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Postharvest of paddy and milled rice affected physicochemical properties using different storage conditions

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Abstract

This study investigated the physicochemical properties of two cultivars of paddy and milled rice (Kalasin11 and KhawDokMali105). They were stored for ten months at three different conditions: cold room (20±5°C); room temperature (30±5°C); and warehouse (40±5°C). The results showed that amylose and protein content of both samples did not change significantly over the storage time. The gel consistency, the elongation ratio and the RVA pasting properties depended on storage time and temperature. Kalasin11 was found to have less gel consistency than KhawDokMali105, but its grain elongation ratio was higher under the same storage conditions. This result was found no significantly difference for both paddy and milled rice under the same condition. The breakdown (BD) value decreased with the increasing of storage time whereas the setback (SB) value increased. The setback value of Kalasin11 was significantly higher than KhawDokMali105. Storage conditions were found more affect on RVA pasting properties of paddy rice than milled rice. It can be concluded that warehouse storage condition affected on physicochemical properties for both paddy and milled rice comparing with the other conditions.

Introduction

Recently, 500,000 tonnes/year of Thai rice has been produced for both domestic consumption products and exported products. In 2011, Thailand exported 190,485 tonnes of rice products such as rice flour, rice noodle and rice paper and earning USD 313.61 million (Ministry of Commerce, 2012). Rice products, rice noodle and rice paper, are made from long-grain rice with high amylose content (above 27% amylose) (Tungtrakul, 1998). It plays a critical role in creating a gel network and sets the noodle structure (Mestres *et al*., 1988). It has been reported that rice noodle characteristics correlated significantly with swelling power (SP), paste viscosities and gel texture of starch presented in rice flour (Bhattacharya *et al*., 1999). Moreover, rice noodles made from local rice varieties with high amylose content showed desirable quality characteristics (Fari *et al*, 2011).

Kalasin local rice is one of the best rice varieties that Thai government has promoted since 40 years ago. Nowadays, this variety has less favourable as a cooking quality is not meet consumer requirement due to high amylose content (37-40%) (Suksomboon and Naivikul, 2006). Whereas, rice with high amylose content is suitable for food products such as noodle and rice paper as elasticity is required.

Generally, new crop paddy should be stored for three to four months before processing. It has been found that aged rice is more capable of absorbing water as well as its sized is increased compared to the fresh one (Howell and Cogburn, 2004). Changes during storage include increases in grain hardness and peak viscosity (Siebenmorgan and Meullenet, 2004). Therefore, steaming of aged rice will provide more disaggregated product with harder texture (Barber, 1972). Undoubtedly, any product, such as noodles, made from aged rice will be less sticky.

Rice flour from freshly harvested rice is generally softer and stickier than that from aged rice. Storage of harvested rice for a certain period is needed to facilitate processing. During that time, a quality of rice can be measured by the changes of chemical and physical properties, which begin prior to harvesting. These changes affect the cooking quality of the rice, especially its texture, flavour and the quality of the

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product after processing (Chrastil, 1992; Noomhorm *et al*., 1997). Regarding the rice quality to produce rice flour, many researches have focused mainly on the effects of storage condition on chemical and physical properties of rice (Teo *et al*., 2000; Zhou *et al*., 2003). Perez and Juliano (1981) reported that 3 months was the minimum storage period giving an effect on hardness, gel consistency and amylograph viscosity values for cooked rice. Starch retrogradation increased with increasing of storage period which provided linear trends with firmness (Perdon *et al*., 1999). Changes in protein properties (Zhou *et al*., 2003) and protein-starch interactions (Teo *et al*., 2000) contribute to the effect of aging on pasting properties of rice. Therefore, composition of the storage rice grain may be caused by those phenomenons. Since the paddy contains approximately 1.5-2.3% lipids and 5.8-7.7% protein, while milled rice is generally much lower in lipid (approximately 0.3-0.5%) and protein (approximately 4.5-10.5%). These values can vary greatly due to varietal, environmental, or processing variability (Siebenmorgan and Meullenet, 2004). Thus, the objective of this study was to investigate the effect of storage conditions on chemical and physicochemical properties from paddy and milled Thai rice. Since difference rice cultivars affected the changes on pasting properties of rice flour using aged paddy and milled rice during storage (Villareal *et al*., 1976; Sodhi *et al*., 2003; Zhou *et al*., 2003; Wiset *et al*., 2005); two cultivars with different starch properties were studies which were Kalasin11 and KhawKokMali105. Physicochemical properties of Kalasin11 which is high amylose content cultivar was compared with KhawDokMali105 which is medium amylose content cultivars because of the first one better for rice noodle processing and another one better for eating quality and flavour.

