# Changes of physical and chemical properties of rice (cv. Mentikwangi) as affected by storage conditions

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**Abstract.** The quality charcteristics of rice could be changed during storage caused by respiration and enzyme activity. The respiration process remains during storage, producing carbon dioxides, vapour, and heat. This study aimed to examine the changes in physical and chemical properties of rice (cv. Mentikwangi) for six months of storage. Rice samples were packed using plastic polypropylene and stored at ambient temperatures of 27-30 $^{o}$C and 54-62% of humidity. Rice sampling was done four times, i.e., months 0, 2, 4, and 6. Observations were made on starch crystallinity, particle morphology, reducing sugars, amylose, glucose, and maltose. The SEM image and XRD data showed that rice starch was less rigid and more amorphous after four months. In addition, eating quality data showed that the rice had high swelling and needed more water. Amylographic also performed that rice samples were getting harder. Sugar and amylose reduction levels increased by 1.84% and 2.5%, respectively. Unlike both, around 7.94% of starch was reduced. The γ-amylase had broken the amylopectin chain according to the glucose content degradation and occurred naturally during the six-month storage period.

**Keywords :** physical properties, chemical properties, rice, storage, enzyme

## 1 Introduction

The quality charcteristics of rice could be changed during storage caused by respiration and enzyme activity. The respiration process remains during storage, producing carbon dioxides, vapour, and heat. If these processes are not immediately controlled, paddy and rice will be spoil. One of the effects of these changes is an alteration of the texture, taste, flavour of rice, and commercial value[1–3]. Although rice (moisture 14%) was stored at ambient temperature for more than four months, the physical and textural properties of cooked rice had reduced[4,5]. Hence, the quality of rice as affected by storage conditions. In addition, the activity of the amylase enzyme could change rice's physical and chemical characteristics. This enzyme hydrolyses the starch rice leading to physical, chemical, and biochemical changes[6]. Starch, including amylose and amylopectin chains, can be broken by the amylase enzyme. The 1,6 β-glycosidic chain on amylopectin was hydrolysed by the amylase enzyme forming a 1,4 α -glycosidic chain on amylose[7]. These processes were occurred in a different path, depending on the type of amylase enzyme, α-, β- or γ-amylase[7]. Therefore, it is believed that both respiration and enzyme activities are becoming essential factors to further

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observation on the quality of rice. This study aimed to investigate the changes in physical and chemical properties of rice (cv. Mentikwangi) from Indonesia for six-months storage.

## 2 Materials and Methods

### 2.1 Rice samples preparation

Rice sample (cv. Mentikwangi) was obtained from the Extension Agriculture Institute, Ministry of Agriculture, Magelang, Central Java, Indonesia. Rice samples were weighed for 5 Kg per bag and were packed in polypropylene plastic (size 12.7 cm × 15.2 cm, thickness 30 µm). The trial samples were 12 packages, of which three samples represented the storage time: 0, 2, 4, and 6 months. Then, all samples were stored at ambient temperature 27-30ºC and humidity 54-62% for six months. Analysis of rice's physical and chemical properties was conducted in months 2, 4, and 6 of storage. The storage room condition was clean, dry, well-air circulation, prevented pests and placed on the pallet.

### 2.2 Physical properties determination

The crystallinity of rice starch was identified by XRD *(X-Ray Diffraction*) Advance (D8 Germany) as an indicator for breaking the short-chain on amylopectin of starch[8]. The starch granule in 2D-image was captured by *Scanning Electron Microscopy* (SEM)[9]. The viscosity of the starch was identified by *Rapid Visco Analyze*r (RVA) (Tecmaster)[10]. Rice texture was analysed by *Texture Analyzer* Pro CT3 (Brookfield, Ametek US)[11].

