Agriculture and Food

AIMS Agriculture and Food, 7(1): 184–196.
DOI: 10.3934/agrfood.2022012
Received: 12 November 2021
Received: 17 March 2022
Accepted: 23 March 2022
Published: 31 March 2022

http://www.aimspress.com/journal/agriculture

Research article

The effect of different storage times and methods on the chemical and organoleptic properties of white cooked rice and black cooked rice

Heni Purwaningsih[1], Kristamtini[1,*], Pamudji Rahardjo[2], Bangun Prajanto Nusantoro[2],Erni Apriyati[1], Siti Dewi Indrasari[1] and Rubiyo[3]

[1] Yogyakarta Assessment Institute for Agricultural Technology, 55584, Indonesia
[2] Faculty of Agricultural Technology, Gadjah Mada University Yogyakarta, 55281, Indonesia
[3] Indonesian Center for Agricultural Technology Assessment and Development, West Java, 16114, Indonesia

***Correspondence:** Email: krisniur@yahoo.co.id; Tel: +6285228619027.

Abstract: Storage of rice for a certain period of time can lead to decrease in the quality of rice, hence the purpose of this study was to determine the effect of storage method and duration on total sugar content, starch, and preference level of Inpari 43 GSR white rice and black rice Sembada Hitam varieties. The research was conducted at the Food Biochemical Chemistry Laboratory, Faculty of Agricultural Technology, Gajah Mada University The stage of this research is to cook the rice, and the storage time in two ways inside and outside the rice cooker is 0, 9, 18, and 27 hours, respectively. Then tested for sugar content, starch and level of preference. The experimental design used was factorial randomized design with 3 replications The stage of this research is to cook the rice, and the storage time in two ways inside and outside the rice cooker is 0, 9, 18, and 27 hours, respectively. Then tested for sugar content, starch and level of preference. The experimental design used was a factorial randomized design with 3 replications, while the Sembada Hitam variety had initial sugar content of 0.019%, and 0.007% when in stored in the rice cooker and 0.001% outside the rice cooker. The increase in starch content increased at 9 hours of storage in Inpari 43 GSR and Sembada Hitam varieties and a decreased at 18 and 27 hours. Based on the test of preference for color, aroma, taste and texture, panelists preferred 9 hours of storage in the rice cooker both on rice Inpari 43 GSR and Sembada Hitam because more suitable for consumption.

Keywords: black rice; white rice; sugar; starch; sensory evaluation

1. Introduction

Rice is the staple food for half of the world's population [1]. Based on color, rice is divided into three kinds, namely white rice (*Oryza sativa* L.), red rice (*Oryza nivara*), and black rice (*Oryza sativa* L. Indica) [2]. However, the most consumed rice by Indonesian people's white rice. Colored rice usually has a harder texture and tasteless sensation if compared with white rice, so it is less preferred by Indonesian people. Each kind of rice contains different components and benefits.

Black rice derived from black rice (*Oryza sativa* L. Indica) is a local variety that contains a different pigment from white rice or other colored rice. Besides the low glucose levels, black rice also has dietary fiber and hemicellulose content of 7.5% and 5.8%, greater than those of white rice which are only 5.4% and 2.2% respectively [3].

Diabetes Mellitus is one of degenerative diseases syndrome that has high prevalence rate. Lifestyle changes including consumption pattern is one of the causes of this diseases. Now people are starting to limit themselves to consume rice because of the high sugar content in rice. There are several methods of processing rice into cooked rice, namely the traditional method using cormorant and the modern method using rice cooker [4]. In this era of increasingly developing technology, the method of cooking rice using rice cooker is preferred because this method is considered more practical and easy.

In Indonesia, rice that has been cooked can be stored in two ways, namely in a plastic basket in room temperature and in a rice warmer such as a rice cooker. Storage of cooked rice using a rice cooker also aims to preserve rice by heat treatment. Nowadays there are many housewives who use electronic devices such as rice cookers for the purpose of processing rice into cooked rice. Apart from being a cooking tool, rice cooker is also used as a tool to store of cooked rice. Heat is used to raise the temperature of food and plays a role in the process of inhibiting microbial growth and increasing a chemical reaction, for example for enzyme inactivation. Therefore, heating is known as a method of food preservation. However, giving heat for a long time can result in a decrease in the quality of food, both in terms of physical and nutritional levels [5].

