International Journal of Agricultural Technology 2016 Vol. 12(6):1113-1124
Available online http://www.ijat-aatsea.com
ISSN 2630-0192 (Online)

Effects of Materials Used for Storage on Physical and Chemical Properties of Rice

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Somporn, C., Bangnoo, P. and Srichamnong, W. (2016). Effects of materials used for storage on physical and chemical properties of rice. International Journal of Agricultural Technology 12(6):1113-1124.

Abstract The study was conducted on the effects of storage materials, plastic and mesh bag for storing Thai paddy and husked rice grain: glutinous rice (RD6 and Lao Taek) and non glutinous rice (Jasmine 105) for 3 months, on the physical and chemical properties of paddy rice and husked rice. Weight of paddy rice and husked rice stored in plastic bag can be maintained better than the case of mesh bag. For quality of color, Jasmine 105, glutinous rice varieties RD6 and Lao Taek stored in mesh bag had lightness (L^*) value greater than plastic bag. In yellow color (b^*), rice stored in plastic bag had higher b^* value. Different storage materials were found to affect chemical properties of rice in terms of moisture content which is also unstable as it is a function of atmosphere. Rice stored in plastic bag had lower moisture content than that stored in mesh bag but not statistically significant across the three varieties of rice. On water uptake, both plastic and mesh bags were found not statistically significant in this capacity to affect all three rice varieties. Similarly the cooking quality of rice in terms of weight was not affected at significantly different level by the choice of storage material.

Keywords: Rice; physical properties; chemical properties; cooking quality

Introduction

Rice (*Oryza sativa* L.) is carbohydrate food, which provides energy to body. Moreover, it has lysine that is an essential amino acid. More than half of people in the world consume rice as the staple food especially, Asian. Asia produces approximately 90% of the world's rice Thailand is one of the leading rice producing countries in Asia and the second major Asian rice exporter behind India Thailand has exported about 40 % of its rice output each year and more recently Jasmine rice has constituted the major portion of its export (FAO, 2016; Office of Agricultural Economics, 2005).Apart from milled rice, Thailand also processes broken rice into such products as flour and starch. Rice

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flour is further processed into various products in traditional Asian culture such as Japanese Moji, Chinese noodle, and Vietnamese dough sheet. In addition, rice flour also has industrial use, for instance, as substrate for coating cloth, as emulsifier, and simply as an ingredient of face or body powder and in medical products. However, consumers and buyers of cooked rice and rice products as well as users of rice raw material as one of the ingredients in industrial production invariably are particular with the appropriate quality of rice and rice flour for their specific purposes. Different rice varieties are different in quality and properties which is a function of amylose content in rice and age of rice. The International Rice Research Institute (IRRI) classifies rice according to cooked rice characteristics into 4 kinds as affected by the amylose content namely very low amylose rice with amylase content less than 1.0% which will give very sticky cooked rice, low amylose rice with content less than 10% giving rather sticky cooked rice, medium amylose rice with content in the range of 10-25 % giving rather crumbly cooked rice, and high amylase rice with content more than 25% which makes cooked rice very crumbly and hard. Thai rice varieties can be distinguished into three groups (IRRI, 1980; Genkawa *et al*., 2008; Zhang *et al*., 2012) including the low amylose sticky rice such as RD6 and San-pah-tawng varieties, the medium amylose rice such as Khao Dawk Mali 105, Phisanulok1, Phatum Thani1, RD 15 and Sungyod rice, and the high amylose rice such as Phisanulok2, Suphan Buri90, Suphan Buri1 and Leuang Patew. Rice with low amylose content will be tender when cooked whereas that with high amylose content when cooked will become hard upon cooling. A survey on customers demand found the respondents like to consume sticky rice that has been stored for less than six months as the cooked rice will be gummy and has good smell, whereas they preferred consuming Jasmine rice that has been stored for 1-2 years as the rice will be soft and not watery when cooked. High amylase rice tends to be consumed around six months after harvest because the cooked rice will have good elongation. In industrial sector, manufacturer of flour and starch always mix broken rice of approximately 2-4 varieties for controlling desirable properties of the products (Butsatand Siriamornpun, 2010; Gariwait *et al*., 2006).

