Australian Journal of Crop Science
AJCS

AJCS 5(6):635-640 (2011) ISSN:1835-2707

Effects of in-bin aeration storage on physicochemical properties and quality of glutinous rice cultivar RD 6

L. Wiset[1*], P. Laoprasert[2], C. Borompichaichartkul[2], N. Poomsa-ad[1] and V. Tulyathan[2]

[1]Faculty of Engineering, Mahasarakham University, Kantarawichai, Maha Sarakham, Thailand
[2]Department of Food Technology, Faculty of Science, Chulalongkorn University, Pathumwan, Bangkok, Thailand

***Corresponding author: lamulwiset@hotmail.com**

Abstract

The aim of this research is to study the effects of storage conditions on the properties and quality of glutinous rice cultivar RD 6. The storage conditions were cold aeration and stored at 15 and 20 ºC, ambient aeration and stored at ambient temperature compared to paddy stored in gunny bags. Paddy was taken before storage and after 2, 4 and 6 months of storage to be determined for the disulfide linkage, thermal and textural properties including sensory evaluation. The results showed that the changes of disulfide linkages in protein were slightly increased with storage periods. Thermal properties were measured by differential scanning calorimetry and found that the enthalpy of gelatinization was the highest in gunny bags storage after 6 months. The textural properties showed that hardness, cohesiveness and chewiness was increased, while adhesiveness was decreased after storage. Furthermore, the paddy stored at ambient temperature and the paddy stored in the gunny bags had the greatest change in textural properties. Sensory evaluation of cooked rice by trained panelists showed that the paddy stored at ambient temperature and in gunny bags had a yellowing color and abnormal aroma. Base on overall acceptance score, panelists preferred the paddy stored at 15°C and 20°C than that stored in gunny bags.

Keywords: aeration; waxy rice; protein; storage; textural properties; thermal properties

Introduction

Sticky rice, waxy rice or glutinous rice is a kind of rice which is classified as very low amylose content. Milled waxy rice appears opaque or milky color, as opposed to non-waxy rice, which is translucent. Sticky rice is not only consumed as main dish, but also modified in different forms to make various kinds of food products such as dessert, snack and topping. These due to its starch properties generate different texture of end use under various moisture contents. Aged non-waxy rice provides the firmer and expanded cooked rice which is consumer preference. In opposite way, consumers prefer the taste of cooked newly waxy rice due to its soft and sticky. After harvesting, the moisture content in paddy is reduced to a safe level of 14% wet basis or less by drying before the paddy can be stored. During storage, gradual changes in the physical, chemical and physico-chemical properties of the rice occur depending on chemical components and surrounding conditions. The changes lead to both desirable and undesirable characteristics. Consumers, on one hand, prefer the better cooking quality of aged rice, but the off-flavor and increased yellowing are disliked (Widjaja et al., 1996; Meullenet et al., 1999; Pearce et al., 2001; Zhou et al., 2002; Wongpornchai et al., 2004). The yellowness and off-flavor are a result of improper storage time and conditions (Soponronnarit et al., 1998). The advantages of proper storage include gaining a high percentage of head rice yield, improving overall quality, and maximizing the selling price. Poor storage reduces the quantity of available paddy and dilutes the quality. Improper storage of bulk paddy under high temperature and high relative humidity conditions is risky in that it promotes rapid deterioration. Heat accumulates inside the paddy bulk and accelerates the loss of quality. If the rice kernel is stored in a high humidity environment, it will absorb moisture. As a result, increasing of its breathing which produces heat that accumulates in the bulk paddy and ultimately promotes unwanted microbial growth and discoloration (Zhou et al., 2002). However, proper aeration that allows the heat to escape from the paddy mass preserves the quality of the grain. Several researches further indicate that proper storage of paddy in an aeration bin can reduce the accumulation of heat in the bin caused by breathing, reduce moisture content, inhibit microbial growth and slow the yellowing color (Phillips et al., 1988; Ranalli et al., 2003). Cold aeration is beneficial to slowing the negative changes in quality. Once the grain paddy has been initially cooled to the required temperature, the temperature can be maintained for a long period due to the insulating property of the paddy. Therefore, it is not necessary to keep paddy in a refrigerator or cold room all the time. Ambient aeration and cold aeration might be interesting methods for preserving the better quality of waxy rice during storage (Ma and Sun, 2008). As such, this research aims to study the effects of in-bin aeration storage on the physicochemical properties and quality of glutinous rice cultivar RD 6 during storage at ambient temperature, cool aeration and stored at 15, cool aeration and stored at 20°C, and storage in gunny bags, and study the possibilities of how to keep aged rice looking fresh to meet the need of consumer.

