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Research Article

Effect of rice storage on pasting properties, swelling and granular morphology of rice flour

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Abstract

Storage of rice is a normal step between harvest and consumption. This study investigated the effect of rice storage on pasting properties, thermal properties, swelling and granular morphology of milled rice cultivar 'Khao Dawk Mali 105' (KDML 105). Rice grains of freshly harvested and aged for twelve months were used in this study. The rice samples were milled, ground to flour and sieved. Storage of rice produced changes in pasting properties as a significant decrease in peak viscosity and breakdown but an increase in final viscosity, setback and pasting temperature. Results from differential scanning calorimeter revealed that aged rice had higher peak temperature and gelatinization enthalpy than fresh rice. On the other hand, swelling value of fresh rice flour was higher than aged rice. This result was related to starch granule morphology after heating in which fresh rice had a larger size than that of aged rice. Both results of granular morphology and swelling values explained a decrease in peak viscosity and an increase in final viscosity. Storage of rice influences property changes namely; the swelling of starch granule, pasting properties and thermal properties of rice. The findings of this study can be applied to improve the quality of cooked rice.

Keywords: thermal properties, viscosity, starch, Thailand.

Introduction

Rice has been the main staple and the main export product of Thailand for centuries. The most popular rice is the Khao Dawk Mali 105 (KDML105) variety because of good consumption quality and good flavour.

Quality of cooked rice depends on many factors. One of these factors is storage, which is a step between harvest and consumption. The changes during storage have been reported to be greater in non-waxy rice than waxy rice [1]. Three months of storage is regarded as the minimum period for major changes to occur in the hardness of cooked rice, gel consistency and amylograph viscosity values [2]. The starch content is not affected by storage [3]. Several researchers reported that peak viscosity and breakdown of fresh rice was higher than aged rice [4, 5, 6, 7]. Teo *et al.* [8] found that the thermal properties of purified rice starch remained unchanged upon storage and concluded that the non-starch constituents, particularly protein, were responsible for the increased gelatinization temperature and enthalpy in rice flour. For the textural properties, freshly harvested cooked rice is generally softer and stickier than that from aged rice [4, 7, 9] and the soft and sticky rice is generally preferred by Thai people [7]. During storage of rice, the number of disulfide bonds and the average molecular weight of oryzenin, which is a major protein in rice, increased [10]. Hamaker and Graffin [11] reported that protein with disulfide bonds in the rice flour restrict starch granule swelling during gelatinization and make the swollen granule less susceptible to disruption by shear. Therefore, the changes in physicochemical and textural properties of aged rice have been associated with the protein content [6].

An understanding of the changes in physicochemical properties during aging of rice provides important data that can be useful to improve the quality of cooked rice. Therefore, the objective of this study was to describe the changes in some physicochemical properties of milled rice, i.e. pasting properties and thermal properties. Moreover, swelling value and granular morphology of rice flour were also examined.

Materials and Methods

Materials

Milled rice of Khao Dawk Mali 105 (KDML 105) cultivar of freshly harvested and aged for twelve months were used in this study. Samples were packed in nylon pouches under vacuum and stored at 15°C. The samples were ground and passed through a 100-mesh sieve screen for analysis.

Swelling value

The method adopted by Nor Nadiha *et al.* [12] was used to determine swelling value of rice flour. Rice flour (0.4 g, dry basis) was accurately weighed in a centrifuge tube prior to the addition of 40 ml of distilled water. The suspension of rice flour was heated at 65, 75 and 85°C for 30 min. Subsequently, samples were cooled to room temperature and the solution was centrifuged at 3,000 g for 15 min. The measurements were performed in two replicates. The swelling value was calculated as follows:

$$\text{Swelling value (g/g)} = \frac{\text{Weight of the wet sediment (g)}}{\text{Weight of the dry flour (g)}} \times 100$$

