*J. Trop. Agric. and Fd. Sc. 32(2)(2004): 155–162*

# Effect of heat treatment (accelerated ageing) on the physicochemical and cooking properties of rice at different moisture contents

(Kesan perlakuan haba terhadap sifat fizikokimia dan masakan beras pada kandungan lembapan berbeza)

A. Rosniyana*, M.A. Hashifah* and S.A. Shariffah Norin*

Key words: aged paddy, physicochemical, cooking properties, heat, moisture content

**Abstract**

The effect of heat treatment (accelerated ageing) on physicochemical and cooking properties of rice was determined. Accelerated ageing was accomplished by heating paddy with different moisture contents (18, 20 and 24%) at high temperatures (80, 100 and 120 °C) in a sealed container without loss of moisture to avoid grain cracking. Comparison of treated paddy to fresh paddy and naturally aged paddy was done statistically. Accelerated ageing and natural ageing caused the grains to elongate, and the elongation ratio was greater than 2. In most cases, rice from the heat-treated paddy had softer gel compared to fresh paddy and naturally aged paddy and this was found to differ significantly. The solid loss in cooking liquid for fresh paddy was significantly higher than that of naturally aged paddy and treated paddy.

## Introduction

Rice is stored in paddy form and then milled for market distribution. The product, however, stays in the market for a short period before consumer purchases it. Storage is therefore an important requirement, but it causes the rice to age. The ageing phenomenon may be the result of a sol gel transformation of colloidal starch and protein deposited during ripening into a stable, water insoluble physical form during storage. Ageing may also lead to a progressive decrease in amylose content and changes in various physicochemical properties of rice. In addition, a decrease in the fragility of the cell wall, the development of free fatty acids and their complexions with some starches have been shown to be associated with ageing (Perez and Juliano 1981).

Some rice varieties require quality enhancement particularly with respect to cooking and eating quality through the ageing process. Under the normal situation, these varieties require at least a 4-month ageing period. As this process involves holding cost, it is therefore necessary to accelerate ageing not only to minimise processing cost but also storage losses.

The process for accelerated ageing could be developed either by dry or wet heat. Dry heat treatment is preferred since it is easier and cheaper. Heating wet paddy is preferable, as dry paddy tends to crack when the grain is over dried. This study was carried out to determine the effect of accelerated ageing using dry heat on the physicochemical and cooking properties of rice.

*MARDI Station, Bukit Raya, P.O. Box 1, 06707 Pendang, Kedah, Malaysia
Authors' full names: Rosniyana Ahmad, Hashifah Mohd. Ali and Shariffah Norin Syed Abdullah
E-mail: rosa@mardi.my

## Materials and methods

### *Sample preparation*

Freshly cleaned and dried (12% moisture content) Q34, a locally developed high quality rice variety was used in the study. The moisture content of the paddy was modified to 18, 20 and 24% by adding several calculated amounts of water (Dunstan et al. 1973). The paddy was equilibrated for 48 h and kept at 5 °C. One batch was subjected to heat treatment and air dried to 12% moisture content (accelerated ageing). A second batch was dried to 12% moisture content by control ambient drying (fresh samples). Dried paddy was also packed then stored at ambient temperature for 6 months, and was labelled as naturally ageing paddy.

### *Heat treatment*

The paddy sample (2 kg) was filled into a glass bottle that can withstand high temperature, covered tightly and then placed in a forced air oven. Three different oven temperatures, namely 80, 100 and 120 °C, were used. At 80 °C the paddy was heated for 5, 10 and 15 h, while at 100 °C, 3 h and 5 h were used. For exposure times of 1.5 h and 3 h, the paddy was heated at 120 °C. These parameters were selected based on a preliminary study, which indicated that very high temperatures and longer exposure times resulted in discolouration and cracking of rice kernels. The samples were allowed to cool completely before opening the bottles. Each treatment was replicated.

### *Quality determination*

Paddy samples were milled and quality analyses were done in duplicate on the milled rice samples. The amylose content was determined according to the simplified assay of Juliano (1971). The gelatinisation temperature was estimated from the alkali spreading value of 10 grains of milled rice soaked in 15 mL of 1.7% KOH for 23 h at room temperature (Little and Hider 1958). The gel was determined based on the method of Cagampang et al. (1973).