Changing properties of rice between storage depend on time, temperature and storage method. Rice stored at high temperature for long time would change as old rice faster than at low temperature due to interaction among components of rice such as starch, protein, and lipid. Rancidity odor in rice is caused by oxidation of fatty acid to unusual smell compounds. Old rice when cooked has crumbly texture and it takes longer cooking time than newly harvested rice due to protein changing at starch surface in storage. (Butsat and Siriamornpun, 2010) Amylose and lipid of long storage rice will change into amylose-lipid complex during cooking (Zhou *et al*., 2002). In addition, the problems in long time storage of rice include snout weevil, ant, rat, moisture, storage area, and management cost. However, different rice varieties will face different changes in various properties not only because of different storage time and method but also the fact that there is a difference in amylose content and in interaction among starch, protein, and lipid components of the rice. Therefor, this research determined of three varieties of Thai paddy and milled rice grain: glutinous rice (RD6 and Lao Taek) and non glutinous rice (Jasmine 105) for a comparative study on quality of rice stored in different methods. Specifically this research is aimed to study effects of storage materials on properties of rice such as weight, color, moisture content, water uptake, and cooking quality to identify suitable storage materials for different classifications of rice.

Materials and methods

Rice samples three varieties of Thai paddy and milled rice grain: glutinous rice (RD6 and Lao Taek) and non glutinous rice (Jasmine 105) were used in this study. All three varieties were freshly harvested in Roi Et province area.

Figure 1. glutinous rice (RD6)

Figure 2. non glutinous rice (Jasmine 105)

Figure 3. glutinous rice (Lao Taek)

Storage conditions

The paddy rice was packed in polypropylene bags (10 kg per bag) and stored for three months (storage duration before harvest a new crop) in room temperature (30±5^{o}C) in plastic and mesh bags at Roi Et Rajabhat University, Thailand.

Physical analysis

100 kernel weight

100 seeds of paddy rice and husked rice were counted randomly in triplicate and weighed separately. Mean of three replications was reported.

Color analysis

Color analysis was carried out on husked rice using a tristimulus colorimeter (Chromameter-2 CR-300, Minolta, Osaka, Japan). The instrument was standardized on a white tile before each sample measurement. The color parameters corresponding to the uniform color space CIELAB (1986) were obtained directly from the apparatus. Within the approximately uniform space CIELAB, 2 chromaticity coordinates *a** and *b** as well as lightness *L** are defined. Coordinate *a** takes positive values for reddish colors and negative values for greenish ones whereas *b** takes positive values for yellowish colors and negative values for bluish ones. *L** parameter is an approximate measurement of lightness taking values within the range of 0 (black) and 100 (white) (Kim *et al*., 2000).

Preparation of husked rice

The cooked rice was prepared as described by Kim*et al* (2000). The husked (800 g) was washed using rice cleaner (PR-7J, Aiho, Tokyo, Japan) to prevent the experimental errors. After washing rice, 1.45× water to husked (w/w) with 14% moisture content was added. Rice was cooked using a rice cooker (SJ-185R, Samsung Electrics, Suwon, Korea) and husked was held for 10 min after cooking.

Moisture content

Chemical properties analysis Moisture content was determined using the Approved Method 44-15A. (AACC, 2000)

Water uptake ratio

Husked rice samples (2 g) for each cultivar were cooked in 20 ml distilled water for a minimum cooking time in a boiling water bath. The contents were drained and the superficial water on the cooked rice was sucked by pressing the cooked samples in filter paper sheets. The cooked samples were then weighed accurately and the water uptake ratios were calculated (Juliano and Bechtel, 1985).