Granular morphology

The suspension of rice flour was prepared by mixing rice flour with water in a ratio of 1:1. The samples were centrifuged at 2,500 g for 20 min. Next, the supernatant was removed. The water was added to the precipitate and the centrifugation was repeated. The precipitate was collected and dried with a hot air oven at 40°C overnight. Dry flour was ground and passed through a 100-mesh sieve screen. This method facilitates clear observation of granular morphology because the composition other than starch such as protein and lipids in rice flour were partially removed. Rice flour suspensions (8% w/w) were heated in a water bath with stirrer at 65, 75 and 85°C for 30 min. Following this, the starch granules were stained with iodine solution and observed with a light microscope at 40x magnification.

Pasting properties
A Rapid Visco Analyzer (RVA3D, Newport Scientific Instrument & Engineering, Australia) was used to study the pasting properties of the flour samples. The pasting viscosity profile was examined using Approved Method 61-02 [13]. All measurements were performed in two replicates.

Thermal properties
The gelatinization properties of flour were analyzed using a differential scanning calorimeter (DSC, Pyris-1, Perkin Elmer, Norwalk, CT, USA). Rice flour suspension (6 mg, dry basis) at 70% moisture content was prepared in stainless steel pan. Samples were hermetically sealed and allowed to stand for 1 h at room temperature (25 ± 2°C) before heating in DSC. The empty stainless steel pan was used as a reference. The samples were heated at a rate of 10°C/min from 25°C to 140°C [14]. All measurements were performed in two replicates.

Statistical analysis
A completely randomized design was used. The difference between means was determined using the Duncan's new multiple range test. All statistical analyses were performed using SPSS 12.0 for Windows.

Results and Discussion

Swelling value
The swelling value shows the hydration characteristics of rice starch granules. Rice flour from fresh rice had higher swelling value than that of aged rice both at 65 and 75°C (Table 1). Similar findings were reported by Bolling *et al.* [15]. These indicated that starch granules of aged rice were more resistant to swelling than those of fresh rice. This property was probably due to effect of rice storage, the molecular weight of oryzenin increased significantly, which correlated with an increase in disulphide bonding [12, 16, 17]. However, the swelling value of fresh and aged rice flour was not significantly different ($P \geq 0.05$) at 85°C because the starch granules of fresh rice were disrupted.

Table 1. Swelling value (g/g) of rice flour with two storage durations after heating at 65, 75 and 85°C.

Storage duration (months)	Temperature (°C)		
	65	75	85
0	$10.63^{aB} \pm 0.06$	$11.57^{bB} \pm 0.07$	$10.53^{aA} \pm 0.22$
12	$8.66^{aA} \pm 0.06$	$10.63^{bA} \pm 0.06$	$10.95^{bA} \pm 0.43$

$^{a-b}$: means with different letters in the same row are significantly different ($P < 0.05$)
$^{A-B}$: means with different letters in the same column are significantly different ($P < 0.05$)

Granular morphology
The light microscopic images of rice starch granules heated at 65, 75 and 85°C for 30 min are shown in Figure 1. The result showed that starch granule sizes increased with increasing heating temperature of both samples. However, fresh rice flour had larger granule sizes than those of aged rice, in particular at 85°C. This result is clearly seen in the incidence of the higher swelling value of fresh rice.