Materials and Methods

Rice samples

Two varieties of Thai paddy and milled rice grain: medium amylose content (KhawDokMali105) and high amylose content (Kalasin11) were used in this study. All two varieties were freshly harvested in Kalasin province area.

Storage conditions

The paddy and milled rice were packed in polypropylene bags (1 kg per bag) and stored for ten months (storage duration before harvest a new crop) in dark room at three conditions with different temperature regimes: cold (20±5^{o}C); room temperature (30±5^{o}C) at the Department of Biotechnology, Faculty of Agro-Industry, Kasetsart University; and warehouse (40±5^{o}C) at Kalasin rice mill.

Rice flour preparation

The paddy samples (two varieties) were de-husked and polished. The polished rice grains (both fresh and stored) were ground using a hammer mill and passed through 100 mesh sieve. The samples were kept in the polyethylene bag, sealed and stored in a cold room (4^{o}C) for further analysing.

Chemical properties analysis

Moisture and protein content were determined using the Approved Method 44-15A and 46-11A (AACC, 2000). Amylose content was measured using the method of Morrison and Laignelet (1986).

Elongation ratio

Ten stored rice grains were placed in a 20-mL glass test tube and soaked in 5 mL of tap water for 20 minutes. The test tubes were then put in a boiling water for 30 minutes. The test tube was drained after boiling for 30 min. The cooked grains were kept on a glass sheet for few minutes to remove any excess moisture. The length of the cooked rice grains were measured by Vernier Caliper. The elongation ratio was calculated by the average length of cooked rice grain divided by the average length of ten precooked kernels (Faruq *et al*., 2003).

Gel consistency

A hundred milligrams of rice flour prepared using a Wig-L-Bug amalgamator was placed in 13x100 mm culture tubes containing 0.2 mL of 95% ethanol with 0.03% thymol blue (Cagampang *et al*., 1973). Two millilitres of 0.2N KOH was added and vigorously mixed (2-3 sec) using vortex mixer. The tubes were covered with glass marbles and heated in a vigorously boiling water bath for 8 min, ensuring that the contents reached at two-thirds of the height of the tube. The tubes were removed from the water bath and left for 5 min at ambient temperature and cooling in an ice bath for 20 min. A content was then laid flat on a laboratory table over ruled graphing paper for 1 h. An index of gel consistency was calculated by measuring a total length of blue-coloured gel in millimetres.

Pasting properties

Pasting properties of rice flour was determined by using a Rapid Visco Analyser (RVA) (Newport Scientific Pty, Ltd., Australia) according to the approved methods of AACC 61-02 (AACC, 2000).

The samples (3 g, 12% w/w dry basis) were suspended in 25 mL distilled water. A programmed heating and cooling cycles were used by holding at 50°C for 1 min, heating to 95°C in 3 min 45 sec, holding at 95°C for 2 min 30 sec, before cooling to 50°C in 3 min 45 sec. Peak viscosity, trough, breakdown, final viscosity, and setback were recorded.

Statistical analysis

Statistical analyses were performed by using the one-way ANOVA and Duncan's multiple range test (DMRT) was used compare the differences in the mean values at 0.05 confidence level.