The cooking time for milled rice was estimated according to the method of Juliano (1982). The elongation ratio of pre-soaked rice after cooking was estimated based on the length of 10 cooked and raw kernels, according to the method of Juliano and Perez (1984).

The cooking characteristics were determined by boiling the milled rice in a cylindrical basket (diameter 43.5 mm and length 98 mm) following the small scale cooking method (Juliano 1982). Water uptake was calculated from the ratio of the weight of cooked rice to that of raw rice. Volume of expansion was calculated from the ratio of the height of the cooked rice to that of raw rice. Total solids were determined from the residues of 10 mL cooking liquid after drying at 100 °C for 18 h.

### *Data analysis*

The data were statistically analysed by the analysis of variance. The Duncan Multiple Range Test was used to detect differences between fresh paddy and treated paddy. The test of significance was also applied to fresh paddy and naturally aged paddy. The results for the three different moisture contents (18, 20 and 24%) at each treatment were analysed separately.

## Results and discussion

### *Amylose content*

Amylose content is the most important criterion of rice quality and is classified on the milled rice basis as low (below 20%), intermediate (20 – 25%) and high (above 25%). The mean amylose content of fresh paddy was 24.4%. There seemed to be no significant difference in amylose content for aged paddy as compared to fresh paddy. The slight reduction was probably due to alpha and beta amylases attacking paddy starch during storage, converting it into dextrins and maltose (Houston 1972). Results showed that treated paddy remained in the intermediate group. However, at 20% and 24% moisture contents, the treated paddy

(100 °C/5 h) had significantly lower amylose content than fresh paddy and aged paddy *(Table 1).*

***Alkali spreading values***

No significant difference was observed between the alkali spreading values of fresh paddy and aged paddy *(Table 1)*. In most cases, the alkali spreading values were not significantly affected by the heat treatment. However, there was a significant reduction in the alkali spreading values for the treated paddy (120 °C and 100 °C) at moisture content of 18% as compared to the fresh paddy and the aged paddy. At 20% moisture content, a similar trend was also observed with heat treatment at 120 °C with exposure time of 1.5 h and 3 h. Accordingly, the gelatinisation temperatures for this paddy were significantly increased.

It was reported by other researchers that environment at conditions such as temperature influence gelatinisation temperature (Barber 1972). A high

Table 1. Amylose contents (%), alkali spreading values and gel consistency (mm) of milled rice for fresh, naturally aged and treated paddy (using different temperatures and times) at three moisture contents