According to [6], storage of cooked rice in rice cookers can reduce the physical quality of rice. The decrease in the physical quality of the rice is marked by the color of the rice being yellow and the smell becoming rotten. In addition to changes in physical quality, cooked rice stored in rice cookers will also experience changes in the quality of nutritional levels, especially carbohydrate levels [7]. In the Indonesian community, there are various ways of limiting rice consumption to reduce sugar intake from food, including eating yesterday's cooked rice (sego wadang). There is an assumption that yesterday's cooked rice (sego wadang) can help control blood sugar levels, especially for people with type 2 Diabetes Mellitus and pre-diabetes. Scientifically this can be explained as a result of changes in temperature that affect the structure of starch in rice so that resistant starch, especially in the form of increasing in amylose levels [8,9]. In addition to affecting starch levels, the continuous heating process in rice will also cause a decrease in sugar levels in rice [10].

Based on the description above, several factors can affect changes in rice nutrient content during storage, namely the length of time and temperature of storage [11]. Research related to food storage (temperature and storage time) is very important so that we can store it properly so that its nutritional value is still good enough to be eaten. These results were studied by [12] on Baobab fruit (*Adansonia digitata* L.) juice showed that storage condition (temperature and storage time) affect the stability of natural flavonoids and their resulting antioxidant activity in food. Based

on the background above, it is necessary to study the effect of cooking process and storage method on sugar content, starch content and sensory preference level of white rice and black rice.

2. Materials and methods

Materials and testing were performed by the Laboratory of Food Biochemical Chemistry, Facultyof Agricultural Technology, Gajah Mada University, Yogyakarta, Indonesia. The materials used assamples in this study were white rice with a new superior variety, namely Inpari 43 Agritan GSR,obtained from Indonesian Center for Rice Research (ICRR) at Sukamandi, West Java planted onaluvial soil at an altitude of 40–50 m asl and black rice Sembada Hitam variety, obtained from farmer, Sleman, Yogyakarta planted on regosol soil at an altitue of 400–600 m asl.

The chemicals used for the analysis included Nelson A and B solution (25:1), distilled water, anhydrous glucose solution, arsenomolybdate solution, Pb-acetate solution, Na-oxalate solution, 30% HCl solution, 40% NaOH solution, standard amylose 40 mg/100 mL, 1 N acetic acid solution, 0.2% iodine solution, 95% ethanol solution, and 1 N NaOH solution.

The stage of this study was rice cooking, and the storage times for the two storage methods (in the rice cooker and outside the rice cooker) were 0, 9, 18, and 27 hours, respectively. Then, the sugar content, starch and sensory evaluation was performed on white and black rice samples stored in a certain manner and for a certain period of time rice. This test was carried out using 30 sample panelists, carried out with a hedonic rating test both from a sensory and physical perspective, which included the attributes of taste, aroma, texture, color, and overall. The hedonic rating test uses 6 rating scales, namely: very dislike (1), dislike (2), not very like (3), somewhat like (4), like and very like (5). The sensory testing method did not compare between the types of rice (black rice and white rice), and between types of treatment (method and duration of storage).The experimental design used was a factorial randomized design with 3 replications.

Rice preparation includes weighing of the rice, washing of the rice, adding water and cooking using rice cooker. Rice from each variety was weighed to an appropriate weight for testing, which was 250 grams. Afterwards, the rice was washed 2 or 3 times to make sure that the rice was clean from dirt and suitable for consumption [13]. Hence, the amount of water added in this study was 500 mL. Next, the cooking was done using rice cooker until the rice was fully cooked. Once fully cooked, let the rice rest for about 30 minutes before proceeding to the next step (Figure 1).