Results and Discussions

Effect of storage conditions on chemical properties of non-glutinous rice

Chemical properties of Kalasin11 and KhawDokmali105 (KDML105) paddy and milled rice at different storage conditions during ten months are shown in Figure 1. The results showed that the amylose contents of Kalasin11 and KDML105 variety were 34.5% and 16.7%, respectively. During ten months storage, amylose content of paddy and milled rice from both two rice varieties did not change significantly (Table 1). This result was found consistency with Barber (1972); Qiu *et al*. (1998) and Teo *et al*. (2000) carried out on the close storage times of milled rice. Moreover, Chrastil (1990a) found that only the slight increased of amylose content of milled non-waxy rice grains during storage at 40°C over an extended period of 12 months, while total protein and starch contents remained unchanged. Although there is minimal change in gross chemical composition of rice grain during storage, some hydrolysis or degradation probably occurs, leading to proportional increase in reducing sugars and a decrease in non-reducing sugars and starch (Zhou *et al*., 2002).

The protein content of both varieties (7.8% for Kalasin11 and 7.3% for KDML105) of paddy or milled rice before and after storage at cold room (20±5°C), room temperature (30±5°C) and in a warehouse (40±5°C) for 10 months are shown in Table 1. According to statistical analysis, the results showed that the protein content remained unchanged over this storage period. This result was consistency with Barber (1972), Noomhorm *et al.* (1997), Teo *et al*. (2000) and Chrastil (1990a) as found that temperature and time had no influence on protein content during storage. However, even no gross chemical composition change in the rice grain was observed during storage, Chrastil (1990a) considered that interactions between the protein and starch may possibly occur resulting in an increase in the

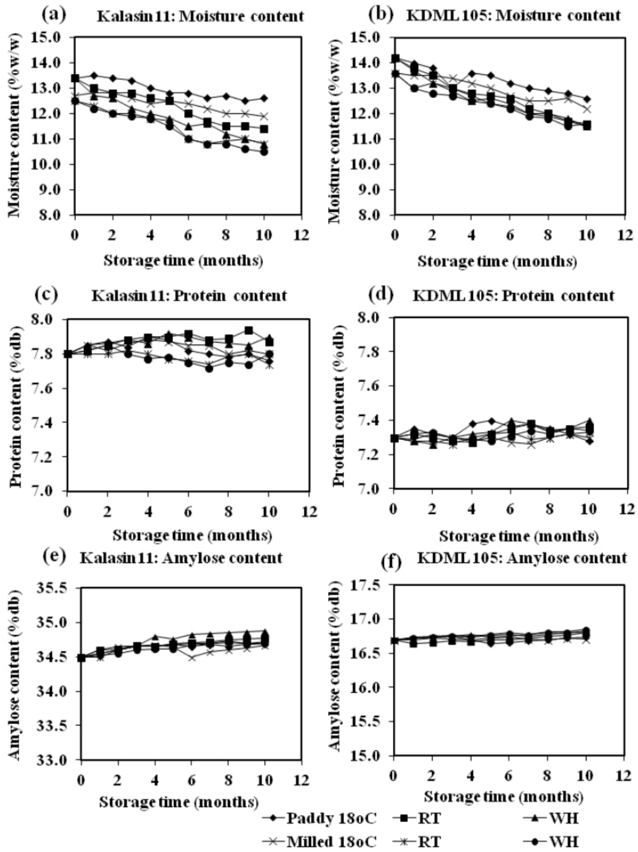

Figure 1. Comparison of some chemical properties of Kalasin11 and KhawDokMali105 (KDML105) paddy and milled rice stored at CR = cold room (20±5°C), RT = room temperature (30±5°C) and WH = warehouse (40±5°C) at Kalasin rice mill for 10 months. Moisture content (a,b); protein content (c,d) and amylose content (e,f)

disulfide bonds and consequently the protein content. Moreover, protein oxidation (formation of disulphide linkages from sulphydryl groups), together with an increase in the strength of micelle binding of starch, inhibits swelling of starch granules and affects cooked rice texture (harder and less sticky) (Zhou *et al*., 2002). These changes were strongly supported by higher storage temperature (Chrastil, 1990a).