Cooking quality analysis

Optimum cooking time was found out for husked rice by Ranghino test (Juliano and Bechtel, 1985). In a 250 ml beaker, about 100 ml-distilled water was boiled (98 ± 1 ^{o}C) and 5 g of samples dropped into it. Measurement of cooking duration was started immediately. After 10 min and every minute thereafter, 10 grains of husked rice were removed and press between two clean glass plates. Cooking time was recorded when the least 90% of the grains no longer had opaque core or uncooked centers. The rice was then allowed to simmer for about another 2 min to ensure that the core of all grains had been gelatinized. Optimum cooking time included the additional 2 min of simmer. Volume expansion ratio, length expansion ratio, and water uptake ratio, were determined by cooking 1 g of the husked rice in 15 ml boiling water, till optimum cooking time. Volume expansion ratio, length expansion ratio, water uptake ratio, were determined by cooking 1 g of the husked rice in 15 ml boling water, ill optimum cooking time (Juliano and Bechtel,1985). Length expansion ratio as ratio of length of cooked grain to that of the raw grain was calculated.

Statistical analysis

The experiment was set up in a completely randomized design. Analysis of variance was performed on the data, and significant differences among treatment means were calculated by Duncan's multiple range test (DMRT) ($p <$ 0.05).

Results

Results of changing physicochemical properties of paddy rice varieties: glutinous rice (RD6 and Lao Taek) and non glutinous rice (Jasmine 105) those were stored in plastic and mesh bags for 3 months.

Physical properties

Weight (100 seeds)

The results show the 100 seeds weights of paddy rice stored in plastic bags to be the highest 2.751 g for RD6, 2.725 g for Lao Taek rice, and the lowest 2.605 g for Jasmine 105. The highest weight of milled rice was RD6 1.961 g then followeds by Jasmine 105, and the lowest weight was Lao Taek 1.876 g. Apparently all three rice varieties stored in plastic bag could maintain weight quality better than in mesh bag (Table 1). Weights of three rice varieties were significantly different but weights of three rice varieties stored in different materials were not significantly different.

Table 1. Weights of 100 seeds paddy rice and husked rice of Jasmine 105, RD6 and Lao Taek varieties those were stored in plastic and mesh bags**.**

Conditions	**Paddy rice weight** (g/100 grain)	**Husked rice weight** (g/100 grain)
Jasmine 105 rice +plastic bag	2.490[c]	1.906[ab]
Jasmine 105 rice + mesh bag	2.720[ab]	1.763[c]
RD6 rice+plastic bag	2.748[ab]	1.961[a]
RD6 rice+ mesh bag	2.775[a]	1.888[ab]
Lao Taek rice+plastic bag	2.755[ab]	1.876[ab]
Lao Taek rice+ mesh bag	2.675[b]	1.810[bc]
F	**	**
Rice varieties		
RD6 rice	2.751[a]	1.925[a]
Lao Taek rice	2.725[a]	1.843[b]
Jasmine 105 rice	2.605[b]	1.835[b]
F	*	*
Package		
Plastic bag	2.749[a]	1.960
Mesh bag	2.638[b]	1.775
F	**	ns

ns is not significant difference. Different letters in the column indicate significant differences.
*,** significant and highly significant at the 0.05 and 0.01 probability levels, respectively.

Brightness properties *L red value *a** and yellow *b****

Color change in rice of Jasmine 105, RD6 and Lao Taek varieties that were stored in plastic and mesh bags at room temperature for 3 months.

From analysis of color of 3 rice varieties, it was found that the lightness content of RD6 was the highest 20.837 followed by Lao Taek 16.988and Jasmine 105 was the lowest 15.555. The quality of *a** of 3 rice varieties that were kept in different packaging materials was not significantly different. The part of *b** quality found that sticky rice had the highest yellow color 9.018 followed by Jasmine 105 7.910 and Lao Taek 7.385, respectively as shown in Table 2. Mesh bag was the most suitable for retaining color quality at significantly different level ($p \leq 0.01$). In addition, all package materials did not affect the red content (*a**) of 3 rice varieties which are not significantly different ($p \leq 0.01$). This result was consistent with that of Butsat and Siriamornpun (2010) who found that dark brown color on rice came from mallard reaction which is a non-enzymatic browning reaction. Mallard reaction produces melanoid that shows brown color therefore the rice is dark in color.