Materials and methods

Materials

Glutinous rice cultivar RD 6 was cultivated in Maha Sarakham Province, Thailand, in 2007. Immediately after harvesting, the paddy was sun dried by local farmers until the moisture content came down to less than 14 % wet basis. Foreign matter and immature grains were then removed from the paddy and the paddy was placed in storage bins and gunny bags.

Storage conditions

The paddy was stored in three separate insulated bins and gunny bags. The three storage bins were made from steel in a cylindrical shape with a 78 cm diameter and 120 cm height. Each bin contained 250 kg of paddy. The bin 1 was used for ambient aeration with a 0.5 m/s air flow rate. Its contents were then stored at room temperature with an automated fan blowing air over the contents for 2 hours a day from 5 to 7 pm. (Fig 1.) For the bin 2 and bin 3, cool aeration and storage at 15°C and 20°C (Fig 2.) was employed. Thermocouples along the core of the bins at different locations were used to detect temperature changes. The thermocouples were located at the bottom (30 cm height), centre (60 cm height) and top (90 cm height) of the bin. An automatic fan was activated when the average temperature of the kernel, as measured by the thermocouples, became higher than the setting storage temperature. The fan stopped blowing when the average temperature of the kernel temperature was equal to 15°C and 20°C. During the period from December 2007 to May 2008, samples from the four storage conditions were taken every two months by sampling from the top, centre and the bottom of the bin. The *samples were taken to be analyzed for the various properties of glutinous rice.*

Fourier Transform Infrared Spectroscopy

Fourier transform infrared (FT-IR) spectroscopy was used to evaluate structural differences in the samples. An appropriate amount of rice flour was pressed into a crystal window and the FT-IR spectra were recorded on a Fourier transform infrared spectrometer (Perkin-Elmer model spectrum one, USA). FT-TR studies were carried out in the range of 4000 to 400 cm^{-1} in the absorbance mode. Each spectrum was the average from 16 scans at a resolution of 4 cm^{-1}. The changes of disulfide linkages in protein was evaluated for the deconvoluted spectra by the ratio of absorbance of peak height at the wave number of 500-400 cm^{-1} and the peak height at the wave number of 1047-1022 cm^{-1} (Li et al., 2008).

Thermal properties

Thermal analysis of milled rice flour was performed using a differential scanning colorimeter (DSC) (Perkin-Elmer, model Diamond-DSC, USA) (Chang & Lin, 2006). A known weight of rice flour was directly placed in a DSC