Gel consistency

The gel consistency and the elongation ratio of paddy and milled rice for two varieties (Kalasin11 and KDML105) of paddy and milled rice held at different temperatures during storage are shown in Figure 2. Normally, gel consistency is related to the eating quality of rice as the higher the gel the harder the rice is. At three storage conditions, gel consistency of the rice was decreased after four months storage and tended to be stable. While storing at room temperature and warehouse temperature, a decrease rate was observed more than storing at cold room temperature. At the same storage temperature, KDML105 rice showed a higher gel consistency than that of Kalasin11 ($P \leq 0.05$) during the aging process. These results could be

Table 1. Physicochemical properties of fresh and stored paddy and milled rice (Kalasin11 and KhawDokMali105) stored at cold room, room temperature and warehouse for 10 months

Cultivar	Storage condition	Moisture (%w/w)	Protein (%db)	Amylose (%db)	Elongation ratio	Gel consistency (mm)
Kalasin11	Fresh	12.5	7.80 b	34.50 b	1.71 d	72 cd
Paddy	CR	12.6	7.76 b	34.70 b	1.88 e	68 bc
	RT	11.4	7.87 b	34.77b	2.10 f	63 a
	WH	10.8	7.90 b	34.88 b	2.20 f	61 a
Milled rice	CR	11.9	7.80 b	34.67 b	1.86 e	69 b
	RT	10.8	7.74 b	34.72 b	2.05 f	64 a
	WH	10.5	7.80 b	34.70 b	2.10 f	63 a
KDML105	Fresh	14.2	7.30 a	16.70 a	1.20 a	81 e
Paddy	CR	12.6	7.28 a	16.74 a	1.35 b	75 d
	RT	11.6	7.36 a	16.80 a	1.45 c	70 b
	WH	11.5	7.40 a	16.83 a	1.46 c	69 b
Milled rice	CR	12.2	7.30 a	16.71 a	1.33 b	76 c
	RT	11.5	7.33 a	16.82 a	1.42 c	72 c
	WH	11.6	7.34 a	16.85 a	1.42 c	71 bc

CR = cold room (20±5°C) RT = room temperature (30±5°C), WH = warehouse (40±5°C) at Kalasin rice mill.
Mean values followed by the same letter in the same column are not significantly difference at 5% significance levels by DMRT

due to the amylose content difference of two varieties (Villareal *et al.*, 1976). Zhou *et al.* (2002) suggested that during storage, lipid hydrolysis produce free fatty acid and the complexation of free fatty acid with amylose probably occurred after gelatinization with explained the influence of storage on viscosity. Storage conditions of temperature was particularly important to the reaction rate for hydrolysis. Moreover, a formation of amylose-lipid complexes (Sodhi *et al.*, 2003) which made the aged rice harder and less inclined to disintegration. Gel consistency between the paddy and milled rice of both varieties at various storage conditions was slightly difference. At warehouse temperature, stored paddy had minimum gel consistency. The results indicated that the gel formed by aged rice flours were harder than those of fresh rice flours and gave firmer texture of flours. This was consistent with the report of Wiset *et al.* (2005).

Elongation ratio

The results of elongation ratio of Kalasin11 and KDML105 for both paddy and milled rice under various storage conditions are shown in Table 1 and Figure 2. Elongation ratio indicated the cooking quality of rice as the higher elongation ratio means the better the cooking quality. During first month (fresh rice), the elongation ratios of Kalasin11 and KDML105 were 1.71 and 1.20, respectively. This property increased with increasing of storage period where the elongation ratio of paddy and milled rice were 2.20, 2.10 (for Kalasin11) and 1.46, 1.42 (for KDML105) respectively. At cold room storage condition, the elongation ratios of both varieties gradually increased during four month storage and did not change after four months until ten months. On the other hand, the elongation ratios increased during

