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Statistical Analysis of Changes in Physical and Chemical Parameters and Cooking Quality of Rice with a Combination of Temperature Treatment and Amylose Content During Storage

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ABSTRACT

*Rice is one of the staple foods produced in Indonesia. One of the postharvest processes experienced by rice is storage. During the storage process, rice changes cooking quality, physical and physicochemical qualities. This research aims to analyze changes in cooking, physical and physicochemical qualities of Indonesian rice varieties. The rice varieties used, namely Sintanur, Ciherang, and IR 42 were stored at storage room temperatures of 30℃, 20℃, and 10℃. Rice taken from farmers was stored for 4 months and changes were measured for parameters of water content, color (chroma, hue, whiteness), amylose, elongation ratio, gel consistency, alkali spreading value (ASV), water absorption, and texture profile (packability, hardness, cohesiveness, extrudability, chewiness). The results showed that the lowest water content was at sintanur which was stored at 10 ℃, namely 3.09% wb, elongation, and ASV increased with the highest final value at sintanur 30 ℃, namely 2.07 and 4.45, the consistency of the gel decreased in the first week then stable in the following week, on the other hand, water absorption increased at the beginning of storage and did not change much until the end of storage. Statistical tests showed that there was an interaction between time*variety*temperature on the parameters of water content, whiteness, elongation ratio, water absorption, amylose, and chewiness. Based on the research results, it was found that several parameters did not interact with temperature, namely hue, packability, hardness, and extrudability.*

1. INTRODUCTION

Indonesia is ranked third after China and India as a country that produces and consumes rice as a staple food source. In 2019 the total consumption of rice was 37.4 million tons (FAOSTAT, 2021; Sawe, 2019). Rice contains starch, protein, fat, minerals, vitamins and several other components in each grain. Each grain of rice is composed of nearly 80% starch, which consists of amylose and amylopectin which are important factors in determining its characteristics (Juliano, 1979; USDA, 2019a; Alhambra *et al*., 2019). To get optimal rice quality, a good rice post-harvest process or Good Manufacturing Practice (GMP) is needed.

During the storage process, rice quality decreases (Indiarto & Nurannisa, 2021; Jumali *et al*., 2021, Park *et al*., 2012, Keawpeng & Venkatachalam, 2015). This decline in quality is influenced by a number of factors, namely physical factors, chemical factors, physiological factors, biological factors and packaging factors.

Physical factors include the temperature and humidity of the storage room and the condition of the storage room building. Park *et al*. (2012) examined changes in the physical and chemical characteristics of rice during storage at various temperatures. Japonica rice harvested from Korea was stored for 4 months at 4, 20, 30, and 40 °C. Effect of storage temperature on changes in the physical-chemical properties of rice, namely fatty acids, water content, *b** value, whiteness and characteristics of the paste. Changes in these parameters will affect the cooking quality of rice as well as being influenced by rice varieties, storage conditions (temperature and exposure to light) and amylose content in rice (Teo *et al*., 2000). Faruq *et al*. (2015) analyzed local Malaysian rice varieties, namely Puteri and Mahsuri with a harvest age of 30 days, stored at 25 °C for 5 months for natural aging, while artificial aging was carried out at 90 °C, 100 °C and 110 °C for The 5 time periods are 1, 3, 5, 7 and 9 hours. Another study related to rice storage was conducted by Parnsakhorn (2013). Brown rice and germinated brown rice were stored at 4 and 37 °C for 0 – 8 months.

During storage, several changes occurred in the characteristics of rice according to (Bhattacharya, 2011), including: (a) rice experienced an increase in head rice yield; (b) the hardness of the material increases; (c) the ratio of water absorption, loss of solids and volume expansion increases during the cooking process; (d) the elongation ratio increases; (e) rice cooking time has decreased; (f) the characteristics of the paste material will increase at the beginning of storage but decrease with increasing storage period, this is due to the activity of the amylase enzyme; (g) the texture will harden during storage and be less sticky; and other changes.

Research on the effect of storage with treatment of storage time, temperature and rice varieties that are widely consumed in Indonesia was conducted by Jumali *et al*. (2021). In his research several varieties of rice namely Inpari 10, Inpari 13, Inpari 16, Inpari 20, Inpari 30, Sintanur, Ciherang, Mekongga, Situ Bagendit, and Situ Patenggang were stored at room temperature for 6 months. The selection of varieties was based on the variation in the amylose content of the ingredients, namely low (8% – 20%) and medium (20% – 25%). From this study it is known that research on storage space factors and observations of quality changes in rice with high amylose content (> 25%) is still limited, therefore it is necessary to conduct research to determine changes in rice quality at storage room temperatures of 10°C, 20°C, and 30°C. As well as the use of rice varieties with different levels of amylose namely sintanur rice (low amylose), ciherang (medium amylose) and IR 42 (high amylose). The aim of this study was to analyze statistical changes in the physical, chemical and cooking qualities of rice (moisture content, color, elongation ratio, alkali spreading value, water absorption, amylose content, whiteness, texture profile) during storage.

2. MATERIALS AND METHODS

The materials used were polished rice with different varieties namely Sintanur, Ciherang and IR 42 which had amylose content of 18.96 ± 0.04% respectively; 23.32 ± 0.07 % and 26.06 ± 0.06 %. The rice is obtained from farmers in the Yogyakarta area during the harvest period between July and August. The initial water content of the material was 11.10 ± 0.05%wb for sintanur rice; 10.61 ± 0.01 %wb for ciherang; and 11.45 ± 0.11 %wb for the IR 42 variety.

The tools used in this study were an oven (Sanyo model MOV-212), an analytical balance (Shimadzu type AUW 220), a desiccator, a colormeter (TES model 135A) to obtain the *L*a*b* value of rice, a color meter box as a container for reading the colormeter, whiteness meter (MesuLab model WSB-X) to read rice whiteness values, texture analyzer (Brookfield model CT3), waterbath (Neslab type GP-200), vortex (DLAB model MX-S), test tube, blender (Philips model MX- J1G), 100mesh sieve, calipers, petri dishes, incubator (Sanyo model MIR-162), thermocouple (Luthron type TM-946 and Extech model SDL200) and thermohygrometer.