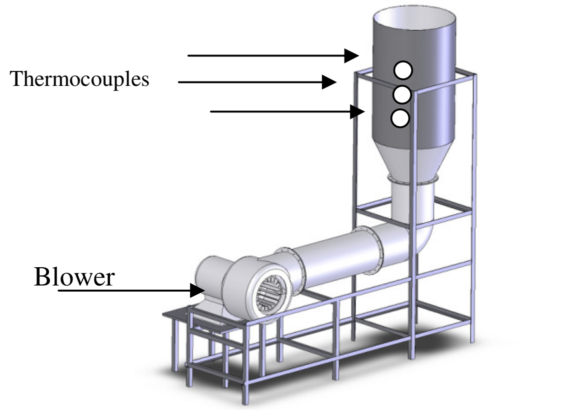

Fig 1. Feature of storage bin with ambient aeration system

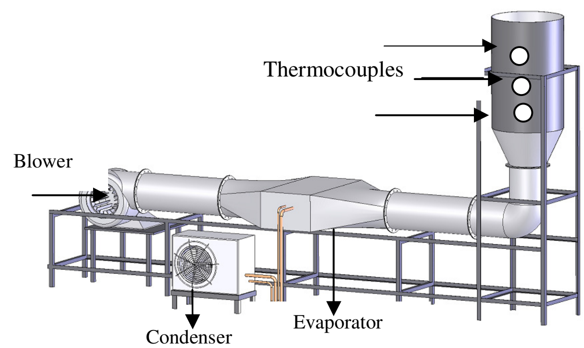

Fig 2. Feature of storage bin with cool aeration system

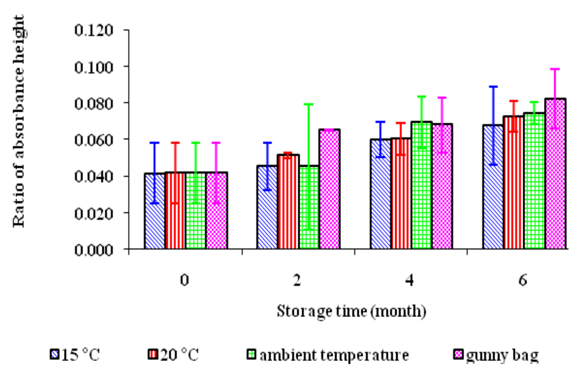

Fig 3. Changes of disulfide linkages in protein of glutinous rice cultivar RD 6 under various

volatile sample pan. A calculated amount of distilled water was added using the ratio of water to rice flour as 3:1 (w/w, db). The pan was hermetically sealed, reweighed and equilibrated overnight at room temperature before the experiment. The total weight of the sample in DSC pans was approximately 15 mg. An empty volatile sample pan was used as a reference. The sample and reference pan were scanned from 25°C to 85°C at a heating rate of 10°C/min. The major parameters of the DSC profiles defined as onset temperature (T_o, °C), peak temperature (T_p, ° C), conclusion temperature (T_c, °C) and ΔH

Table 1. Thermal properties of glutinous rice cultivar RD 6 under various storage conditions for 6 months. (A, B)

Storage condition	Storage time (month)	Gelatinization temperature (°C)			ΔH_{gel} (J/g dry flour)
		T_o ns	T_p	T_c	
-	0	63.15±0.89	71.64±0.18 bc	78.47±0.57 c	8.35±0.19 b
15˚C	2	64.02±0.16	71.48±0.14 c	78.33±0.04 c	9.34±0.78 ab
	4	63.96±0.60	71.83±0.25 bc	79.26±0.34 abc	10.39±0.75 a
	6	64.40±0.75	72.38±0.53 ab	79.22±0.53 abc	9.27±0.69 ab
20˚C	2	63.89±0.54	71.84±0.52 bc	78.75±0.16 c	8.69±0.20 b
	4	64.31±0.16	72.01±0.27 bc	79.19±0.15 abc	9.76±0.58 ab
	6	63.42±1.00	72.11±0.30 abc	79.21±0.25 abc	8.58±0.65 b
ambient temperature	2	63.92±0.42	71.91±0.32 bc	78.91±0.53 bc	9.05±0.89 b
	4	63.55±0.55	71.71±0.19 bc	79.11±0.14 abc	9.26±0.16 ab
	6	63.83±0.67	72.30±0.32 ab	79.23±0.27 abc	9.12±0.85 ab
gunny bags	2	63.54±0.83	72.05±0.89 abc	79.86±1.18 ab	10.26±0.27 a
	4	63.73±0.06	71.64±0.16 bc	79.16±0.05 abc	10.30±0.37 a
	6	64.23±0.95	72.80±0.54 a	79.99±1.10 a	10.53±1.96 a

T_o = onset temperature, T_p = peak temperature, T_c = conclusion temperature, ΔH_{gel}= enthalpy change for gelatinization, [A] Means with the different letter within the column are significantly different ($p \leq 0.05$).[B] Mean ± standard deviation , [ns] Means within the column are not significantly different ($p > 0.05$)

Table 2. Textural properties of glutinous rice cultivar RD 6 under various storage conditions for 6 months. (A, B)