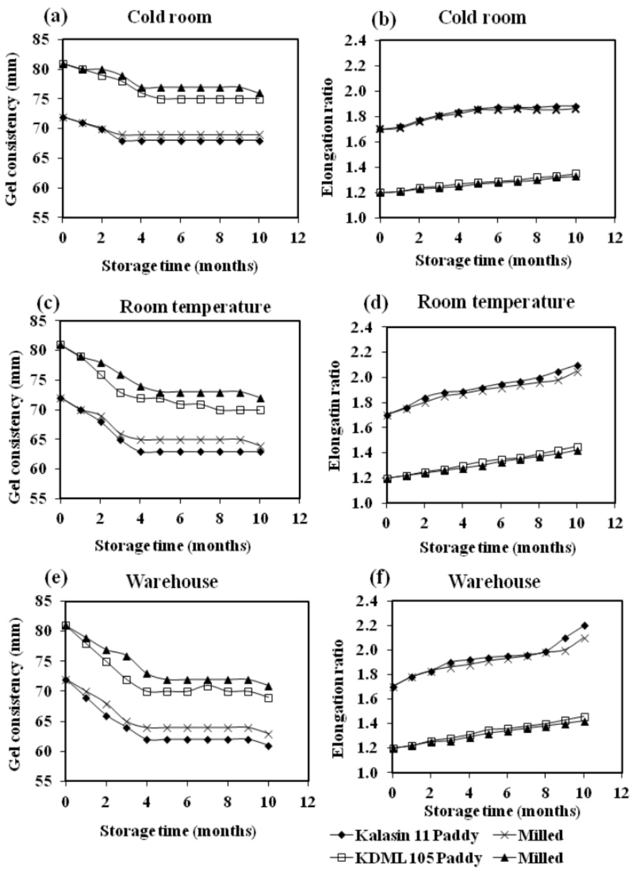

Figure 2. Comparison of elongation ratio and gel consistency of Kalasin11 and KhawDokMali105 (KDML105) paddy and milled rice stored at cold room (20±5°C), room temperature (30±5°C) and warehouse (40±5°C) at Kalasin rice mill for 10 months. Gel consistency (a, c, e) and Elongation ratio (b, d, f)

ten months at room temperature and warehouse condition. The results indicated that the elongation ratio of cooked rice increases during aging process as a result of changes in rice grains leading to water absorption during cooking resulted in larger volume of cooked rice (Chrastil, 1990b). From these results,

Table 2. Comparison of pasting properties of rice flour from fresh rice and aged (paddy and milled) rice from two rice varieties stored at cold room, room temperature and warehouse for 10 months