3. Results and discussion

3.1. Morphological of Sembada Hitam black rice and Inpari 43 Agritan GSR

The morphological quality of rice is strongly influenced by intermittent drying [14] and by the variety and level of fertilization [15]. The morphologies of Sembada Hitam black rice and Inpari 43 Agritan GSR are shown in Table 1. The thing that looks different (Table 1) from the two research materials is the color of the rice and the amylose content.

3.2. Effect of cooking on total sugar

The effect of the cooking process on the total sugar content in black rice Sembada Hitam and Inpari 43 GSR is shown in Table 2.

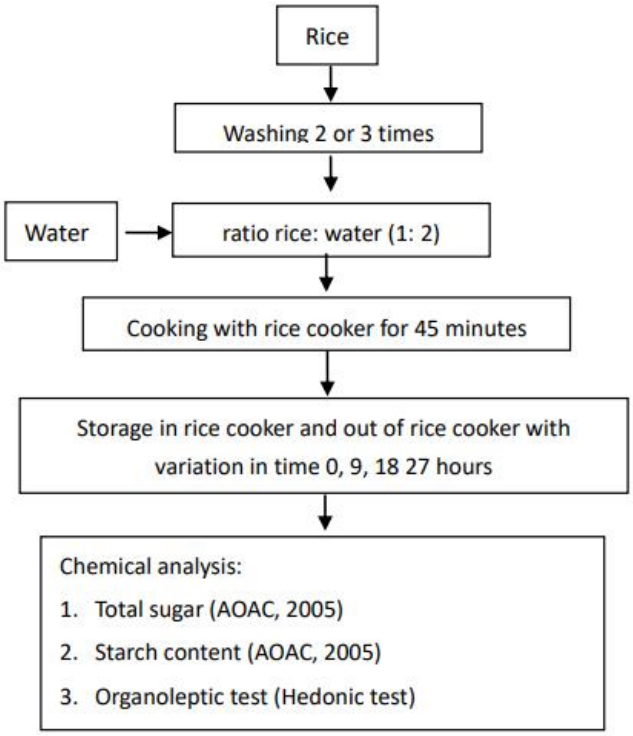


Figure 1. Rice preparations.

Table 1. Morphological of Sembada Hitam black rice and Inpari 43 Agritan GSR.

No.	Character	Variety	
		Sembada Hitam	Inpari 43
1	Origin of selection	Results of Mass Selection of Sembada Hitam black rice local population	Wufengzhan/IRBB5/Wufeng zhan
2	Group	Cere	Cere
3	Plant age	±140 days	±111 days
4	Plant shape	Erect	Erect
5	Plant height	±125 Cm	±88 Cm
6	Number of productive tillers	±10–15 panicle	±21 panicle
7	Culm colour	Green	Green
8	Colour of auricle	Purple stripe	No colour
9	Colour of ligule	White	No colour
10	Colour of culm	Green	Green
11	Colour of leaf blade	Green	Green
12	Leaf surface	Medium/Hair	Rough
13	Leaf attitude	Erect	Erect
14	Flag leaf: Attitude	Erect	Erect
15	Grain shape	Slim	Slim
16	Grain colour	Black stripe yellow	Yellow straw
17	Rice colour	Black	White

Continued on the next page

No.	Character	Variety	
		Sembada Hitam	Inpari 43
18	Rice shape	Slim	Slim
19	Panicle: Threshability	Medium	Medium
20	Lodging incidence	Hold	Hold
21	Yield potential	6.0 t/ha	9.02 ton/ha
22	Average yield	4.0–5.0 ton/ha	6.96 ton/ha
23	1000 grain weight	24.0 g	23.74 g
24	Rice texture	Very mushy	Mushy
25	Brown rice yield	72.97%	77.58%
26	Milled rice yield	65.52%	94.15%
27	Amylose content	5.891%	18,99%
28	Release of year	2019	2016
29	Minister of agriculture decree	125/HK.540ic/03/2019	369/Kpts/TP.010/6/2016

Table 2. Total Sugar of rice (before and after cooking).