Table 2. light content (*L**), red content (*a**) and yellow content (*b**)of 3 rice varieties stored as paddy for 3 months in plastic bag and mesh bag.

conditions	***L****	***a****	***b****
Jasmine 105 rice +plastic bag	16.092 [c]	0.625	8.136 [abc]
Jasmine 105 rice + mesh bag	15.018 [c]	0.640	7.685 [bc]
RD6 rice+ plastic bag	21.402 [a]	0.561	9.168 [a]
RD6 rice+ net bag	20.343 [ab]	0.603	8.868 [ab]
Lao Taek rice+ plastic bag	16.772 [c]	0.505	7.466 [bc]
Lao Taek rice + mesh bag	17.203 [bc]	0.330	7.305 [c]
F	**	ns	**
Varieties			
RD6 rice	20.837 [a]	0.582	9.018 [a]
Lao Taek rice	16.988 [b]	0.417	7.385 [c]
Jasmine 105 rice	15.555 [c]	0.623	7.910 [b]
F	**	ns	**
package			
plastic bag	15.607 [b]	0.375	6.927 [b]
mesh bag	20.003 [a]	0.738	9.282 [a]
F	**	ns	**

** Highly significant at the 0.01 probability levels, ns is not significantly different.
Different letters in the column indicate significant differences.

Chemical properties

Moisture content

From analysis of effect on the moisture content of 3 rice varieties from keeping in different types of packageplastic bag and mesh bagfor 3 months, it was found that the moisture content of all rice varieties had reduced from the levels before storage. The moisture content of rice kept in mesh bag was lower than that in plastic. But statistical analysis showed that the package materials did not affect the moisture content of rice, which is not significantly different.(Table 3) Rice can exchange the moisture with atmosphere therefore the moisture content in rice changes following atmosphere.(Zhang *et al*., 2012) The loss of moisture content in rice during storage is due to atmospheric factor.

Table 3. the moisture content of paddy riceand milled riceafter paddy storage for three months.

Conditons	**Moisture content of paddy (% dry basis)**	**Moisture content of milled rice (% dry basis)**
Jasmine 105 rice+plastic bag	14.483	14.438
Jasmine 105 rice+mesh bag	14.467	14.343
RD6 rice+ plastic bag	14.403	14.540
RD6 rice+ net bag	14.385	14.425
Lao Taek rice+ plastic bag	14.451	14.431
Lao Taek rice + mesh bag	14.405	14.315
F	ns	ns
Varieties		
RD6 rice	14.394	14.482
Lao Taek rice	14.428	14.373
Jasmine 105 rice	14.480	14.390
F	ns	ns
package		
plastic bag	14.324	14.259
mesh bag	14.543	14.571
F	ns	ns

ns is not significantly different

Water uptake ratio

The water uptake ratio was studied by soaking rice for a period of 16 hours at room temperature. This condition explains available water absorption by hydration, which is used for measuring the quality of rice. The results of water absorption of 3 rice varieties after storing in different storage materials for 3 months displayed the highest water absorption in the case of RD6 (2.819 g) followed by Lao Taek (2.736 g)and Jasmine 105 (2.585 g) as shown in Table 4. In addition, both storage materials mesh bag and plastic bagdid not affect the ratio of water uptake ratio.