Rice sample	Storage condition	PV (RVU)	T (RVU)	BD (RVU)	FV (RVU)	SB (RVU)
Kalasin11	Fresh rice	247.64 ± 3.95 f	131.66 ± 1.80 f	115.98 ± 5.75 e	267.63 ± 3.95 g	135.97 ± 5.75 d
Paddy	CR	225.66 ± 2.64 h	143.45 ± 1.17 de	82.21 ± 3.81 g	282.81 ± 3.13 e	139.36 ± 1.96 d
	RT	199.60 ± 3.93 j	151.62 ± 2.26 bc	47.99 ± 1.68 i	334.33 ± 1.97 b	182.72 ± 0.29 b
	WH	186.99 ± 6.26 k	154.54 ± 3.81 ab	32.46 ± 10.08 j	356.49 ± 3.15 a	201.96 ± 0.66 a
Milled	CR	239.51 ± 2.50 g	138.63 ± 2.53 e	100.88 ± 0.03 f	276.50 ± 0.93 f	137.87 ± 1.61 d
	RT	211.79 ± 3.50 i	147.27 ± 4.26 cd	64.52 ± 7.76 h	322.48 ± 3.17 c	175.22 ± 1.10 c
	WH	201.94 ± 3.52 j	152.58 ± 2.60 bc	49.36 ± 6.12 i	331.47 ± 1.66 b	178.89 ± 4.26 bc
KDML105	Fresh rice	331.62 ± 4.58 a	126.34 ± 4.06 f	205.28 ± 0.52 a	219.68 ± 1.21 j	93.34 ± 2.85 g
Paddy	CR	303.34 ± 2.95 c	141.66 ± 2.02 de	161.68 ± 4.97 c	234.38 ± 2.09 i	92.72 ± 4.11 g
	RT	288.50 ± 3.92 d	155.86 ± 4.77 ab	132.64 ± 0.84 d	265.44 ± 1.02 g	109.58 ± 3.75 f
	WH	276.57 ± 3.08 e	159.57 ± 1.48 a	117.00 ± 4.55 e	293.51 ± 2.41 d	133.94 ± 3.89 d
Milled	CR	322.90 ± 3.00 b	139.58 ± 0.90 e	183.33 ± 3.90 b	231.39 ± 1.06 i	91.82 ± 0.16 g
	RT	301.40 ± 2.64 c	142.04 ± 1.29 de	159.37 ± 3.94 c	251.76 ± 1.61 h	109.72 ± 0.31 f
	WH	287.55 ± 1.94 d	151.08 ± 1.08 bc	136.47 ± 3.03 d	274.38 ± 2.09 f	123.30 ± 3.17 e

PV= peak viscosity, T= trough, BD= breakdown (PV-T), FV= final viscosity, SB= setback (FV-T), CR = cold room (20±5°C) RT = room temperature (30±5°C), WH = warehouse (40±5°C) at Kalasin rice mill.
Mean values followed by the same letter in the same column are not significantly difference at 5% significance levels by DMRT

it can be concluded that increasing of storage time and temperature can improve a cooking quality of rice.

Pasting properties

The pasting properties of two varieties of rice flour prepared from stored paddy and milled rice under different storage conditions are shown in Table 2. There was a significant amylose content effect on the RVA pasting properties of fresh rice flour. A significant difference of pasting properties (for stored paddy) was found over a storage period which compatible with Noomhorm *et al*. (1997) and Zhou *et al*. (2003). The result shows that the peak viscosity (PV), trough (T), final viscosity (FV) and setback (SB) of Kalasin11 rice flour were higher than KDML105 rice flours which obtained from stored paddy and milled rice. Moreover, the changes in pasting properties observed for stored paddy were higher than stored milled rice. The results showed that the effect of paddy and milled rice storage on the pasting properties depended on amylose content, storage temperature and duration (Noomhorm *et al.*, 1997; Sowbhagya and Bhattacharya, 2001; Zhou *et al.*, 2003; Wiset *et al.*, 2005). It was found that PV decreased with aging but the rice stored at warehouse temperature showing the highest change in pasting behaviour. As shown on Figure 3, decreasing of PV values presented that the starch granules of stored rice were more resistant to swelling than fresh rice. Zhou *et al.* (2003) proposed that oxidation of non-starch would contribute to cross-linking and increased strength of cell wall during storage resulted in inhibits swelling of starch granules.

Storage at a relatively low temperature of cold room (20±5°C) increased a final viscosity (FV) gradually. Conversely, increasing of FV values were observed when stored at the high temperature of the warehouse (40±5°C). Meanwhile, paddy and milled rice, stored at the intermediate temperature (room temperature; 30±5°C), exhibited FV values between those of rice stored at cold (20±5°C) and warehouse (40±5°C) storage conditions. The final viscosity of both paddy and milled rice increased gradually to maximum value after ten months storage in the warehouse condition (Figure 3).