2.1. Research Design

The rice obtained from farmers was analyzed for initial characteristics using the Indonesian National Standard (SNI) number 6128: 2015 about Rice (BSN, 2015). The experimental design in this study used 3 factors, namely variety, temperature and storage time. The rice varieties used were Sintanur, Ciherang and IR 42, storage temperature (10 °C, 20 °C and 30 °C) and storage time (4 months). Storage at 10 °C was obtained from storage in a refrigerator, and a temperature of 20 °C was obtained in an air-conditioned room measuring 2 x 3 meters while a temperature of 30 °C was obtained from storage at room temperature in the laboratory. The physical and cooking parameters of rice were measured weekly including water content, chroma, hue, whiteness, texture profile, water absorption, elongation ratio, alkali spreading value, and gel consistency. Meanwhile, the chemical parameter, namely amylose, was measured every 2 months.

Measurement of sample parameters in the form of rice, namely water content, color, elongation ratio (rice grain sample), alkali spreading value and gel consistency. While the measurement of cooking quality parameters was carried out in the form of rice, namely amylose, water absorption, elongation ratio (rice grain sample), and texture profile. The rice-making process was modified by Oko *et al*. (2012) by mixing 60 grams of rice with 200 mL of hot water (98±2 °C) in a 250 mL beaker. The beaker glass is covered with aluminum foil to reduce water evaporation and then placed in a water bath at boiling water. Cook the rice for 100 min and then cool it down until the rice reaches room temperature. The data obtained was then analyzed using the IBM SPSS version 25 application.

2.2. Physical Parameters

In stored rice there is a change in the value of the physical parameters during the given time period. The physical parameters observed were:

2.2.1 Color

The color of the rice was measured weekly and repeated 5 times for each sample. The color parameters taken are lightness (L), redness (a*) and yellowness (b*). And from these data the chroma and hue angle values are also calculated with equations (1) and (2) (ISO/CIE, 2019):

$$Chroma = \sqrt{a^{*2} + b^{*2}} \tag{1}$$

$$Hue\ Angle = 180 + \arctan\left(\frac{b^*}{a^*}\right) \tag{2}$$

2.2.2. Whiteness

Whiteness was measured using a calibrated whiteness meter before each sample reading. Data collection was carried out every week with 5 repetitions.

2.2.3. Water Content

The moisture content of the wet base material was measured using the standard method (AOAC, 1999) by taking around 5 grams of sample with 5 repetitions at 105 °C for 3 hours of drying. The water content, *WC* (in %wb) was calculated from initial sample mass (m_i) and final sample mass (m_f) as the following:

$$WC = \frac{m_i - m_f}{m_i} \times 100\% \tag{3}$$

2.2.4. Texture profile

Material texture was measured using a modification of the back extrusion method by Reyes & Jindal (1990). To test the texture profile of the material, it was started by taking a sample of around 7 grams of material and then placing it in a tubular texture test container with an inner hole dimension of 16.3 mm in diameter and a hole length of 35 mm. The bottom of the container can be removed from the top tube. The schematic of the container can be seen in Figure 1. By using a Brookfield type CT 01 texture analyzer, the sample is pressed with a load of 10 grams, the suppression target is 30 mm deep, the speed of pressing and returning the probe is 0.1 mm/s. The material was tested 3 times and the temperature of the material was the same as room temperature. From the measurement results analyzed the parameters packability, hardness, cohesiveness, extrudability, and chewiness. Determination of parameters in the texture profile test was a method taken from the research of Sodhi *et al* (2003).

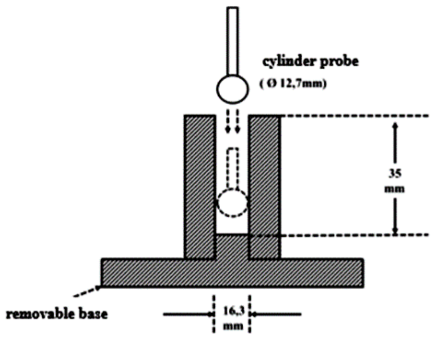

Figure 1. Schematic of sample container for texture test

2.3. Chemical Parameters

Amylose measurement using a modification of the method of Li *et al*. (2021). To measure amylose levels, it was started by preparing 5 grams (±0.1 mg) of rice and then mixing it with distilled water with a mixed volume of 25 mL in a 50 mL tube. Then the tube was moved at 160 rpm in a water bath for 1 hour at 40 °C. If it is assumed that the ingredients have been mixed evenly, distilled water is added again until the volume of the solution becomes 50 mL. The sample was agitated 5 times and then centrifuged at 7741 x g for 30 minutes. A total of 5 mL of the supernatant was taken from the tube to be put into another tube containing 4 mL of deionized water; 2 g/L iodine solution; and 0.5 mL of 0.1 mol/L HCl. Then deionized water was added again to a total volume of 50 mL. The mixture obtained was stirred until smooth and then let stand for 15 minutes.

Then the absorbance of the sample was measured using a spectroscopy at a wavelength of 620 nm. Deionized water liquid was used as a control.

2.4. Cook Quality Parameters

2.4.1. Water Absorption

To measure the degree of water absorption (DAA) of the sample, equation (4) was used:

$$DAA = \frac{B_n}{B_b} \tag{4}$$

where B_n is weight of cooked rice, and B_b is weight of uncooked rice.

2.4.2. Elongation Ratio

Measurement of the elongation ratio was carried out using the method of Juliano (1979) by taking 10 samples of uncooked rice grains and then measuring the length of the rice grains. The ratio between the length of the rice grains and the rice grains shows the elongation ratio of the material.

2.4.3. Gel Consistency

In measuring the consistency of the gel, the first step was to prepare a sample of 500 milligrams of rice flour. Then the sample was placed in a tube and added 0.03 mL of 95% ethanol and 2 mL of 2N KOH. The sample is mixed evenly using a vortex. Samples were put into a water bath with a water temperature of 92 °C for 6 minutes. Then the samples were allowed to stand for 5 minutes and put in the freezer for 15 minutes. The tube was then placed in a horizontal position on the paper block for 30 minutes. The length of the gel tip from the base of the tube was measured in centimeters (cm). This method is a modification of the research method conducted by Chemutai *et al*. (2016).