Storage condition	Storage time (month)	Hardness (gf)	Adhesiveness (gf-mm) ns	Cohesiveness	Chewiness (gf) ns
-	0	1055.79±57.30 f	418.4±41.49	0.11±0.02 d	53.95±18.31
15˚C	2	1179.43±77.15 e	349.29±84.15	0.15±0.05 cd	52.77±9.23
	4	1288.08±80.78 de	327.59±14.35	0.17±0.04 bc	62.39±25.63
	6	1394.07±100.39 bcd	327.62±61.14	0.21±0.01 ab	64.62±23.37
20˚C	2	1201.86±77.98 e	351.12±83.06	0.17±0.04 bc	52.25±13.97
	4	1388.80±65.15 bcd	312.53±69.84	0.19±0.04 abc	61.15±30.04
	6	1440.39±95.42 bc	265.37±55.45	0.19±0.03 abc	68.42±30.91
ambient temperature	2	1329.01±77.3 cd	304.41±74.28	0.19±0.05 abc	58.03±13.12
	4	1476.48±70.59 ab	258.63±81.19	0.19±0.03 abc	71.14±49.67
	6	1581.81±110.14 a	270.54±56.24	0.19±0.03 abc	77.33±41.12
gunny bags	2	1291.90±57.12 de	307.57±99.44	0.20±0.01 abc	51.26±20.36
	4	1419.57±68.11 bc	285.56±87.83	0.23±0.03 a	62.21±10.9
	6	1475.73±124.25 ab	253.33±112.67	0.19±0.03 abc	70.01±44.82

[A] Means with the different letter within the column are significantly different ($p \leq 0.05$). [B] Mean ± standard deviation , [ns] Means within the column are not significantly different ($p > 0.05$).

(J/g dry flour) which were calculated from the area of the gelatinization peak from the DSC.

Textural properties

Cooked rice was subjected to texture profile analysis (TPA) using an Instron universal materials testing machine (Instron Corporation model 5565, USA) (Gujral and Kumar, 2003). A sample of cooked rice kernels (10 g, spherical shape, 3 cm diameter) was placed on the platform of an Instron universal materials testing machine. A 5 cm diameter cylindrical probe was attached to a 50 N load cell and used to compress the sample to 60% of its original height at a crosshead speed of 3 mm/s for two cycles. The values reported were the mean of five replicates. A force-distance curve was obtained from the test and the following textural parameters were determined: Hardness = peak force of the first compression cycle, Adhesiveness = negative force on the upstroke representing work to pull the compression probe away from sample, Cohesiveness = ratio of area under second compression to area under first compression, Springiness = Height that the food recovers during the time that elapses between the end of the first compression and the start of the second bite, Chewiness = hardness X cohesiveness X springiness

Sensory characteristics of the cooked rice kernels

Quantitative Descriptive Analysis (QDA) was used in sensory evaluation. Color, abnormal aroma, texture characteristic (hardness, adhesiveness, cohesiveness and chewiness) and overall acceptance test were evaluated using a ten-point intensity rating scale. Fifteen-grams of each cooked sample were served. Each panelist received