Variety	Total sugar (mg/g db)	
	Before	After
Inpari 43 GSR	0.045	0.538
Sembada Hitam	0.035	0.185

Sugar white rice of the Inpari 43 GSR variety had higher total sugar content than black rice of the Sembada Hitam variety before and after cooking (Table 2). What's more, the analysis results show that the cooking process can increase the sugar content in rice. Before the cooking process, the total sugar content in white and black rice was 0.004% and 0.003%, while after the cooking process, the total sugar content in white and black rice increased to 0.053% and 0.018%respectively. The increase in total sugar content by an increase in temperature during the cooking process. According to [16] higher temperatures during the cooking process will result in the leaching process or damage to starch molecules due to hydrolysis. Hydrolysis is a decomposition reaction between a compound and water which causes the compound to break or decompose [4]. Starch molecules will be hydrolysed into their constituent compounds, namely glucose. The more effective the hydrolysis process is, the more glucose is produced. With the increase in glucose, the total found in rice also increases. The following is the hydrolysis reaction of starch to form glucose.

$$\underset{\text{Starch}}{(C_6H_{10}O_5)\,n} + n(H_2O) \longrightarrow \underset{\text{Glucose}}{n(C_6H_{12}O_6)}$$

Based on the results of the ANOVA, the DMRT follow-up test at the 5% real level, there Sig. of 0,000 for both varieties, so that the total sugar content in white and black rice before the cooking process has significant as compared with that after the cooking process.

3.3. Effect of cooking on total starch

Starch is a complex carbohydrate that is insoluble in water. The starch content after cooking is shown in Table 2. The starch content of white rice Inpari 43 GSR was higher than that of black rice Sembada Hitam before and after cooking (Table 3).

Table 3. Total Starch before and after cooking.

Variety	Starch content (%)	
	Before	After
Inpari 43 GS	92.35	76.58
Sembada Hitam	89.35	56.14

Analysis of starch content in rice showed that the cooking process could reduce the starch content. In rice before the cooking process, it can be seen that the starch content in white and black rice is 92.3527% and 89.3543% respectively. After cooking total sugar content of white rice and black rice dropped to 76.5794% and 56.141% respectively.

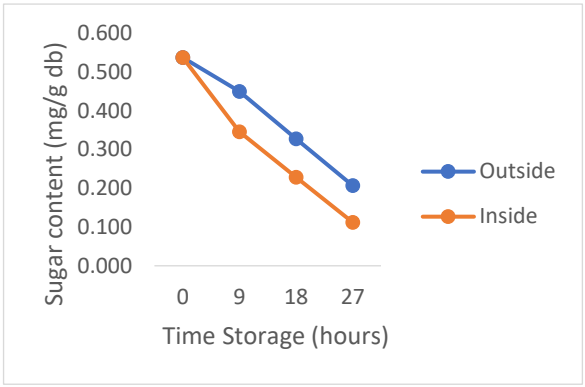
The heating process can cause the starch to transform into starch, resulting in more and more starch granules. Gelatinization is the process by which starch granules expand when heated in an aqueous medium. According to [17], gelatinization begins with the swelling of the starch is reversible (can return to its original form), but when the temperature increases, the swelling of the starch granules becomes irreversible. The condition of the swelling of the starch granules that is irreversible is called gelatinization. The swelling of the starch granules is caused by the diffusion of water into the are followed by the entry of water into the amorphous area, which results in the swelling of the granules.

The starch gelatinization process is influenced by the amount of water, temperature and heating time. The more water is added during the heating process, the more gelatinized the starch will be. Higher temperatures and longer heating duration can result in the development of more swollen starch granules and further breakdown of the starch granules, which are then evenly distributed. In this case, the starch polymer will be hydrolysed and broken so that it can cause a decrease in starch content.