2.4.4. Alkali Spreading Value

Alkali spreading value (ASV) was measured using the method of Chemutai *et al*. (2016) where 6 grains of rice were placed in a petri dish and then 1.7% (w/v) KOH solution was added as much as 10 mL. stored in an incubator at 30°C for 23 hours. All treatments were repeated 3 times. The process of reading ASV results is measured visually with evaluation standards from IRRI (2002)

Table 1. Alkaline spreading value classification

Degree of Breakdown	Classification	AVS
Grains are unaffected	Low	1
Grains are swollen	Low	2
Grains are swollen with collar incomplete or narrow	Low	3
Grains are swollen with collar complete and wide	Intermediate	4
Grains are splitted or segmented with collar complete and wide	Intermediate	5
Grains are dispersed merging with collar	High	6
Grains are completely dispersed and cleared	High	7

Source: IRRI (2002)

2.5. Statistic Analysis

This study used the Randomized Complete Block Design (RCBD) method with 3 factors and 3 replications for each treatment combination. Statistical analysis was performed using the IBM Statistics 25 application. The selected analysis was one way ANOVA to determine the significance of each sample (final value of each rice parameter) and three way repeated measures to determine the interaction between factors with a 95% degree of confidence and Duncan's Multiple Range Test (DMRT).

Table 2. Values of physical, chemical, and cooking properties of rice at the end of storage

Parameters	Sintanur			Ciherang			IR 42		
	30 °C	20 °C	10 °C	30 °C	20 °C	10 °C	30 °C	20 °C	10 °C
WC	10.25±1.18^{d}	9.22±0.08^{c}	3.09±0.04^{a}	10.03±0.05^{d}	10.38±0.09^{d}	3.96±0.04^{b}	10.45±0.03^{d}	10.55±0.03d	4.10±0.03^{b}
C	26.17±1.09^{bc}	25.98±0.69^{abc}	26.14±0.07^{abc}	25.11±0.76^{ab}	25.82±0.78^{abc}	26.63±0.97^{c}	25.20±0.49^{abc}	25.11±0.21^{a}	26.19±0.34^{abc}
H	178.99±0.02^{ab}	178.97±0.04^{a}	179.01±0.00^{abc}	179.01±0.04^{abc}	179.05±0.02^{abc}	179.05±0.03^{c}	179.05±0.02^{bc}	179.02±0.06^{abc}	179.04±0.03^{c}
W	36.33±1.27^{a}	38.30±0.40^{bc}	39.60±0.00^{de}	37.30±0.00^{ab}	39.33±1.05^{cde}	40.47±0.64^{de}	38.73±0.45^{cd}	39.90±0.00^{d}	41.47±0.21^{e}
A	16.01±0.02^{a}	16.40±0.15^{b}	16.86±0.03^{c}	20.23±0.15^{d}	20.51±0.06^{e}	20.90±0.01^{f}	23.01±0.01^{g}	23.15±0.02^{h}	23.37±0.06^{i}
E	2.07±0.16^{d}	2.02±0.16^{cd}	2.00 ±0.07^{cd}	1.66±0.01^{a}	1.92±0.01^{cd}	1.73±0.00^{ab}	1.75±0.02^{ab}	1.64±0.08^{ab}	1.88±0.00^{bc}
ASV	4.45±2.21^{c}	3.00±0.00^{b}	2.33±0.00^{ab}	1.39±0.09^{a}	1.33±0.00^{a}	1.06±0.09^{a}	2.22±0.19^{ab}	1.94±0.19^{ab}	1.78±0.39^{ab}
K	4.40±0.00^{a}	4.5±0.00^{a}	4.6±0.00^{a}	4.77±1.19^{ab}	4.67±0.42^{ab}	4.87±0.32^{ab}	4.63±0.40^{ab}	5.57±0.60^{b}	5.30±0.00^{ab}
WA	4.21±0.01^{e}	4.08±0.00^{c}	4.07±0.00^{bc}	4.09±0.01^{d}	4.62±0.00^{g}	4.03±0.01^{a}	4.06±0.02^{b}	4.81±0.00^{h}	4.4±0.01^{f}
P	5.21±0.36^{bc}	5.11± 0.38^{bc}	5.28±1.62^{bc}	5.75±0.31^{bc}	4.64±1.14^{bc}	5.28±0.81^{bc}	4..00±1.11^{ab}	2.62±0.86^{a}	3.83±0.56^{ab}
HA	44.9±13.00^{bc}	43.42±3.47^{bc}	63.92±16.18^{d}	50.53±4.08^{cd}	50.08±11.85^{cd}	62.78±3.37^{d}	40.22±2.54^{bc}	22.27± 3.70^{a}	31.00±4.01^{ab}
CO	187.33±50.36^{bc}	212.00±54.69^{cd}	266.00±39.74^{de}	235.00±19.31^{cde}	206.67±22.55^{cd}	295.33±44.09^{e}	129.67±36.46^{ab}	107.00±14.17^{a}	133.33±11.50^{ab}
EXT	40.72±4.18^{bcd}	37.76± 3.67^{bcd}	45.38±2.53^{d}	42.48±3.39^{cd}	35.73±9.36^{bcd}	43.49±5.78^{cd}	29.78±9.59^{ab}	21.67±4.66^{a}	32.39±5.79^{bc}
CHE	6718±653^{cd}	6776±495^{cd}	7300±250^{d}	7340±857^{d}	6053±506^{c}	8392±263^{e}	5076±209^{b}	3385±313^{a}	4613±334^{b}

*Values are expressed as mean ± standard deviation (n = 3). Numbers followed by different superscript in the same row are significantly different at DMRT ($p < 0.05$)

Note : WC = water content, C = Chroma, H = Hue, W= Whiteness, A = Amylose, E = Elongation, ASV = Alkali spreading value, K = gel consistence, WA = Water absorption, P = Packability, HA = Hardness, Co = Cohesiveness, Ext = Extrudability, Che = Chewiness.

3. RESULTS AND DISCUSSION

3.1. Physical Parameters

3.1.1. Water Content

From the results of the study it was found that the initial water content of the Sintanur variety rice was 11.10±0.05 %wb; the Ciherang variety was 10.61±0.01 %wb and the IR 42 variety was 11.45±0.11 %wb. Changes in the value of water content can be seen in Figure 2. Meanwhile, the final water content of final rice can be seen in Table 2. The biggest decrease occurred in rice stored at 10 °C, especially in the IR 42 variety with a decrease of 64.16%. This can be due to low environmental humidity and causes the water content in the material to escape into the surrounding environment. Environmental humidity at each storage room temperature is 23±3.3 % (10 °C), 73±2.8 % (20 °C) and 67±3.4 % (30 °C). The influence of the storage container may contribute to air exchange during storage. The container used is woven plastic rice sacks made from polyprophelene. Based on research by Hasbullah *et al*. (2018) it is known that the plastic permeability for CO_2 is 44.9 ml.mm.m^{-2}.day^{-1}.atm^{-1}. So that the process of air exchange occurs in the material.