Table 4. water uptake ratios of 3 rice varieties consisting of Jasmine 105, RD6 and Lao Taek after storing in plastic bag and mesh bag.

conditions	**water uptake ratio (%dry basis)**
Jasmine 105 rice+plastic bag	2.530[d]
Jasmine 105 rice+mesh bag	2.641[cd]
RD6 rice+ plastic bag	2.881[a]
RD6 rice+ net bag	2.756[b]
Lao Taek rice+ plastic bag	2.740[bc]
Lao Taek rice + mesh bag	2.786[ab]
F	**
Varieties	
RD6 rice	2.819[a]
Lao Taek rice	2.736[b]
Jasmine 105 rice	2.585[c]
F	**
package	
plastic bag	2.727[a]
mesh bag	2.717[a]
F	**

** Highly significant at the 0.01 probability levels.
Different letters in the column indicate significant differences.

Cooking quality analysis

As indicated by Table 5, optimum cooking time, the results showed that the Lao Taek, RD6, and Jasmine 105 had weight increase from the beginning to the levels of 2.765 g, 2.745 g, and 2.580 g respectively. When analyze statistically, increase in weight of Lao Taek, RD6 was not significantly different. In addition, the rice stored in plastic bag could increase weight ratio of rice more than mesh bag. The quality of cooking methods related to absorption of water which slightly changed. Therefore, the cooked rice had weight not significantly different.

Table 5. The cooking quality of 3 rice varietiesLao Taek, RD6 and Jasmine 105 after paddy storge for three months.

conditions	**The ratio of cooked rice gain (%dry basis**)
Jasmine 105 rice+plastic bag	2.435
Jasmine 105 rice+mesh bag	2.725
RD6 rice+ plastic bag	2.748
RD6 rice+ mesh bag	2.741
Lao Taek rice+ plastic bag	2.775
Lao Taek rice + mesh bag	2.755
F	ns
Varieties	
RD6 rice	2.745
Lao Taek rice	2.765
Jasmine 105 rice	2.580
F	ns
package	
plastic bag	2.921
mesh bag	2.742
F	ns

ns is not difference significant.

Discussion

Study on the effect of storage materials for 3 months storage on weight of rice kernel of three rice varieties revealed that plastic bag was the better option. In addition, RD6 had the highest weight (2.751 g) followed by Lao Taek (2.725g) and jasmine 105 (2.675 g) respectively.On the effect on color of 3 rice varieties (Lao Taek, RD6, and Jasmine 105), this research showed that plastic bag could retain the quality more than mesh bag. The rice with high lightness content will be white and clear and in contrast low lightness will cause the rice to look dark which is not acceptable by consumers. The part of red color content, three rice varieties were not significantly different. The *b** content is yellow and blue color; plus *b** is yellow color opposite minus *b** is blue color. Therefore cause of dark rice while storage is probably a non-enzymatic browning reaction as suggested in research by Cao *et al*. (2009); Meullenet *et* *al*., (2000); Park *et al*., (2012) The research found that the white color of rice stored less than 3 months was not significantly different ($p > 0.05$) .

As for moisture content of Jasmine 105, RD6 and Lao Taek, mesh bag appeared to retain moisture in rice more than plastic bag because kernel rice could exchange the moisture content with water uptake and the moisture content varies with weather condition. From water uptake ratios of all 3 rice varieties (Jasmine 105, RD6 and Lao Taek), plastic bag had demonstrated greater water uptake ratio than mesh bag. The extent of water uptake varies with the moisture content of paddy rice during storage. The results are in consonance with the findings of Cao *et al*.,(2009); Meullenet *et al*., (2000); Park *et al*., (2012) in that the water uptake ratios of all rice varieties in different packaging materials were not significantly different ($p > 0.05$). On the effect on cooking quality of rice of all 3 rice varieties rice (Jasmine 105, RD6 and Lao Taek), the results of experiment revealed that rice stored in plastic bag when cooked will have higher weight than the case of the otherwise storage material. The cooking quality is however stable in tendency because the weights of cooked rice were not significantly different.

Acknowledgement

The research project is fully supported by Roi Et Rajabhat University, Thailand.

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(Received: 7 July 2016, accepted: 31 October 2016)