### 2.3 Chemical properties determination

Rice starch was analysed by *Luff Schoorl* method AOAC (2005)[12], and spectrophotometer analysed the reducing sugar content, amylose content was determined according to Suarni et al.,[13]. Glucose and maltose were analysed using an HPLC (*High-Performance Liquid Chromatography*) with carbohydrate column, Corona and Change Aerosol Detectors, mobile phase: acetonitrile: $H_2O$ = 85: 15, flow rate: 1 ml/ min, RT: 17 minutes, sample temperature: 26ºC and column temperature:35ºC[13]. Amylase activities were analysed by spectrophotometer at 540 nm[14].

### 2.4 Cooking method

According to the methodology proposed by Kaminski et al.[5], The beakers were incubated in a hot water bath at 95 ºC, partially covered, until no effluent was discovered. Weight yield (final weight of cooked rice/initial weight of raw rice), volume yield (volume occupied by cooked rice/volume occupied by raw rice), cooking time (total incubation time), and look of cooked grains (60 minutes after incubation) were all evaluated in this way.

## 3 Results and Discussion

### 3.1 Crystallinity

After six months of storage, the x-ray diffractogram of rice flour showed diffraction peaks were at 15º, 17º, 19º, and 25º C (Fig. 1), equivalent to the crystal structure of the A-type compared to the previously reported[15]. These peaks were also higher than those of rice flour before being stored (months 0). In addition, rice (cv. Mentikwangi) samples became more amorphous during storage, correspond to the amylopectin chain breakdown as an indicator. The amorphous increased by 3.7%, while the crystalline decreased by 3.7% (Table 1). This decreasing of crystalline was lower than those by Tang et al.[15], which found about 38% crystalline in barley seeds.

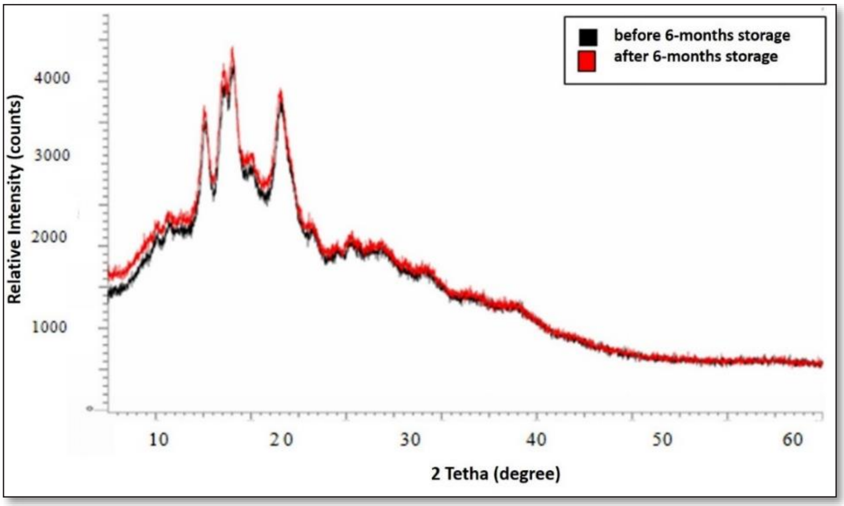


**Fig 1.** X-ray diffraction-grams of rice flour: months 0 (black line) and months 6 (red line)

**Table 1** Fraction of rice (cv. Mentikwangi) starch for months 0 and 6 of storage

| Month- | Fraction(%) | |
|---|---|---|
| | Amorphous | Crystalline |
| 0 | 70.7 | 29.3 |
| 6 | 74.4 | 25.6 |

### 3.2 Particles morphology

The crystallinity changes were demonstrated by the SEM images (Fig 2). Fresh rice showed a smooth and compact surface, while six months stored rice was rough and disordered. Fig 2a and 2b showed that fresh rice was more rigid and harder than the six months stored rice (Fig. 2c and 2d). These facts were possibly because the amylopectin content on fresh rice was high compared to the six months stored rice. These results were inline with those of Tester at.al[16], who also found that the amorf surface of rice starch became loose as affected by increasing amylose.