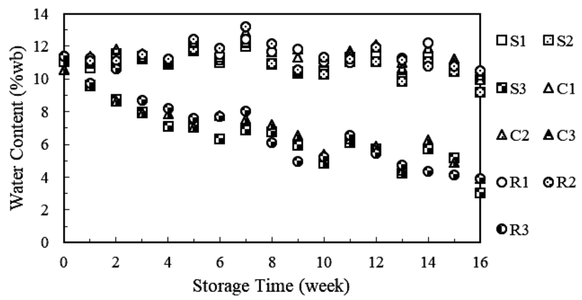

Figure 2. The change of water content of rice during storage (S1: Sintanur, 30 °C; S2: Sintanur, 20 °C; S3: Sintanur, 10 °C; C1: Ciherang, 30 °C; C2: Ciherang, 20 °C; C3: Ciherang, 10 °C; R1: IR 42, 30 °C; R2: IR 42, 20 °C; R3: IR 42, 10 °C)

A decrease in water content was also reported by Park *et al*. (2012) who stored rice at 30 °C by 12.12% and at 20 °C by 6.06%. This difference can be caused by differences in humidity and storage containers used. The statistical test results showed that there was an interaction between time*variety*temperature, time*variety, and time*temperature on the water content of the sample. The effect of variety, temperature and variety*temperature interaction also had a significant effect on the moisture content of rice during storage. This shows that there is a change in the value of the moisture content of each variety and temperature during the storage period.

3.1.2. Color

During the storage process there was growth of rice lice (sitophilus oryzae) which caused rice which should have decreased in color parameters to actually increase after the 10th week. The emergence of fleas can be due to improper post-harvest processes while in the hands of farmers. Changes in chroma, hue, and whiteness during the storage period can be seen sequentially in Figure 3 to 5.

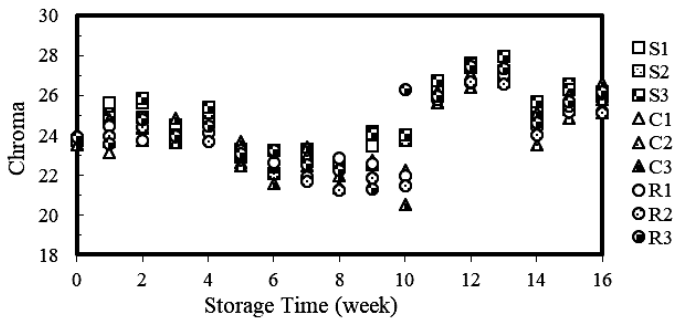

Figure 3. Chroma change of rice during storage

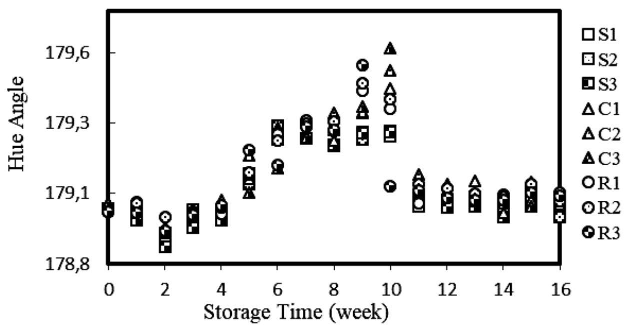

Figure 4. The change of hue angle of rice during storage

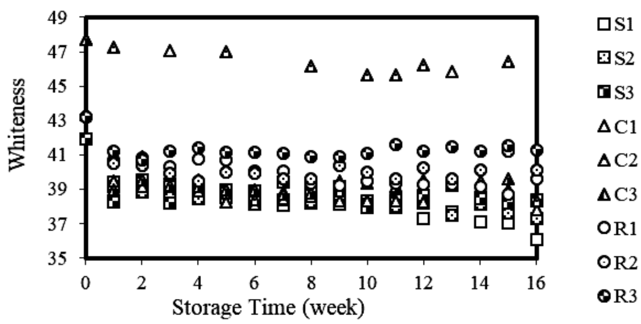

Figure 5. The change of whiteness of rice during storage

Chroma showed an increase with initial values for the sintanur variety, namely 22.37; ciherang of 23.54 and IR 42 of 23.90. The final value of chroma can be seen in Table 2. The increase occurred in all varieties and temperatures. The highest increase occurred in the ciherang variety stored at 10 °C of 11.77%, while the smallest was obtained by IR 42 rice stored at 20 °C of 4.20%. This is in accordance with research conducted by Belefant-Miller *et al*. (2005) which showed that the chroma value of the material will increase during the storage process. The increase in chroma value in the study by Belefant-Miller *et al*. (2005) for the wells variety of rice was 133.33% while for the L-205 variety it was 90.91%. However, in this study the increase ranged from 4.20% - 11.77%. This difference could be due to different storage temperatures where in Miller's study it was 70 °C. Statistical test results show that chroma is influenced by time, variety and temperature.

The hue angle of the material was also calculated during storage and generally increased slightly until the 10^{th} week. The hue angle value at the start of storage was 178.99 for sintanur; 179.04 for ciherang and 178.99 for IR 42. It is known that the highest increase occurred in rice variety IR 42 which was stored at 10°C, namely 0.04%. The final value of the hue angle can be seen in Table 2. The increase in the value of the hue angle of the material is in contrast to the research conducted by Belefant-Miller *et al*. (2005) because in their research it was found that the hue angle value would decrease due to the decreased moisture content of the material after the incubation process was complete. In the Belefant study, it was found that the decrease in hue angle in Wells variety rice was 11.36% and L-205 rice was 2.35%. This difference can be due to different storage temperatures and the type of rice used. The temperature used by Miller is 70°C and the varieties are Wells and L-205.