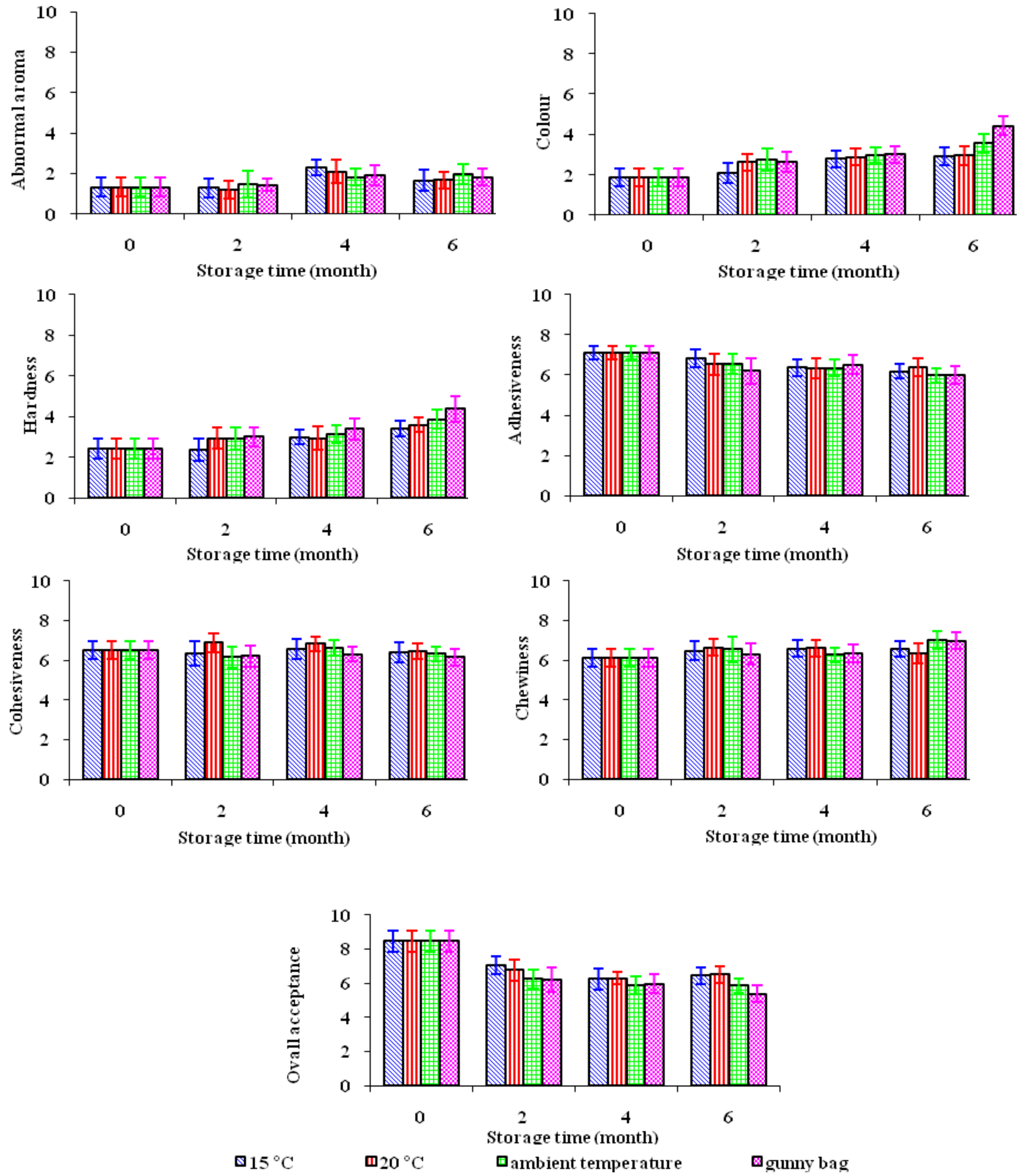

Fig 4. Sensory evaluation score by QDA of glutinous rice cultivar RD 6 under various storage conditions.

one sample at a time. Temperature of each served sample was approximately 40-50°C. Eight trained panelists were both male and female aged 23-30 years old. Factorial in Randomized Completely Block Design (RCBD) was used in this part of the experiment. All analyzes were run in duplicate. Analysis of variance was performed. The differences of means were reported at 5% significance level using Duncan's New Multiple Range Test.

Statistical analysis

Statistical analysis was conducted using analysis of variance (ANOVA). Significant calculated mean values were compared using Duncan's New Multiple Range Test at 5% significance level.

Results and discussion

Changes of disulfide linkages in protein

Disulfide linkages are shown in the IR adsorption band at wave number of 400 cm^{-1}. The ratio of absorbance height expresses the changes of disulfide linkages during storage period compared with the structure of starch that was not change during storage. The IR adsorption band at 1047 cm^{-1} is characteristic of crystalline starch and the band at 1022 cm^{-1} is characteristic of amorphous starch (Li et al., 2008;

Yang and Tao, 2008). From the results it was found that the IR adsorption band at 1022 and 1047 cm^{-1} was not changing during storage. The changes of disulfide linkages of glutinous rice cultivar RD 6 in various storage conditions for 6 months are shown in Figure 3. The measurements show that the paddy stored in gunny bags had an increase of disulfide linkages greater than in the ambient temperature, 20°C and 15°C conditions, respectively. However, the increase of disulfide linkages was not different by storage conditions (p>0.05). Disulfide linkages were significantly increased by storage duration (p≤0.05). The increase of disulfide linkages is caused from a reaction between protein and oxygen (Juliano, 1985). Chrastil (1990) reported that oryzenin was the abundant component of protein in rice. Parts of the cysteine (-SH) of oryzenin were oxidized to cystine (-SS-) during storage. The thiol (-SH) group would be oxidized easily by oxygen leading to an increase of disulfide linkages. Then, oryzenin interacted with starch by binding to amylopectin and amylose. Therefore, increasing the amount of disulfide linkages could further retard the water absorption and swelling of starch granules leading to the decrease of cooked rice adhesiveness.