The effect of storage temperature and time on setback and breakdown values of rice flour prepared from paddy and milled rice stored at ten months are shown in Figure 4. The results showed that paddy stored in various conditions had a higher setback (SB) value than that of stored milled rice and established a similar trend for both two rice varieties (Kalasin11 and KDML105). FV and SB values increased with increasing of storage time and temperature (Table 2). FV value of Kalasin11 rice flour obtained from stored paddy was relatively high. Furthermore, an increase of SB value indicates a higher degree of retrogradation as a result of rice firmness was increased (Tulyathan and Leeharatanaluk, 2007). Obviously, it was found that rice flour obtained from stored paddy and milled rice was firmer than that of the flour obtained from the fresh rice, thus the flour obtained from stored rice provided less stick property (Zhou *et al*., 2002). Moreover, SB value was found to be affected by variety (amylose content) and age of the rice

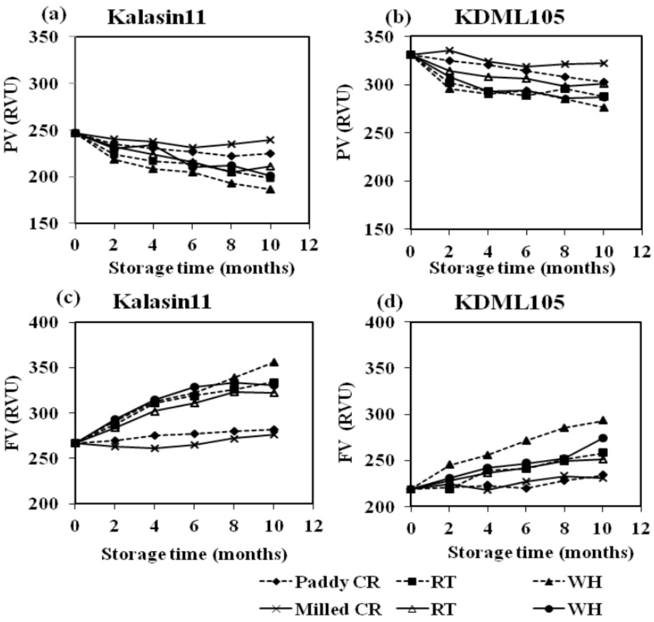

Figure 3. Peak viscosity (PV) and final viscosity (FV) values during storage time at CR = cold room (20±5°C), RT = room temperature (30±5°C) and WH = warehouse (40±5°C) at Kalasin rice mill for 10 months. PV (a,b) and FV (c,d)

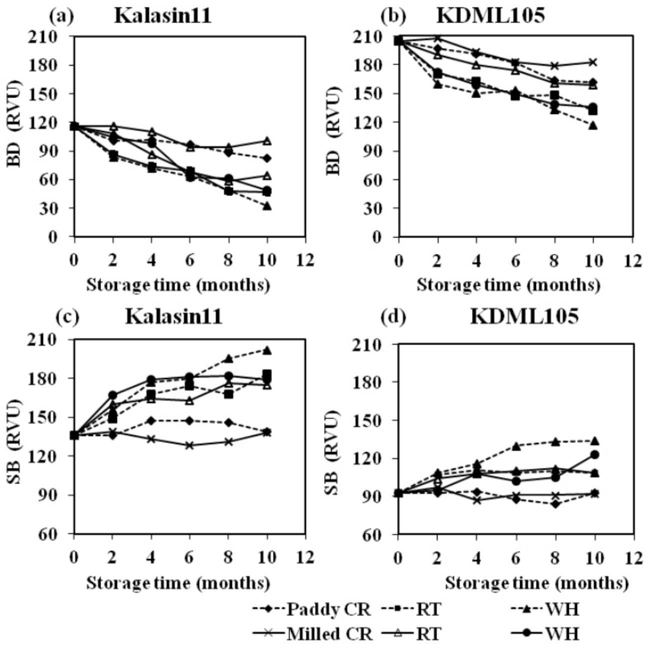

Figure 4. Breakdown (BD) and setback (SB) values during storage time at CR = cold room (20±5°C), RT = room temperature (30±5°C) and WH = warehouse (40±5°C) at Kalasin rice-mill for 10 months. Breakdown (a,b) and setback (c,d)

(Sowbhagya and Battacharya, 2001). As shown in Table 2 and Figure 4, the results indicated that paddy of Kalasin11 stored at warehouse temperature for ten months had a higher firmness than that of KDML105 and the fresh paddy with having higher SB value.