The increase in hue values was due to the yellowing process in the rice grains due to storage temperature, storage time, mold growth, water activity in the grains, oxygen and carbon dioxide levels, non-enzymatic browning, and biochemical reactions that occur in rice (Liu *et al*., 2022). Based on the statistical results it is known that only the time factor and variety have a significant effect on the hue parameter.

Whiteness value generally decreased during storage. The initial whiteness value was 41.91 for the sintanur variety; 47.70 ciherang variety and IR 42 variety of 43.18. The final value of whiteness can be seen in Table 2. The biggest decrease in whiteness occurred in rice which was stored at 30 °C and the amylose content from low to high, namely sintanur, ciherang then IR 42. Changes in whiteness during storage can be seen in Figure 5. A greater decrease in whiteness occurs in materials at high temperatures, this is in accordance with research conducted by Park *et al*. (2012). The decrease in whiteness of Japonica rice stored in polyethylene plastic at 20 °C was 5.13% while at 30 °C it decreased by 12.82%. Whereas in this study the decrease in the whiteness value of the sintanur, ciherang and IR 42 varieties was sequentially greater, namely 14.17%; 21.80 %; 11.16 % at 30 °C and 9.53 %; 17.54 %; 8.49% at 20 °C, while at 10 °C it was 6.46%; 15.16 %; 4.89 %. From the reduction data it is known that temperature affects the whiteness of the material. The higher the storage temperature, the greater the decrease in whiteness. The decrease obtained in this study was greater than the research conducted by Park, this could be due to differences in the type of rice used and the storage containers used. Statistical tests (Table 3) showed that there was an influence of time, variety, temperature and interactions between factors (time*variety, time*temperature, variety*temperature, time*variety*temperature) on the whiteness parameter.

Tabel 3. Effect of factor interaction on the physical, chemical, and cooking parameters of rice

Factor	Physical Parameters				Chemical Parameters	Cooking Parameters								
	WC	C	H	W	A	E	ASV	K	WA	P	Ha	Co	Ext	Che
Time (t)	*	*	*	*	*	*	*	*	*	*	*	*	-	*
Variety (V)	*	*	*	*	*	*	*	-	*	*	*	*	*	*
Temperature (T)	*	*	-	*	*	*	-	*	*	-	-	*	-	*
t*V	*	-	-	*	*	*	*	-	*	*	*	*	-	*
t*T	*	-	-	*	*	*	-	*	*	-	-	-	-	*
V*T	*	-	-	*	*	*	-	-	*	-	-	-	-	*
t*V*T	*	-	-	*	*	*	-	-	*	*	-	-	-	*

Note : WC = water content, C= chroma, H= hue, W= whiteness, A = Amylose, E= Elongation, ASV= Alkali spreading value, K = gel consistence, WA= Water absorption, P = Packability, Ha = Hardness, Co = Cohesiveness, Ext = Extrudability, Che = Chewiness, * = significant, and - = not significant.

3.2. Chemical Parameter

The amylose content of rice in all samples decreased (Figure 6), this was because amylose was used as energy for metabolism during storage (Abeysundara *et al*., 2017). The amylose enzyme remained active during rice storage although its activity decreased over time. The interior of the endosperm has a higher temperature and is an ideal condition for the activity of amylase and other hydrolytic enzymes. So that amylose levels will decrease during storage (Patindol *et al*., 2005).

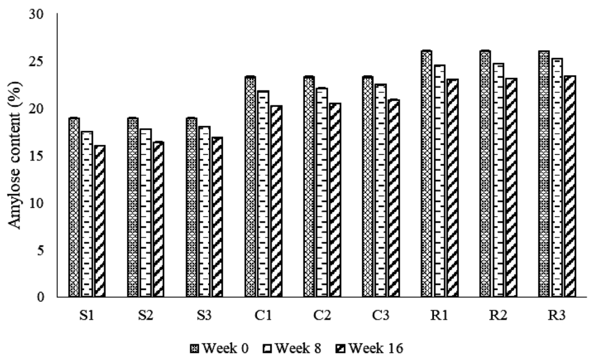

Figure 6. The change of amylose content of rice during storage (S = Sintanur, C = Ciherang, R = IR 42, 1 = 30 °C, 2 = 20 °C, 3 = 10 °C)

From the figure it is known that at 30 °C there was a decrease in the amylose content of the sintanur, ciherang and IR 42 varieties respectively, namely 15.57%; 13.22 %; and 11.70%. Furthermore, at 20 °C there was a decrease of 13.53%; 12.02 %; and 11.19 %. Whereas at 10 °C it decreased by 11.11 %; 10.38 %; and 10.35%. From these data it is also seen that the higher the storage temperature the lower the amylose content.

In a study conducted by (Ral *et al*., 2008), it was found that a temperature of 30 °C had a significant effect on reducing amylose levels. High temperatures cause faster degradation reactions so that materials stored at high temperatures will experience a faster reduction in amylose content. The same results were also observed by Abeysundara *et al*. (2017) with 13 weeks of storage in the Bathalegoda and

Ambalangoda rice varieties (Sri Lanka rice varieties) a decrease in amylose levels. The decrease in amylose content was 0.72% for the bathalegoda variety.

The difference in the decrease in amylose content could be due to differences in rice varieties and storage conditions. Abeysundara *et al.* (2017) storage conditions are 26-30 °C with an RH of 70% – 80%. Based on statistical tests, it was found that there was an interaction between time*variety*temperature, time*variety, and time*temperature on the amylose content of rice. The effect of variety, temperature and variety*temperature interaction also had a significant effect on the amylose content of rice during storage.

3.3. Cook Parameters

3.3.1. Elongation Ratio

The elongation ratio of rice increased during storage. During storage, rice grains experience damage to the endosperm. This causes cracks to appear on the grain surface (Parnsakhorn & Noomhorm, 2012). As the length of the grain of rice increases, the grain becomes softer and crumbles easily. The increase in the elongation ratio at 30 °C for sintanur, ciherang and IR 42 varieties respectively was 85.99%; 81.67 %; 79.46% and at 20 °C 10.41%; 27.87 %; 15.40 %. Whereas at 10 °C it was 53.73%; 54.56 %; and 65.15 %. From these results it is known that in the sintanur variety there is an effect of temperature on the increase in the elongation ratio where the higher the temperature, the greater the increase in the elongation ratio. Higher temperature causes greater thermal stress and higher shrinkage. This causes changes in grain structure and accelerates changes in rice morphological characteristics (Dong et al., 2007 in Parnsakhorn & Noomhorm, 2012). Changes in the elongation ratio during storage can be seen in Figure 7.

