). This classification approach provided guidelines for selection of rice cultivars based on starch processability and desired paste properties.

High stability ratio (> 0.95) category

Cluster F represented those rice cultivars with high stability ratio, offering ingredient with good resistance against shearing under hot condition. They were "Semanyok Merah" and "Seratus" from northern areas of Sarawak. The texture of these rice cultivars after being cooked could be less sticky due to less starch granule rupture upon heating and shearing. The peak viscosity and final viscosity of these cultivars fell within the medium ranges of 140 – 190 and 200 – 300 RVU, respectively.

Medium stability ratio (0.65-0.95) category

Rice cultivars with medium starch stability ratio were grouped under cluster A, B, D and E. Starch swelled gradually and would resist to shearing stress moderately upon heating. These rice cultivars would undergo different amylose and amylopectin restructuring approaches upon cooling, and hence resulted in different level of final viscosity.

Cluster E, consisting of "Siam" and "Thomas", also from northern areas of Sarawak, showed high level of final viscosity (> 300 RVU) in potential of giving stiff and flaky gels. More than half (Cluster A and B) of the rice cultivars in the rice collection exhibited medium final viscosity. These rice cultivars would offer a medium cooked texture. Low final viscosity (< 200 RVU) was found for rice cultivars grouped under cluster D, which would develop into soft and clear gels. These cultivars could offer good

Table 2. Classification of rice cultivars based on RVA pasting profiles

Stability Ratio	Final Viscosity (RVU)	Cluster	Rice Cultivars/Sampling area
High > 0.95	High (> 300)	-	-
	Medium (200 – 300)	F	Semanyok Merah (Miri), Seratus (Limbang)
	Low (< 200)	-	-
Medium 0.65 – 0.95	High (> 300)	E	Siam (Miri), Thomas (Limbang)
		A	3A (Limbang), Adan (Limbang), Bario Panjang (Limbang), Biris (Limbang), Jepun (Miri), Kubok (Limbang), Mayang (Limbang), Meet (Limbang), Pandan (Limbang), Pusu (Limbang), Rengut Putih (Miri), Roti (Miri), Salleh (Limbang), Sarau (Miri), Silah (Betong), Tit (Limbang)
	Medium (200 – 300)	B	Adan (Limbang), Adan Kelabit (Miri), Bandul (Limbang), Bario A (Miri), Bario (Limbang), Beras Sederhana (Miri), Biris (Limbang), Biris (Miri), Dari (Limbang), Ensuluai (Miri), Gupung (Limbang), Hitam (Miri), Hitam Keladi (Miri), Merah (Miri), Merah (Limbang), Miri AAA (Miri), Pasir (Limbang), Pusu (Limbang), Pusu Merah (Limbang), Roti (Limbang), Segerit (Miri), Selasih Hitam (Miri), Bario Selepin (Miri), Seluai (Miri), Tit (Miri)
	Low (< 200)	D	Bario Lowland (Sarikei), Pulut Mas (Miri), Rengut Merah (Batu Niah), Sia (Samarahan), Udang Halus (Sri Aman)
Low < 0.65	High (> 300)	H	Minyak (Limbang)
	Medium (200 – 300)	C	Bajong Wangi (Samarahan), Biris (Sri Aman), Boria (Betong), Chelum (Betong), Empawan (Sri Aman), Hitam (Sri Aman), Keladi (Limbang), Keladi-Meritam (Limbang), Lebat (Samarahan), Mamut (Sri Aman), MR219 (Sri Aman), Palang (Meradong), Pandan (Miri), Raden (Sarikei), Rotan Wangi (Samarahan), Sentra (Limbang), Telasih Hitam (Limbang)
		I	Bario Merah (Miri)
		J	Bukit Wangi (Samarahan)
		K	Lemak (Betong)
	Low (< 200)	G	Lemak (Sarikei)

natural source of thickening ingredients especially for food industry.

Low stability ratio (<0.65) category

All the remaining rice cultivars produced pastes with low stability ratio, which were prone to shearing stress and thermal breakdown. These rice cultivars were not suitable for aggressive processing technology such as homogenizer, where starch granules would swell and rupture easily. These rice cultivars also showed different final viscosity at 50°C.

"Minyak" in Limbang was under cluster H, exhibited a high final viscosity and possible of high retrogradation behavior of starch paste. Meanwhile, cluster C indicated 20% of the rice collection with medium final viscosity (200 – 300 RVU). "Bario Merah" in Miri (cluster I), "Bukit Wangi" in Samarahan (cluster J) and "Lemak" in Betong (cluster K) also gave starch pastes with medium final viscosity. Another cultivar collected from Sarikei with same given name "Lemak" (cluster G) had low final viscosity and presented good thickening properties.

Conclusion

The whole-grain rice in collection showed a diverse rice pasting property among cultivars. The rice cultivars formed 11 clusters based on principal component analysis, which could be fitted into 7 pasting types with different levels of stability ratio and final viscosity. The classification of rice cultivars based on RVA profiles enabled a quick selection of rice cultivars according to their starch processability and pasting properties of whole grain rice. This classification provided a practical guideline for food manufacturers and rice researches in selection of suitable whole-grain rice for further product developments.

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