Conversing to SB, BD and SB values, storage of both varieties at room temperature and warehouse temperature affected breakdown value (BD) which was generally decreased (Zhou *et al*., 2003). The result is shown in Figure 4, where the SB values of the KDML105 flour from stored paddy and milled rice increased at room temperature and warehouse storage condition but in the lower rate compared to those of Kalasin11. KDML105 flour obtained from aged paddy and milled rices showed higher BD value than those of Kalasin11 flour due to higher number of swollen starch granules (higher PV) (Zhou *et al*., 2002). BD value of the two rice varieties flours decreased at the same rate. These changes could be results of starch granule characteristics. Sowbhagya and Bhattacharya (2001) suggested that the rice structure became progressively more organized during storage. Alternatively, the granule surface represents the primary barrier to processes such as hydration that may depend on the charge characteristics of the starch granule surface. Thus, pasting may be influenced by the presence, orientation and nature of surface lipids and proteins. The latter are rich in basic amino acids and are intrinsically hydrophilic. For example, changes at the granule could contribute to a decrease in hydrophilicity that would affect granule hydration and swelling. In either case, the changes induced by ageing result from the increased hardness of the starch granules limiting granule hydration and swelling. Thus, decreasing of BD value indicated that the capacity of starch granules to rupture after cooking was significantly reduced by ageing process (Noomhorm *et al*., 1997; Zhou *et al*., 2003; Tulyathan and Leeharatanaluk, 2007). Basically, a large BD value is one of starch granule characteristics usually associated with good eating quality of rice for the Japanese market, where fresh rice is preferred (Isono *et al*., 1994).

Moreover, ageing was accelerated at a higher storage temperature as observed in previous studies (Zhou *et al*., 2003). Thus, the physico-chemical analyses from paddy and milled rice stored at cold room temperature, room temperature and warehouse temperature provided a valid comparison of effects of ageing on pasting behavior. Furthermore, it can be concluded that rice stored at cold room temperature retarded the changes in the pasting properties (Zhou *et al*., 2003; Wiset *et al*., 2005). Normally, aging mechanism is very complex as it involved starch-protein interaction which led to the increased hardness of the starch granules and limited the granule hydration and swelling (Teo *et al*., 2000; Zhou *et al*., 2003; Tulyathan and Leeharatanaluk, 2007). From the present study, the changes in physicochemical properties of stored paddy rice were more important than those of stored milled rice. In addition, the elevated temperature accelerated these changes (Faruq *et al.*, 2003) giving the paddy of Kalasin11 after ten months storage in the warehouse had the highest changes in physicochemical properties.

From theses results, it can be concluded that storage induced changes in the physicochemical properties of rice may be both desirable and undesirable depending on storage conditions, variety, and end user requirements. Storage temperature and storage time are the factors most influential on the chemical, physical, and functional qualities of rice during post harvest storage. The rate and nature of the change is primarily temperature dependent. Generally the outer layers are more susceptible to these reactions than the endosperm of the rice kernel. Although the physicochemical properties of paddy may exhibit greater changes, milled characteristics can also be altered during storage. Quality shifts generally occur faster with increasing temperature.

Conclusion

Storage of paddy and milled rice (Kalasin11 and KhawDokMali105) at warehouse condition for ten months revealed the highest change in the gel consistency, elongation ratio and RVA pasting properties. However, the obvious change in the physicochemical properties was observed in Kalasin11 than KhawDokMali105. It could be suggested that during rice storage, the aging mechanism induced by temperature and time which depended on rice varieties and type resulting of higher FV and SB value. As observed in this study, the rice varieties had an influence on the cooking, textural and sensory properties of rice noodles, it could be proposed that aged Kalasin11 rice (both paddy and milled rice) could be used for noodle products with a desirable quality.

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