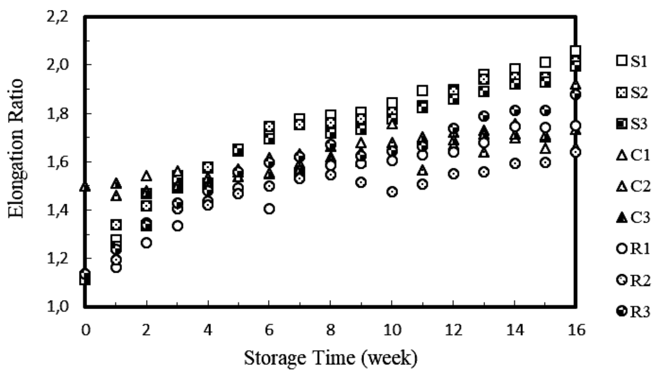

Figure 7. The change of elongation ratio of rice during storage

The increase in the value of the elongation ratio is in accordance with the research conducted by Kaminski *et al.* (2013). This is because in his research there was also an increase in the elongation ratio of rice during the storage period. The increase in the elongation ratio was 33.33% and 56.67% for the BR-IRGA 410 variety at 20°C and 35 °C. The increase in elongation ratio can be caused by the amylose content. The longer rice is stored, the amylose content of rice will decrease c. Amylose decreased one of them because it experienced decay during the cooking process. This decay causes the material to absorb water more easily and causes the rice grains to expand more easily.

Based on the results of the three way repeated measures statistical test, it is known that there is an interaction between time*variety*temperature, time*variety and time*temperature on the elongation parameter. In addition, there is a significant influence of variety, temperature and variety*temperature interactions on the elongation ratio of rice during storage.

3.3.2. Alkaline Spreading Value

Alkali spreading value is measured to determine the gelatinization temperature of the material. During storage, there was a change in ASV content in the ingredients and the biggest change occurred in Sintanur rice at 30 °C. The ASV value at the start of storage was 1.67; 1.00; and 1.00 for sintanur, ciherang and IR 42 varieties. The final ASV values can be seen in Table 2.

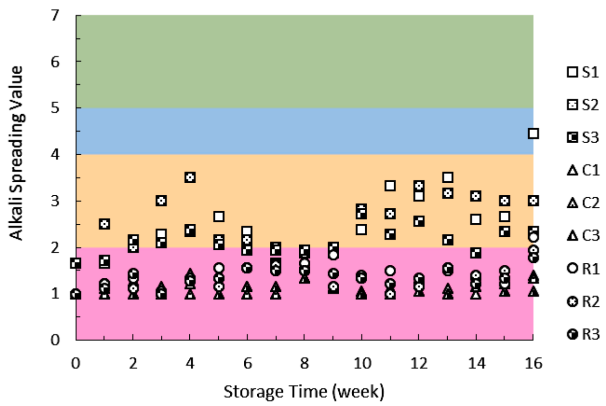

Figure 8. Graph of change in alkali spreading value during storage (Note: red area indicates high gelatinization temperature (74.5 – 80 °C); orange area indicates high intermediate gelatinization temperature (74 – 74.5 °C), blue area indicates intermediate gelatinization temperature (70 – 74 °C), and green area indicates low gelatinization temperature (<70 °C))

Changes in ASV values during storage can be seen in Figure 8. During storage, ciherang rice did not experience significant changes and was the smallest compared to other varieties of rice. The ASV results of the ciherang variety were the same as those of Jumali *et al*. (2021) which showed that there was no change in the ciherang ASV score during 6 months of storage at room temperature. Changes in ciherang ASV may occur on storage at longer periods and at higher temperatures. The final ASV score can be seen in Table 2. The research results are in accordance with the research conducted by Jumali *et al*. (2021) because the ciherang ASV score is around 1 when stored for 3 months. Based on the results of statistical tests it is known that time, variety and time*variety interaction have a significant effect on ASV parameters.

3.3.3. Gel Consistency

At the beginning of storage all varieties had a gel consistency value in the very soft category (green area) which means that after the cooking process the rice was still fluffier and did not harden easily, but after being stored for 4 months the rice experienced a decrease in the gel consistency value to medium (blue area). which shows that the rice turned out to be quite dense after the cooking process. Changes in gel consistency during storage can be seen in Figure 9.

Gel is formed from the chemical reaction of rice flour with alkaline solution (KOH) and decreases with increasing storage time and high storage temperature. Increasing storage time causes amylose content to decrease and the reaction with alkaline solutions decreases. While the temperature of the storage room increases the damage to the material so that the decrease in the gel consistency of the material is even greater (Hadipernata *et al*., 2022).

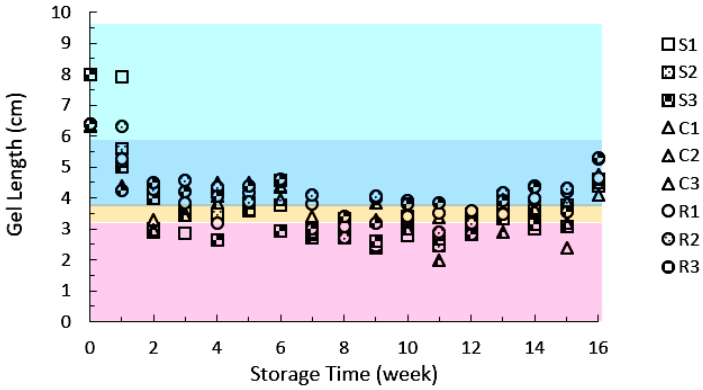

Figure 9. Changes in gel consistency of rice during storage (Note: the red area indicates the characteristics of a hard gel (2.7 – 3.5 cm); the orange area indicates the characteristics of a medium hard gel (3.6 – 4.0 cm); the blue colored area indicates the characteristics of the medium gel (4.1 – 6.0 cm); and green area indicates soft gel characteristic (6.1 – 10.0 cm))

The consistency value of ciherang gel is close to the value obtained by Jumali *et al.* (2021), namely 6.49 cm at the start of storage. Whereas for the Sintanur variety it is 6.55cm, different from the value obtained from direct data collection. This difference is due to differences in amylose content. From the results of the direct test, it was found that the amylose content of Sintanur rice in the 0th week was 18.96±0.04% wb, while in the study conducted by Jumali it was 19.12±1.17. So this can affect the different gel consistency readings at the start of storage. Rice which was previously in the soft category then gradually becomes medium and medium hard in the first few weeks of storage. After being stored for three months (12 weeks) the material tends not to change and remains in a medium hard condition, this also happened in the study of Jumali *et al.* (2021), where in the 3rd month of storage there was no significant difference in the value of gel consistency . Based on the statistical results it is known that there is an effect of time, temperature and time*temperature interaction on the gel consistency parameter.