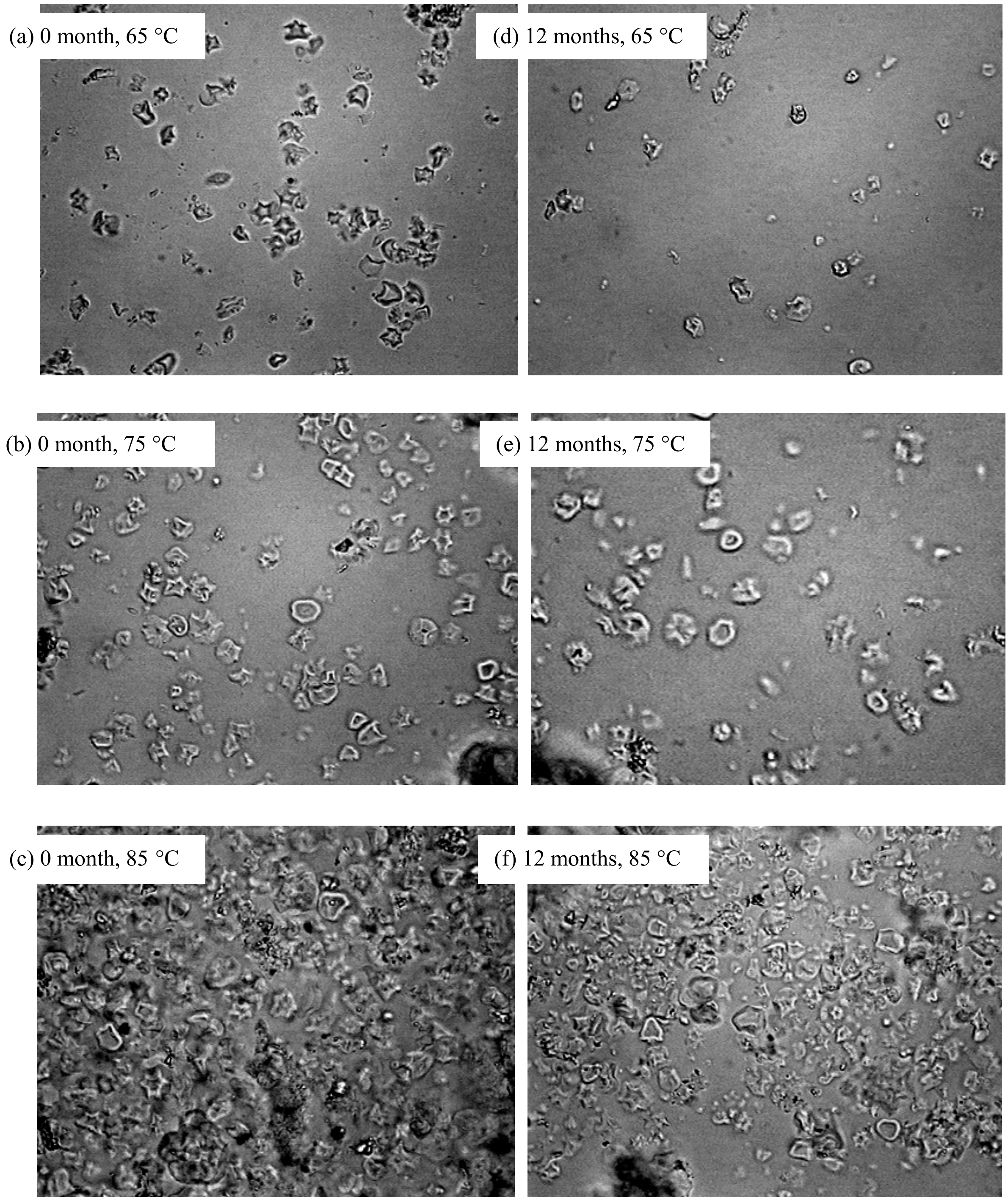

Figure 1. Light microscopic images of rice starch granules of KDML 105 after heating at 65, 75 and 85°C, (a-c) and (d-f) were samples aged for 0 and 12 months, respectively.

Pasting properties

Pasting properties of milled fresh and aged rice flour are shown in Figure 2. From the RVA analysis, the samples showed significant decreases in peak viscosity and breakdown after being aged. The change in some of the pasting properties during aging can be attributed to starch granule characteristics. The decrease in peak viscosity during aging of rice showed that the starch granules of aged rice were more resistant to swelling than that of fresh rice. The change in breakdown indicated that the capacity of the starch granules to rupture after cooking was reduced significantly by aging of the starch granules [4, 5, 6, 7]. However, the final viscosity and setback increased with increasing rice storage duration. These results were due to the strong granules after storage, so some starch granules were not disrupted after cooking. Final viscosity and setback may occur by rearrangement of leached amylose and of the granules which have not been disrupted.