| | | 120 °C | | 100 °C | | 80 °C | | |
|---|---|---|---|---|---|---|---|---|
| | | 1.5 h | 3 h | 3 h | 5 h | 5 h | 10 h | 17 h |
| **Amylose contents (%)** | | | | | | | | |
| 18% mc: | Fresh paddy | 24.40a | 24.40a | 24.40a | 24.40a | 24.40a | 24.40a | 24.40a |
| | Aged paddy | 23.36a | 23.36a | 23.36a | 23.36a | 23.36a | 23.36a | 23.36a |
| | Treated paddy | 24.52a | 24.92a | 23.79a | 24.36a | 24.03a | 23.75a | 23.67a |
| 20% mc: | Fresh paddy | 24.40a | 24.40a | 24.40a | 24.40a | 24.40a | 24.40a | 24.40a |
| | Aged paddy | 23.36a | 23.36a | 23.36a | 23.36a | 23.36a | 23.36a | 23.36a |
| | Treated paddy | 23.18a | 24.11a | 23.18a | 22.84b | 23.27a | 23.26a | 23.39a |
| 24% mc: | Fresh paddy | 24.40a | 24.40a | 24.40a | 24.40a | 24.40a | 24.40a | 24.40a |
| | Aged paddy | 23.36a | 23.36a | 23.36a | 23.36a | 23.36a | 23.36a | 23.36a |
| | Treated paddy | 22.59a | 23.23a | 23.16a | 22.03b | 22.63a | 23.09a | 23.01a |
| **Alkali spreading values** | | | | | | | | |
| 18% mc: | Fresh paddy | 4.22a | 4.22a | 4.22a | 4.22a | 4.22a | 4.22a | 4.22a |
| | Aged paddy | 4.40a | 4.40a | 4.40a | 4.40a | 4.40a | 4.40a | 4.40a |
| | Treated paddy | 3.56b | 3.50b | 3.70b | 3.95b | 4.05a | 4.30a | 4.10a |
| 20% mc: | Fresh paddy | 4.22a | 4.22a | 4.22a | 4.22a | 4.22a | 4.22a | 4.22a |
| | Aged paddy | 4.40a | 4.40a | 4.40a | 4.40a | 4.40a | 4.40a | 4.40a |
| | Treated paddy | 3.90b | 3.80b | 4.15a | 4.15a | 4.00a | 4.10a | 4.00a |
| 24% mc: | Fresh paddy | 4.22a | 4.22a | 4.22a | 4.22a | 4.22a | 4.22a | 4.22a |
| | Aged paddy | 4.40a | 4.40a | 4.40a | 4.40a | 4.40a | 4.40a | 4.40a |
| | Treated paddy | 4.00a | 4.00a | 4.05a | 4.00a | 4.00a | 4.25a | 4.00a |
| **Gel consistency (mm)** | | | | | | | | |
| 18% mc: | Fresh paddy | 32.05b | 32.05b | 32.05a | 32.05b | 32.05b | 32.05a | 32.05b |
| | Aged paddy | 31.50b | 31.05b | 31.05a | 31.50b | 31.05b | 31.05a | 31.05a |
| | Treated paddy | 39.50a | 41.30a | 32.30a | 63.30a | 40.30b | 44.30a | 47.00a |
| 20%mc: | Fresh paddy | 32.05b | 32.05b | 32.05a | 32.05b | 32.05b | 32.05a | 32.05b |
| | Aged paddy | 31.50b | 31.05b | 31.05a | 31.50b | 31.05b | 31.05a | 31.05a |
| | Treated paddy | 47.50a | 43.50a | 42.50a | 39.30a | 48.80a | 52.30a | 39.50a |
| 24% mc: | Fresh paddy | 32.05b | 32.05b | 32.05a | 32.05b | 32.05b | 32.05a | 32.05b |
| | Aged paddy | 31.50b | 31.05b | 31.05a | 31.50b | 31.05b | 31.05a | 31.05a |
| | Treated paddy | 52.75a | 73.00a | 39.00a | 46.25a | 37.25a | 63.25a | 34.50a |

Mean values in each column with the same letter are not significantly different by the Duncan Multiple Range Test at 5%

temperature results in a starch with higher gelatinisation temperature. The high temperature drying of moist paddy may bring about partial gelatinisation of starch. Kulp and Lorenz (1981) indicated that a change in physical order occurs within the granules of starch as a result of heat-moisture treatment. They also observed that treated starches gelatinised over broader and higher temperature range than do the corresponding untreated control starches. Swelling of starch granules occurred, which was accompanied by loss of crystallinity and solubilisation of amylose. Thus, gelatinisation properties of treated paddy were affected by the degree of crystallinity.

***Gel consistency***

The gel consistency test was carried out to index cooked rice hardness. Rice is classified based on gel length, which is soft (61–100 mm), medium (41–60 mm) and hard (27–40 mm). Results showed that fresh paddy had hard gel. After storing for 6 months, the gel consistency for milled rice did not differ significantly. Perez (1979) reported that soft gel was preferred to hard gel and the results *(Table 1)* suggested that the heat treatment improved the quality of rice. This was caused mainly by a significant increase in gel consistency of treated paddy.

***Cooking properties***

**Elongation ratio** Some rice varieties expand more in size than others upon cooking. Length expansion without increase in girth is considered a highly desirable trait in some high quality rice. Accordingly, the quality of milled rice of aged paddy improved since a significant increase in elongation ratio was observed as compared to fresh paddy *(Table 2)*. This was also observed by Indudhara Swamy et al. (1978), who reported that oxidation of the ferulate ester of the hemicellulose fraction of the cell during ageing may contribute to greater resistance of grain disintegration during cooking. Moist heat treatments also showed the same trend. In most cases, the treated