3.3.4. Water Absorption

Water absorption shows the ratio of water absorption by rice. Based on Figure 10 it is known that in the first 2 weeks there was a significant change in water absorption for all varieties and storage room temperature and thereafter did not change much in the following weeks until the end of the storage period. The increase in the value of water absorption is influenced by several factors, one of which is the amylose content and the temperature of the storage room. Amylose has decreased and causes widening of the area that can absorb water and causes starch granules to expand. This has an impact on volume expansion and increased water absorption during the storage period (Huang & Lai, 2014).

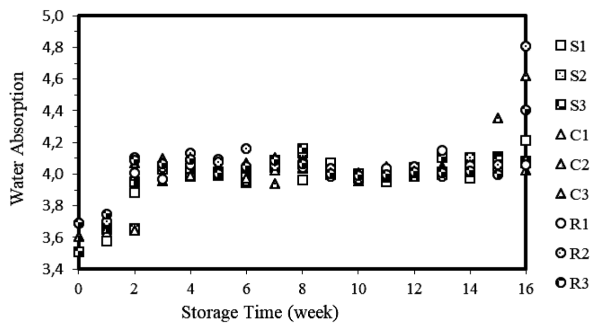

Figure 10. Graph of changes in water absorption of rice during storage

Based on research conducted by Jumali *et al.* (2021) it is known that when rice is stored at room temperature for 0, 3, and 6 months the water absorption of rice will increase. The rice used in this research was rice Inpari 10, Inpari 13, Inpari 16, Inpari 20, Inpari 30, Sintanur, Ciherang, Mekongga, Situ Bagendit, Situ Patenggang. The water absorption values obtained in Jumali's study for the Sintanur variety for storage of 0, 3, and 6 months respectively were 2.7±0.07; 2.9±0.00 and 2.8±0.14. Then for Ciherang Variety rice of 2.8±0.00; 2.9±0.00 and 3.1±0.07 at 0, 3, and 6 months respectively. This value is slightly different from the results obtained in the study. In the research conducted, the water absorption results for Sintanur rice in months 0 and 3 were 3.51 and 4.01; whereas for the Ciherang variety it was 3.61 and 4.01 at months 0 and 3. This difference could be due to the research modifying the rice cooking method to adjust the tools available in the laboratory. Based on statistical tests, it is known that there is an interaction between time*variety*temperature, time*variety and time*temperature on water absorption parameters. In addition, there is also a significant influence of the variety, temperature and variety*temperature factors on the parameters of water absorption during storage.

3.3.5. Texture Profile

During the storage process, the packability value changes which can be seen in Figure 11. The average IR 42 packability value is lower than the Sintanur and Ciherang varieties, this could be because IR 42 has a higher amylose content. High amylose content causes rice to be fluffier and creates less air space than other rice which has lower amylose content which causes the rice to be more flavourful. Sintanur rice experienced an increase in packability values ranging from 27.64% at the end of storage.

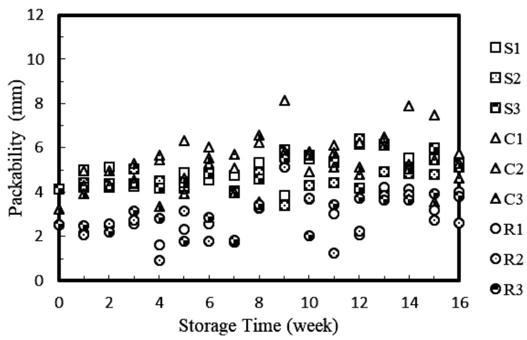

Figure 11. Changes of rice packability during storage

The packability value is different from the results obtained by Sodhi *et al*. (2003). In his research, Basmati-370 and Sharbati rice which had been stored for 1 year had initial amylose levels of 9.40% (Basmati) and 5.90% (Sharbati) which would increase the packability of 76.76% for basmati rice and 107.41% for sharbati rice. This difference could be due to differences in amylose content, storage time, and the type of rice grain. Basmati rice has long grains while sintanur, ciherang and IR 42 have medium grain length. Based on statistical tests, it is known that there is an influence of time, variety, time*variety and time*variety*temperature interaction on the packability parameter.

Changes in hardness during storage can be seen in Figure 12. The hardness value of rice increased at the end of storage except for IR 42 rice which was stored at 20°C and 10°C. This increase was also experienced by basmati and sharbati rice in a study conducted by Sodhi et al (2003). The increase in the sintanur variety was 28.30% at 30° C; 24.07 % at 20°C and 82.67 % at 10°C. This increase has a quite different value from the study of Sodhi et al (2003), namely 144.44% for the basmati variety and 27.37% for the sharbati variety. Based on statistical tests, it is known that time, variety and time*variety interaction have a significant effect on sample hardness.

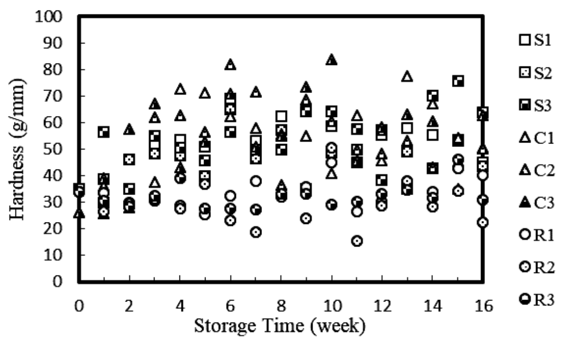

Figure 12. Changes of rice hardness during storage

Cohesiveness is measured at the end of the hardness measurement. The cohesiveness of the material changes which can be seen in Figure 13. During storage, the cohesiveness value increased, with the highest increase occurring in ciherang rice stored at 10 °C. The same thing happened in the study of Sodhi *et al*. (2003) because there was an increase in the cohesiveness value during storage. The cohesiveness value increased by 168.63% in the basmati variety and 105.56% in the sintanur variety. While in this study the ciherang variety increased by 141.69%. Based on statistical tests, it is known that there is a significant influence of time, variety, temperature and time*variety interaction on the cohesiveness parameter.