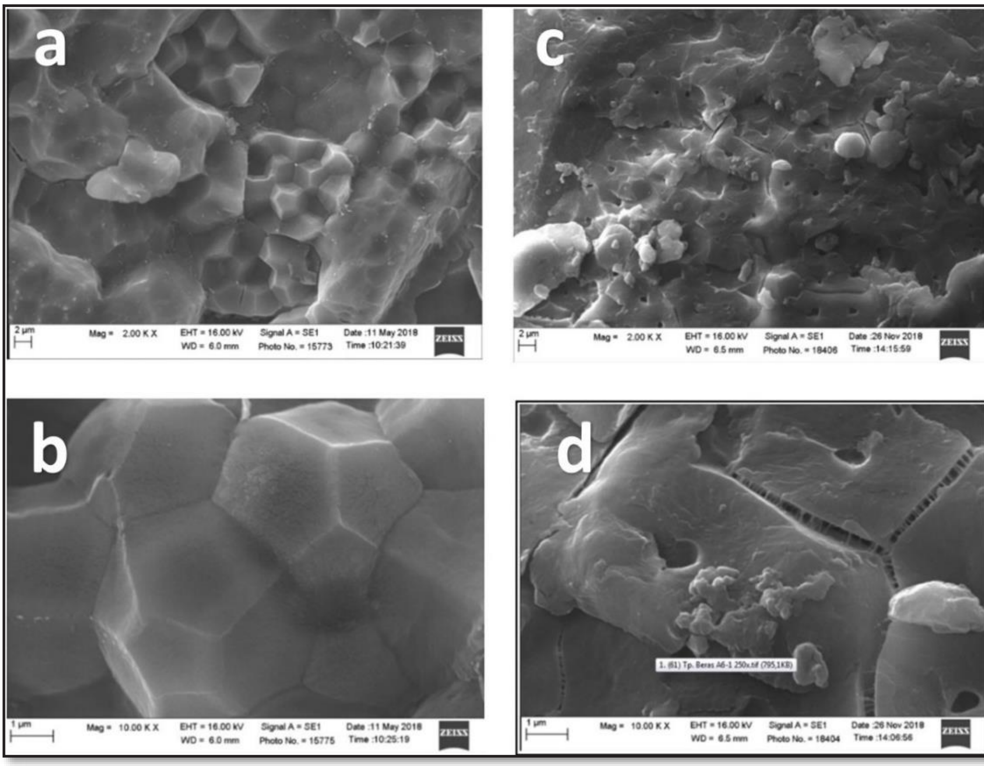


**Fig. 2** SEM micrographs of rice (cv. Mentikwangi) months 0 at 2000x (a) 10000x (b), and months 6 at 2000x (c) and 10000x (d)

### 3.3 Eating quality

The eating quality of rice (cv. Mentikwangi) was investigated through water absorption, changes in volume and texture of rice. From Table 2, it can be seen that the storage time of rice was not significantly ($p > 0.05$) effect on moisture content. This condition was probably because the initial moisture content in rice (cv. Mentikwangi) was about similar. In terms of eating quality, the absorption volume of stored rice was not significantly ($p > 0.05$) different and was in a range of 2.83-3.26 times. According to Shaikrisma et.al[17], the cooking quality of rice was indicated with higher water absorption. Higher values represent more expansion and larger size of cooked rice grains. The rate of development and absorption of water depends on the amylose content. The higher the amylose content, the greater the ability of starch to absorb and expand because amylose can form hydrogen bonds more outstanding than amylopectin[17].

Table 2 also presents the effect of storage time on swelling volume. It was observed that among stored rice samples were not statistically ($p > 0.05$) different. Regarding hardness, it is found that among stored rice were significantly ($p < 0.05$) other. The hardness values ranged from 0.71 to 2.39 Newton. It is observed that the texture of rice increased during six months of storage. The starch hydrolysis processes caused changes in the texture of the rice to become rigid. Reports on the texture of cooked rice affected by ageing showed that their hardness values increased after a period of storage time[17].