Table 2. Elongation ratio, solid loss, volume of expansion, water uptake and cooking time (min) of milled rice for fresh, naturally aged and treated paddy (using different temperatures and times) at three moisture contents

| | | 120 °C | | 100 °C | | 80 °C | | |
|---|---|---|---|---|---|---|---|---|
| | | 1.5 h | 3 h | 3 h | 5 h | 5 h | 10 h | 17 h |
| **Elongation ratio** | | | | | | | | |
| 18% mc: | Fresh paddy | 1.80b | 1.80b | 1.80b | 1.80b | 1.80b | 1.80b | 1.80b |
| | Aged paddy | 2.00a | 2.00a | 2.00a | 2.00a | 2.00a | 2.00a | 2.00a |
| | Treated paddy | 2.14a | 2.00a | 2.13a | 2.03a | 2.09a | 2.11a | 2.14a |
| 20% mc: | Fresh paddy | 1.80b | 1.80b | 1.80b | 1.80c | 1.80b | 1.80b | 1.80b |
| | Aged paddy | 2.00a | 2.00a | 2.00a | 2.00a | 2.00a | 2.00a | 2.00a |
| | Treated paddy | 2.04a | 2.01a | 2.00a | 2.15a | 2.12a | 2.12a | 2.08a |
| 24% mc: | Fresh paddy | 1.80b | 1.80b | 1.80b | 1.80b | 1.80b | 1.80b | 1.80b |
| | Aged paddy | 2.00a | 2.00a | 2.00a | 2.00a | 2.00a | 2.00a | 2.00a |
| | Treated paddy | 1.96a | 1.74c | 1.95a | 1.98a | 1.99a | 2.03a | 2.07a |
| **Solid loss** | | | | | | | | |
| 18% mc: | Fresh paddy | 0.71a | 0.71a | 0.71a | 0.71a | 0.71a | 0.71a | 0.71a |
| | Aged paddy | 0.57b | 0.57b | 0.57b | 0.57b | 0.57b | 0.57b | 0.57b |
| | Treated paddy | 0.48c | 0.48c | 0.47c | 0.49c | 0.69a | 0.58b | 0.68b |
| 20% mc: | Fresh paddy | 0.71a | 0.71a | 0.71a | 0.71a | 0.71a | 0.71a | 0.71a |
| | Aged paddy | 0.57b | 0.57b | 0.57b | 0.57b | 0.57b | 0.57b | 0.57b |
| | Treated paddy | 0.54c | 0.45c | 0.62a | 0.62a | 0.54c | 0.53c | 0.70a |