Extrudability changes during storage which can be seen in Figure 14. The extrudability value increased for sintanur varieties which were stored at all temperatures and IR 42 at 10 °C. This is in accordance with research conducted by Sodhi *et al*. (2003) because in basmati and sharbati rice it was found that there was an increase of 102.00% and 97.75%. Meanwhile, the extrudability increase in the sintanur variety was 29.31% at 30 °C; 19.91 % at 20 °C and 44.09 % at 10 °C. The increase observed by Sodhi *et al*. (2003) was greater than the data obtained during the study. This could be due to differences in varieties and storage time. Based on statistical tests, it is known that only the varietal factor has a significant effect on extrudability.

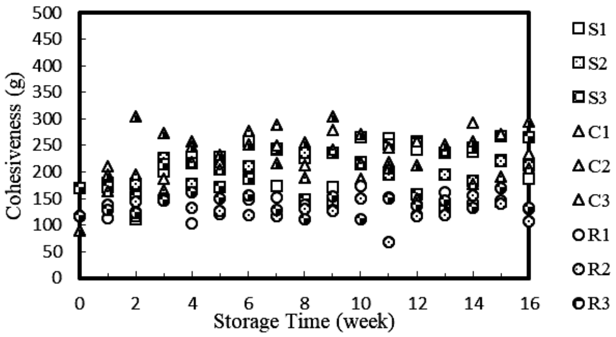

Figure 13. Changes of rice cohesiveness during storage

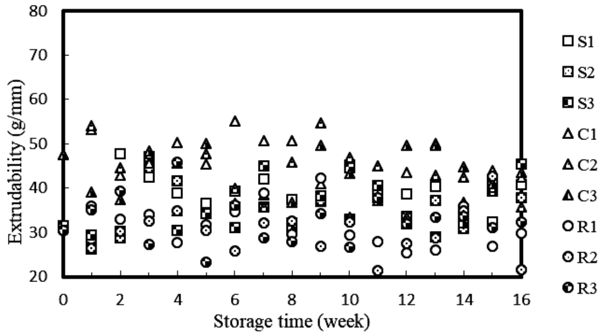

Figure 14. Changes of rice extrudability during storage

The last texture profile parameter is chewiness. Changes in chewiness during storage can be seen in Figure 15. Chewiness is the resistance of a material to be crushed with a certain force and depth of pressing, measured by calculating the area (g.mm) under the texture analyzer reading chart. From the graph it is known that rice variety IR 42 has the smallest chewiness value followed by sintanur and ciherang rice. Chewiness of ingredients experienced the highest increase in ciherang rice which was stored at 10 °C, namely 112.56%. An increase in the chewiness value was also experienced by Sodhi *et al.* (2003) with an increase of 125.66% in basmati rice and 112.82% in sharbati rice. this value is different from the results obtained during the study. This could be due to differences in varieties and length of storage time. Based on statistical tests, it is known that there is a time*variety*temperature interaction on the chewiness parameter.

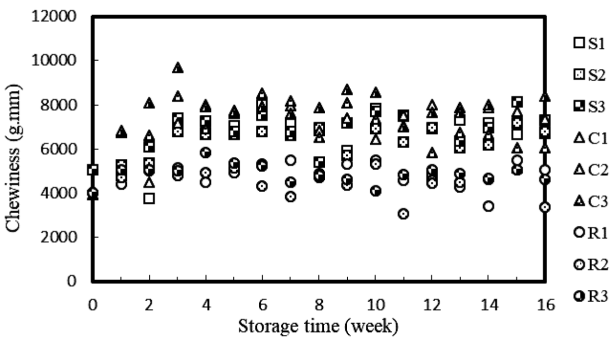

Figure 15. Changes of rice chewiness during storage

4. CONCLUSIONS AND SUGGESTIONS

4.1. Conclusion

During 4 months of storage, the physical, physico-chemical and cooking parameters changed. Physical parameters such as water content decreased due to room RH which was too low so that the water in the material moved to the environment. The highest decrease in water content occurred in IR 42 rice which was stored at 10 °C, namely 64.16%. While the lowest value was obtained by storing ciherang rice stored at 20 °C, which was 2.18%. Rice chroma increased, with the lowest value occurring in IR 42 rice, namely 4.20%, which was stored at 20 °C, while the highest value occurred in ciherang rice, namely 11.77%, which was stored at 10°C. Furthermore, the hue angle increased slightly with the highest change occurring in IR 42 rice stored at 10 °C, namely 0.04%.

The whiteness value of the material experienced a greater decrease at higher storage temperatures. The lowest decrease in whiteness occurred in IR 42 rice stored at 10 °C. The amylose content of the material decreased in all varieties and storage temperatures. The higher the storage temperature, the greater the decrease in amylose content. The lowest reduction in amylose content was obtained by rice of the IR 42 variety at 10 °C. Furthermore, for the cooking parameters it was found that the elongation ratio increased during storage with the highest increase occurring in sintanur rice at 30 °C of 85.99%. ASV did not experience much change during storage with an ASV score of ciherang variety of 1.00 during 3 months of storage. The consistency of the gel decreased, with the highest decreasing value occurring in sintanur rice which was stored at 30 °C, which was 45.00%. Furthermore, the water absorption of the material has increased with the highest value obtained by IR 42 rice stored at 20 °C, namely 30.37%.

The texture profile of rice during storage increased for all parameters. The highest increases in the parameters packability, hardness, cohesiveness, extrudability and chewiness respectively were 78.31% (Sintanur, 30 °C), 141.69% (Ciherang, 10 °C), 231.84% (Ciherang, 10 °C), 44.09 % (Sintanur 10 °C), and 112.56 % (Ciherang, 10 °C).

4.2. Suggestion

The results of this study are expected to be a consideration for farmers or the public who want to store rice at a storage room temperature of 20 °C and 10 °C, with the same variety and time as was done in this study. It is also hoped that similar research can be carried out to improve research results, such as controlling humidity in storage rooms and using vacuum containers.

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