**Table 2** Moisture content and eating quality of cooked rice

| Storage time (month) | Moisture content (%) | Eating quality | | |
|---|---|---|---|---|
| | | Absorption volume (times) | Swelling volume (times) | Hardness (Newton) |
| 0 | 12.30 ± 0.14[a] | 2.83 ± 0.02[a] | 2.81 ± 0.01[a] | 0.71 ± 0.42[b] |
| 2 | 11.98 ± 0.15[a] | 3.03 ± 0.28[a] | 2.92 ± 0.02[a] | 0.90 ± 0.93[b] |
| 4 | 11.18 ± 0.15[a] | 3.15 ± 0.08[a] | 3.04 ± 0.14[a] | 1.41 ± 0.21[ab] |
| 6 | 11.65 ± 0.13[a] | 3.26 ± 0.04[a] | 3.33 ± 0.58[a] | 2.39 ± 0.81[a] |

*Different letters within a column are significantly ($p < 0.05$) different*

### 3.4 Pasting Properties of Rice

Pasting properties of stored rice months 0 and months six are presented in Table 3. It can be observed from Table 3 that gelatinisation temperature and gelatinisation time were statistically ($p < 0.05$) different between both samples. Six months stored rice had a longer gelatinisation time than month 0. This phenomenon was due to increased amylose in rice during storage and indicated high absorption and swelling volume (Table 2). The peak viscosity has risen from 3204 (month 0) to 3320 cP (month 6). This condition indicated the process of starch hydrolysis, and the amylopectin chain was broken down. Set back viscosity values of month 0 and month six were -517 and 640, respectively. A negative value of set-back viscosity indicated high amylopectin content (soft texture), while a high positive value indicated high amylose content (hard surface).

Zhou et al.[18] reported a similar condition of stored rice. The decrease in the breakdown and the gradual disappearance of a clearly defined peak in aged samples were the most notable impacts of ageing. These changes can be attributed to the characteristics of rice grain structure following storage. The study of gelatinization kinetics showed that higher temperature storage resulted in an increase in the breaking point temperature for the aged rice compared to its fresh rice.

**Table 3** Pasting properties of fresh and stored rice (cv. Mentikwangi)

| Parameters | Storage periods | |
|---|---|---|
| | Month 0 | Month 6 |
| Gelatinisation temperature (°C) | 72.2 ± 0.07[a] | 74.5 ± 0.0[b] |
| Gelatinisation time (s) | 171 ± 1.48[a] | 185 ± 0.07[b] |
| Viscosity (cP) | 1555 ± 60.81[a] | 1891 ± 9.19[b] |
| Peak Gelatinisation Temperature (°C) | 95 ± 0.0[a] | 95 ± 0.0[a] |
| Peak Gelatinisation time (s) | 338 ± 2.82[b] | 328 ± 0.0[a] |
| Peak viscosity (cP) | 3204 ± 61.51[a] | 3320 ± 45.25[b] |
| Cold Viscosity (cP) | 2687 ± 16.26[a] | 3960 ± 16.97[b] |
| Breakdown (cP) | 1648 ± 122.3[b] | 1430 ± 36.06[a] |
| Set Back Vicosity (cP) | -517 ± 77.78[a] | 640 ± 28.28[b] |
| Concistency (cP) | 1131 ± 44.54[a] | 2070 ± 7.77[b] |

*Different letters within a row are significantly ($p < 0.05$) different*

### 3.5 Chemical changes in rice starch

Changes in the chemical properties of stored rice are presented in Fig 3. Starch, reducing sugars, and amylose were monitored and determined every two months. From Fig 3, it can be observed that starch was in a range of 71.27-79.21%. Starch content in fresh rice was 79.21%, while starch content was reduced to 71.27% after six months of storage. These findings imply that the effects of storage on rice pasting and thermal properties were linked to interactions between starch and non-starch components[18].