Thermal properties

Thermal properties of glutinous rice flour under various storage conditions for 6 months are shown in Table 1. The results of storage temperature in all four storage conditions show that T_o, T_p and T_c had a slight increase after 6 months. This is due to the interaction of chemical compositions in rice: starch, protein and fat enhance the strength of starch granules which retard the water absorption of starch granules. This resulted in the higher temperature of starch granules followed by swelling and gelatinization (Teo et al., 2000; Iturriaya et al., 2004). Storage temperature in all four storage conditions had a significant effect on ΔH_{gel} (p≤0.05). The ΔH_{gel} slightly increased at all storage conditions and the paddy stored in gunny bags had higher ΔH_{gel} than the paddy stored at 15°C, 20°C and ambient temperature. This might be caused from chemical compositions, fat and protein in the rice kernel during storage changed which affected molecules in the starch granules, such as amylopectin, so the structure was stronger. Higher heat was used to break even more crystal structures (Zhou et al., 2003). A previous study by Fan and Mark (1999) reported that paddy variety Bengal was stored at 4, 21 and 38 °C after 16 weeks, the ΔH_{gel} was increased when the storage temperature and storage time increased.

Textural properties

The important parameters for evaluating the texture of the cooked rice were hardness, adhesiveness, cohesiveness and chewiness. Texture properties of cooked rice are illustrated in Table 2. The results found that the hardness of cooked rice obtained from paddy stored at ambient temperature was higher than that stored in gunny bags, at 15°C and 20°C, respectively. The hardness of cooked rice was increased with storage duration. This might be from an increase of disulfide linkages in protein causing the starch granules in rice kernels to become stronger (Chrastil, 1990). Once the starch granule become stronger it could retard the water absorption during cooking leading to an increase in hardness. Adhesiveness was slightly decreased. The paddy stored at 15°C had the least change but not significantly different (p>0.05). Cohesiveness slightly increased during storage times (p≤0.05). Chewiness increased but was not significantly different among all storage conditions (p>0.05). The paddy stored at ambient temperature had chewiness values higher than the value of paddy stored in gunny bags, 15°C and 20°C, respectively. During a two month period, the chewiness was similar to that of fresh rice but then increased during a 4-6 month period.

Sensory evaluation of the cooked rice kernels

Quantitative descriptive analysis (QDA) scores for sensory evaluation of cooked rice stored under different conditions after 6 months are shown in Figure 4. For the color assessment, the results indicate that the storage conditions had a significant effect on cooked rice (p≤0.05). The paddy stored in gunny bags had a yellowing color more than the paddy stored at ambient temperature, 15°C and 20°C respectively. Also, the yellowing increased with the storage duration. This change of color is attributed to non-enzymatic browning, which corresponded to the report by Soponronnarit et al. (1998) that the storage temperature influenced the yellowing of paddy. For the aroma, the paddy stored at ambient temperature and in gunny bags had more of an abnormal aroma than the paddy stored at 15°C and 20°C. For the texture of cooked rice, the panelist assessed hardness, adhesiveness, cohesiveness and chewiness. The panelists noticed an increase of hardness and chewiness during storage. The paddy stored in gunny bags had the higher hardness and chewiness than that stored at 15 and 20 °C. These results corresponded with the findings from a texture profile analysis. For the adhesiveness and cohesiveness, the trend of these values was a slight decrease after 6 months of storage. Storage at 15°C and 20 °C can preserve adhesiveness and cohesiveness better than the other conditions. For the overall acceptance score**,** panelists significantly accepted paddy, which was stored at 15°C and 20°C, more than stored at ambient temperature and in gunny bag (p≤0.05). Increasing of storage duration led to a significant decrease of overall acceptance (p≤0.05).