*(cont.)*

Table 2. *(cont.)*

| | | 120 °C | | 100 °C | | 80 °C | | |
|---|---|---|---|---|---|---|---|---|
| | | 1.5 h | 3 h | 3 h | 5 h | 5 h | 10 h | 17 h |
| 24% mc: | Fresh paddy | 0.71a | 0.71a | 0.71a | 0.71a | 0.71a | 0.71a | 0.71a |
| | Aged paddy | 0.57b | 0.57b | 0.57b | 0.57b | 0.57b | 0.57b | 0.57b |
| | Treated paddy | 0.62a | 0.53c | 0.64a | 0.70a | 0.53c | 0.55b | 0.70a |
| **Volume of expansion** | | | | | | | | |
| 18% mc: | Fresh paddy | 4.00b | 4.00b | 4.00b | 4.00b | 4.00a | 4.00a | 4.00a |
| | Aged paddy | 4.00b | 4.00b | 4.00b | 4.00b | 4.00a | 4.00a | 4.00a |
| | Treated paddy | 4.30a | 4.32a | 4.42a | 4.33a | 4.08a | 4.16a | 4.12a |
| 20%mc: | Fresh paddy | 4.00b | 4.00a | 4.00a | 4.00a | 4.00b | 4.00a | 4.00a |
| | Aged paddy | 4.00b | 4.00a | 4.00a | 4.00a | 4.00b | 4.00a | 4.00a |
| | Treated paddy | 4.23a | 4.15a | 4.00a | 4.08a | 4.18a | 4.14a | 4.15a |
| 24% mc: | Fresh paddy | 4.00a | 4.00a | 4.00a | 4.00a | 4.00a | 4.00a | 4.00a |
| | Aged paddy | 4.00a | 4.00a | 4.00a | 4.00a | 4.00a | 4.00a | 4.00a |
| | Treated paddy | 3.93a | 3.88a | 3.89a | 3.91a | 3.97a | 3.89a | 3.92a |
| **Water uptake** | | | | | | | | |
| 18% mc: | Fresh paddy | 3.53b | 3.53b | 3.53b | 3.53b | 3.53b | 3.53b | 3.53b |
| | Aged paddy | 3.70a | 3.70a | 3.70a | 3.70a | 3.70a | 3.70a | 3.70a |
| | Treated paddy | 3.78a | 3.61ab | 3.78a | 3.67a | 3.69a | 3.72a | 3.70a |
| 20% mc: | Fresh paddy | 3.53b | 3.53b | 3.53b | 3.53b | 3.53b | 3.53b | 3.53b |
| | Aged paddy | 3.70a | 3.70a | 3.70a | 3.70a | 3.70a | 3.70a | 3.70a |
| | Treated paddy | 3.70a | 3.56ab | 3.78a | 3.75a | 3.84a | 3.78a | 3.71a |
| 24% mc: | Fresh paddy | 3.53b | 3.53b | 3.53b | 3.53b | 3.53b | 3.53b | 3.53b |
| | Aged paddy | 3.70a | 3.70a | 3.70a | 3.70a | 3.70a | 3.70a | 3.70a |
| | Treated paddy | 3.78a | 3.72a | 3.78a | 3.64a | 3.64a | 3.78a | 3.71a |
| **Cooking time (min)** | | | | | | | | |
| 18% mc: | Fresh paddy | 14.80b | 14.80b | 14.80b | 14.80b | 14.80b | 14.80b | 14.80b |
| | Aged paddy | 15.40a | 15.40a | 15.40a | 15.40a | 15.40a | 15.40a | 15.40a |
| | Treated paddy | 14.00c | 14.50b | 14.38c | 13.75c | 14.75b | 14.88b | 14.75b |
| 20% mc: | Fresh paddy | 14.80b | 14.80b | 14.80b | 14.80b | 14.80b | 14.80b | 14.80b |
| | Aged paddy | 15.40a | 15.40a | 15.40a | 15.40a | 15.40a | 15.40a | 15.40a |
| | Treated paddy | 14.75b | 14.75b | 14.50c | 14.00c | 13.25c | 13.50c | 13.50c |
| 24% mc: | Fresh paddy | 14.80b | 14.80b | 14.80b | 14.80b | 14.80b | 14.80b | 14.80b |
| | Aged paddy | 15.40a | 15.40a | 15.40a | 15.40a | 15.40a | 15.40a | 15.40a |
| | Treated paddy | 14.25c | 14.75b | 14.25c | 13.75c | 14.25c | 14.00c | 14.00c |

Mean values in each column with the same letter are not significantly different by the Duncan Multiple Range Test at 5%

paddy had elongation ratio greater than 2. These observations indicate alterations of rice grain structure and composition due to heat moisture treatment. Merca and Juliano (1981) suggested that starch might be the major component in the rice kernel drastically affected by heat moisture treatment.

**Solid loss** The solid loss for naturally aged paddy decreased significantly from that of fresh paddy *(Table 2)*. A similar trend was observed by Houston (1972), who reported that ageing of milled paddy affects the amount of solids in cooking gruels, aged paddy producing less total solids than fresh paddy. The significant difference in solid loss probably reflects the increased water insolubility of starch. Protein solubility in water also decreased during ageing. In addition to that, high alpha amylase activity in freshly harvested paddy, which decreased during ageing has been considered a possible mechanism for pastiness of cooked fresh rice. Results also indicated that solid loss for treated paddy was lower than that of fresh paddy and in most cases, the solid loss was significant. According to Perez (1979), heat treatment might involve condensation of carbonyl compounds from fat oxidation with starch and protein molecules, thus making starch and protein less soluble in water. Also, the amylase might be inactivated by high temperature, thus producing less soluble solids in the cooking water. The difference between solid loss for aged paddy and treated paddy was significant, except for treated paddy (80 $^{o}$C/ 10 h) at 18% and 24% moisture content. The results for this observation could not be explained by this study.

**Volume of expansion** The fresh paddy did not differ significantly from aged paddy *(Table 2).* At moisture content of 24%, similar trend was observed in treated paddy as compared to fresh and aged paddy. However, heat treatment produced higher volume of expansion in treated paddy at moisture content of 18% and 20% than both fresh paddy and aged paddy. Treated paddy at 120 °C and 100 °C differed significantly at 18% moisture content. At moisture content of 20% the volume of expansion in treated paddy increased significantly in heat treatment at 120 °C for 1.5 h. The extent of swelling is determined by the amount of water, which the starch and protein can absorb before the chains separate completely (Wadswarth and Koltun 1986). Swelling is usually limited by long chains and causes a partial fractionation of polymer molecules. These structural changes are irreversible and consequent heating results in a completely different structure. Thus, it is suggested that the heat treatment improved resiliency of cell walls, which resist high pressures developed inside the cell during the cooking process.