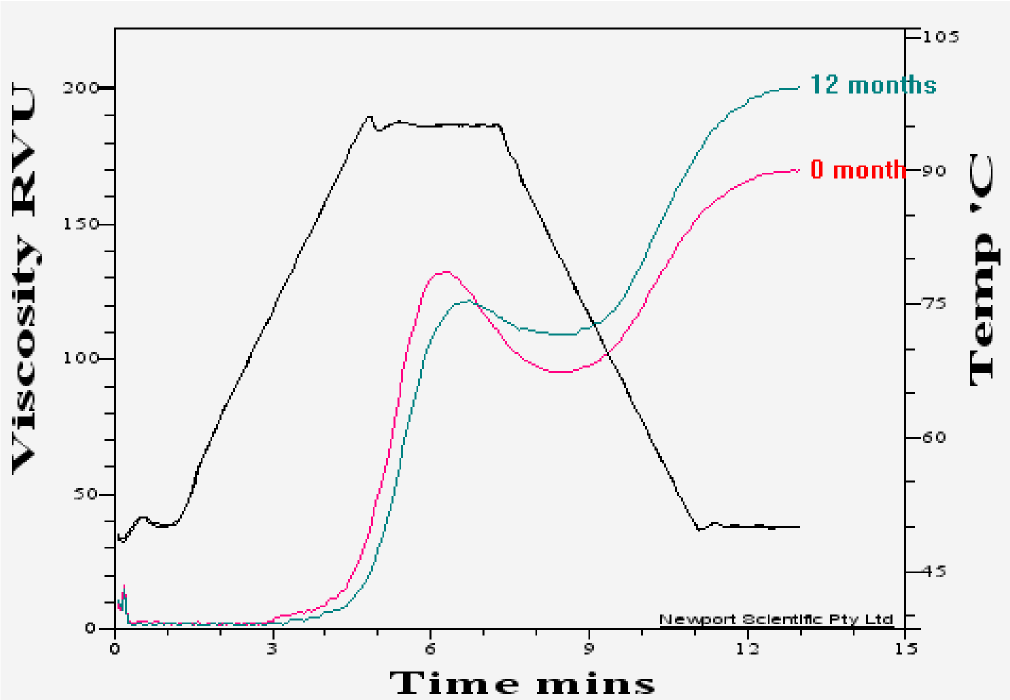

Figure 2. RVA pasting profile of 0 and 12 months rice flour suspension (8% w/w).

Thermal properties

The gelatinization properties of milled rice flour made from fresh and aged rice are shown in Table 2. Aged rice had higher peak temperature and gelatinization enthalpy than fresh rice. Similar findings were reported by Teo *et al.* [8] and Fan and Marks [18]. The higher enthalpy of gelatinization and peak temperature of aged rice reflected the loss of double helical and crystalline structure at higher temperature. These results indicated that storage of rice restricted gelatinization of starch granules.

Table 2. Thermal properties of rice flour with two storage durations.

Storage duration (months)	T_p (°C)	ΔH (J/g)
0	$67.0^a \pm 0.5$	$1.7^a \pm 0.0$
12	$70.3^b \pm 1.1$	$2.0^b \pm 0.1$

a-b : means with different letters in the same column are significantly different ($P < 0.05$)

T_p = Peak temperature and ΔH = gelatinization enthalpy

Conclusions

Aging of milled rice caused a decrease in swelling of starch granules and an increase in gelatinization temperature and enthalpy of gelatinization. This result suggests that aging of milled rice restricts gelatinization of starch granules and explains why the cooking of aged rice requires more water and more time than cooking fresh rice. The findings of this study can be applied for improvement of the quality of cooked rice.

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