Conclusion

The effects of storage conditions on the properties and quality of glutinous rice cultivar RD 6 were investigated. The results show that the changes of disulfide linkages in protein was significantly different by storage time (p>0.05). Thermal properties were measured by using DSC and found that T_o, T_p and T_c at all storage conditions increased. The paddy stored in gunny bags had the higher ΔH_{gel} than that stored at 15°C, 20°C and ambient temperature after 6 months storage. The texture properties analysis of cooked glutinous rice by TPA method showed that all paddy samples had an increase of hardness, cohesiveness and chewiness, while adhesiveness decreased after 6 months storage. The paddy kept at ambient temperature and in gunny bags had the greatest change of texture properties. Sensory evaluation of cooked rice by trained panelists assessing hardness, adhesiveness, cohesiveness and chewiness gave similar results to the measuring tool. The panelists identified the yellowing color and abnormal aroma of cooked rice from paddy stored at ambient temperature and gunny bags. The paddy stored at 15°C and 20°C had the least change of texture properties, and panelists accepted the cooked rice from these conditions more than they accepted that stored in ambient temperature and gunny bags. The storage duration led to a decrease of overall acceptance score.

Acknowledgements

The authors express their sincere appreciation to the Commission on Higher Education and the Thailand Research Fund (TRF) for supporting this study financially.
The authors thank to Associate Professor Dr. Adisak Nathakaranakule and Faculty of Energy and Materials, King Mongkut's University of Technology Thonburi, Thailand for providing an access to support in the laboratory.

References

Chang YH, Lin JH (2006) Effect of molecular size and structure of amylopectin on the retrogradation thermal properties of waxy rice and waxy corn starch. Food Hydrocolloids 21: 645–653

Chrastil J (1990) Protein-starch interaction in rice grains. Influence of storage on oryzanin and starch. J Agric Food Chem 38:1804-1809

Fan J, Marks BP (1999) Effects of rough rice storage conditions on gelatinization and retrogradation properties of rice flours. Cereal Chem 75: 894-897

Gujral HS, Kumar V (2003) Effect of accelerated aging on the physicochemical and textural properties of brown and milled rice. J Food Eng 59: 117–121

Iturriaya L, Lopez B, Anon M (2004) Thermal and physicochemical characterization of seven argentine rice flours and starches. Food Res Int 37: 439-447

Juliano BO (1985) Rice: Chemistry and Technology. 2d ed., American Association of Cereal Chemists, St. Paul, Minnesota.

Li Y, Shoemaker CF, Ma J, Moon K, Zhong F (2008) Structure-viscosity relationships for starches from different rice varieties during heating. Food Chem 106: 1105–1112

Ma Y, Sun D (2008) Hardness of cooked rice as affected by varieties, cooling methods and chill storage. J Food Process Eng 32(2): 161-176

Meullenet J, Marks BP, Griffin VK, Daniels MJ (1999) Effects of rough rice drying and storage conditions on sensory profiles of cooked rice. Cereal Chem 76(4): 483-486

Pearce MD, Marks BP, Meullenet JF (2001) Effects of postharvest parameters on functional changes during rough rice storage. Cereal Chem 78(3): 354-357

Phillips S, Widjaja S, Wallibridge A, Cooke R (1988) Rice yellowing during postharvest drying by aeration and during storage. J Stored Prod Res 24:173-181

Ranalli RP, Howell TA, Siebenmorgen TJ (2003) Effects of controlled ambient aeration on rice quality during on-farm storage. Cereal Chem 80:9-12

Soponronnarit S, Srisubati N, Yoovidhya T (1998) Effect of temperature and relative humidity on yellowing rate of paddy. J Stored Prod Res 34(4): 323-330

Teo CH, Karim AA, Cheah PB, Norziah MH, Seow CC (2000) On the roles of protein and starch in the aging of non-waxy rice flour. Food Chem 69: 229–236

Widjaja R, Craske JD, Wootton M (1996) Changes in volatile components of paddy, brown and white fragrant rice during storage. J Sci Food Agr71: 218-224

Wongpornchai S, Dumri K, Jongkaewwattana S (2004) Effect of dryings and storage time on the aroma and milling quality of rice (*Oryza sativa L.*) cv. Khao Dawk Mali 105. Food Chem 87: 407-414

Yang Y, Tao W (2008) Effects of lactic acid fermentation on FT-IR and pasting properties of rice flour. Food Res Int 41: 937-940

Zhou Z, Robards K, Helliwell S, Blanchard C (2002) Ageing of stored rice: changes in chemical and physical attributes. J Cereal Sci 35: 65-78

Zhou Z, Robards K, Helliwell S, Blanchard C (2003) Effect of rice storage on pasting properties of rice flour. Food Res Int 36: 625-634