**Water uptake ratio** Water uptake ratio increased significantly on storage *(Table 2)*. This was also generally found by other researchers (Chrastil 1990). They reported that aged paddy was more resistant to disintegration during cooking and the cell walls seemed more resistant to disruption during grain swelling. The water uptake ratio was also affected by heat treatment, where significant increases were found for fresh and treated paddy. However, insignificant differences were observed for heat treatment at 120 °C/3 h between paddy with moisture content of 18% and 20%. Matthew et al. (1970) reported that high incidence of breakages and fractures was found in conventially dried kernels. Thus, it seems likely that the headrice in accelerated ageing would have more fractures, allowing hot water to infuse the kernels. The difference between water uptake ratio of aged paddy and treated paddy was not significant.

**Cooking time** The cooking time of naturally aged fresh paddy increased significantly *(Table 2)*. This was consistent with the findings of Pushphama and Reddy (1979) who reported that the optimum cooking time for milled rice is 4 – 6 min longer after 6 months of storage than that it is at harvest. This was probably due to the increased water insolubility of rice starch during the ageing process, resulting in a slower rate of cooking, even when the starch gelatinisation did not increase appreciably. Results showed that moist heat treatment influenced the cooking time of milled rice. Generally, the milled rice of treated paddy had significantly lower cooking time than rice from fresh paddy (14.80 min). The cooking time of aged paddy was 15.40 min, which was significantly higher than the treated paddy (13.50 – 4.88 min). This is supported by Matthew et al. (1970) who reported that severe heating treatment produces small fractures in the head kernels. These cracks would allow hot water to infuse into the kernels at a slightly greater rate than uncracked kernels, resulting in shorter cooking time.

## Conclusion

Heat treatment could accelerate the ageing process of fresh paddy. Milled rice from moist heat treatment showed a significant improvement in its cooking quality as compared to both fresh paddy and aged paddy. There was a desirable characteristic increase in the elongation ratio of cooked rice, which resembled the naturally ageing process. In most cases, the solid loss for treated paddy was significantly lower than that of fresh paddy. The water uptake was also affected by heat treatment, where significant increase was observed. Heat-moisture treatment significantly increased gel consistency, producing softer gel rice than fresh paddy and aged paddy. Generally, the amylose content and the alkali spreading values remained unchanged. Heat-treated paddy required a shorter time to cook than fresh paddy or aged paddy, while aged paddy cooked at a longer time than fresh paddy.

To minimize holding cost and storage losses, accelerated ageing needs to be practised in industry. This can be done by applying heat at high temperature for shorter time to wet paddy by using a special dryer. Heat treatment is recommended, since heat-treated rice are similar to naturally aged rice in some physicochemical characteristics. Also, the cooking quality of fresh rice improved after heat treatment.

## Acknowledgement

The authors would like to thank Mr Tahir Abd. Ghani, Ms Azizah Ibrahim, Ms Zaihairan Mohd. Zain, Ms Meriam Harun and Ms Hadijah Bakar for their assistance in conducting the study.

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**Abstrak**

Kesan perlakuan haba (keusangan cepat) terhadap ciri fisikokimia dan masakan beras dinilai. Keusangan cepat dihasilkan dengan memanaskan padi dengan lembapan berbeza (18, 20 dan 24%) pada suhu tinggi (80, 100 dan 120 °C) di dalam bekas yang tertutup agar tiada kehilangan lembapan untuk mengelakkan keretakan padi. Analisis statistik digunakan bagi mendapatkan perbezaan antara padi yang menjalani perlakuan dengan padi baru dan padi usang. Keusangan secara cepat dan semula jadi telah menyebabkan beras memanjang semasa dimasak dan nisbah pemanjangannya adalah lebih daripada 2. Pada keseluruhannya, melalui perlakuan haba beras mempunyai gel yang lembut berbanding dengan beras baru dan usang dan perbezaannya adalah ketara. Beras baru mempunyai pepejal larut yang ketara tinggi berbanding dengan beras usang dan beras yang menjalani perlakuan.

*Accepted for publication on 13 July 2004*