The reducing sugars and amylose increased by about 1.84 % and 2.5%, respectively (Fig 3). Reducing sugars of rice samples was in a range of 0.33-2.17% and among all samples were significantly ($p < 0.05$) different. Amylose content was in a range of 14.33-16.83% and stored rice samples for 0-4 months were not statistically ($p > 0.05$) different, but they were significantly ($p < 0.05$) lower than six months stored rice.

During storage, the amylase enzyme hydrolysed the rice starch. This natural enzyme was able to break down 1,6 β-glycosidic on amylopectin into 1,4 alpha-glycosidic on amylose. The amylase enzyme activity had increased from 0.2124 to 1.2196 U/g/minute during storage time (data not shown). It was clear that the amylase enzyme occurred naturally in rice starch, although there was no enzyme treatment in this study. Glucose and maltose were observed to determine which type of amylase enzyme, α-, β-, or -γ-amylase, played a role in this study. The starch contained glucose higher than maltose. From these results, γ-amylase had more contributions than the other type of amylase[19].

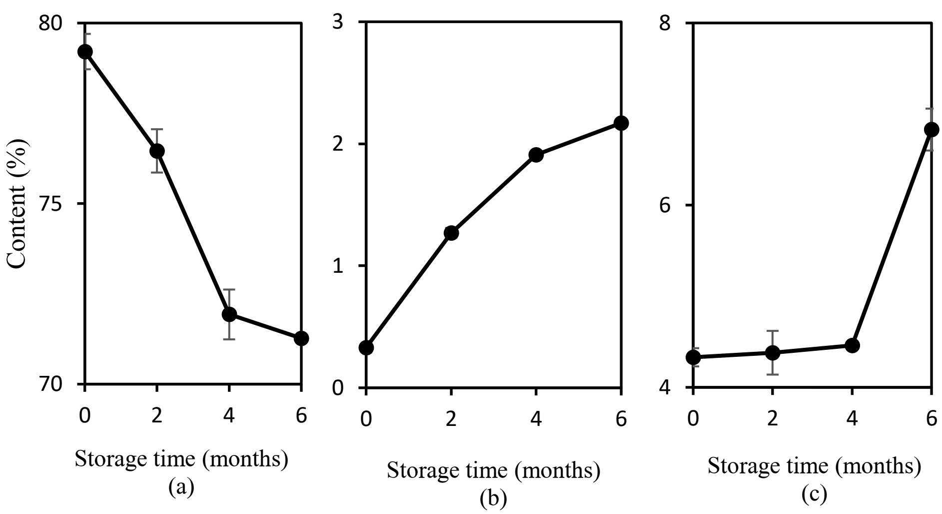


**Fig. 3** Changes of starch content (a), reducing sugars (b), and amylose (c) in rice during six months storage

### 3.6 Impact of study

Rice quality is determined by its physical, chemical, and textural properties. Storage conditions could influence these properties. This study demonstrated that rice storage at room temperature could deteriorate the rice properties. Furthermore, more than four months of storage time caused its eating quality to be poor. Therefore, it is recommended that rice retailers and rice wholesalers put their products in the ideal storage conditions such in this study (air-conditioned and humidity control), and not sell rice aged more than four months.

This study had limitations on the temperature and humidity treatment within the laboratory instead of storage conditions in the warehouse. Conversely, this study revealed the mechanism of deterioration in molecular level (crystallisation and enzyme) from aged rice.

## 4 Conclusion

After six months of storage, physical and chemical properties changes occurred in rice (cv. Mentikwangi) samples. Eating quality of stored rice had high swelling and needed more water. Starch of stored rice shifted to amorphous and less rigid. High glucose content in stored rice samples indicated that γ-amylase occurred naturally to break the amylopectin chain.

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