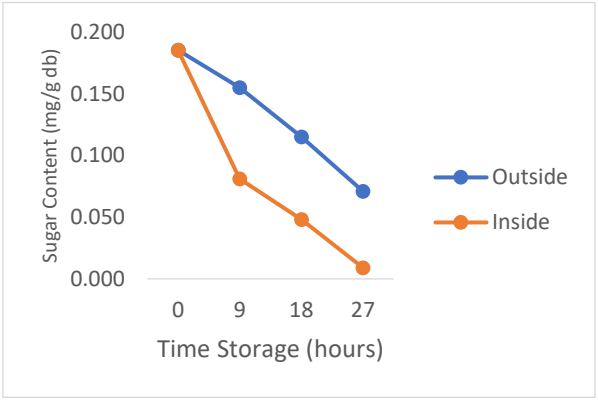
Based on the results of the ANOVA test and further tests with the DMRT method at the 5% level, there were found Sig. of 0.004 for the Inpari 43 variety and 0.001 for the Sembada Hitam variety. The Sig value of the two varieties was still lower than α, namely 0.05 so the starch content in Inpari 43 GSR and Sembada Hitam cooked rice before the cooking process had a significant difference from that after the cooking process.

3.4. Effect of storage methods on total sugar

The treatments in this study were the storage of the cooked rice in rice cooker and outside the rice cooker (room temperature) with a duration of 0, 9, 18 and 27 hours. Observation parameters include sugar, starch, and amylose levels. Effects of the storage process on the total sugar content of Inpari 43 and Sembada Hitam is shown in Figure 2.



(a)



(b)

Figure 2. Effect of storage methods on total sugar (a) white rice and (b) black rice.

Storage methods in the long term can reduce the total sugar content in the two types of rice varieties (Figure 2). The longer the storage time, the less the sugar content will be. The total sugar content before the storage process (0 hours) in Inpari 43 GSR variety was 0.0538%, which after the storage process of 27 hours decreased to 0.0207% for storage outside rice cooker and 0.0112% for storage inside rice cooker. On the other hand, for black rice variety Sembada Hitam, the total sugar content before the storage process (0 hours) was 0.0185%, and after the storage process for 27 hours, it decreased to 0.0071% for storage outside the rice cooker, and 0.0009% for storage in rice cooker. The sugar content of Inpari 43 GSR is higher than Sembada Hitam, so that a higher consumption of white rice is associated with an increased risk of developing diabetes [18];[19].

Storage of cooked rice in rice cooker causes a decrease in total sugar content which is larger than storage outside of rice cooker room temperature (27^{o}C). Therefore, the lowest total sugar content in both varieties is at 27 hours storage duration in rice cooker. This can happen because during storage in rice cooker there is a continuous heating process with a high enough temperature, which can cause damage to the compounds contained in rice so that the total sugar content is reduced.

Another factor that may lead to a decrease in the total sugar content of rice during storage is the growth of microorganisms in the stored rice. According to [20], rice that is stored both inside and outside of rice cooker can be overgrown with bacteria. This event is an important phenomenon because most microorganisms are capable of destroying food. Another factor that may lead to a decrease in the total sugar content of rice during storage is the growth of microorganisms in the stored rice. According

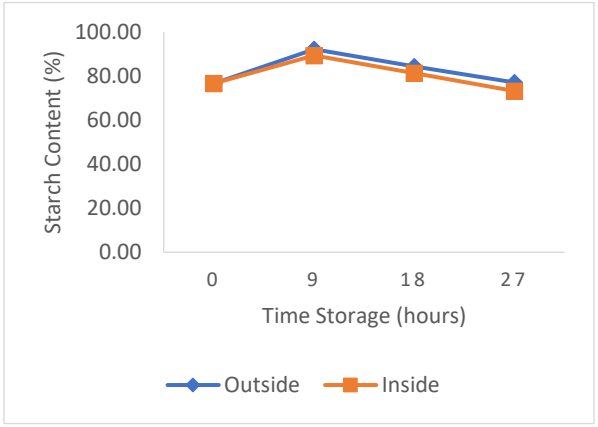
to [21], rice that is stored both inside and outside of rice cooker can be overgrown with bacteria. This event is an important phenomenon because most microorganisms are capable of destroying food.

The temperature presented during storage is the optimum temperature for the growth of mesophilic microorganisms. The longer a food or food is stored, the higher the number of microorganisms, and therefore the lower the total sugar content in these foods. To grow and survive, the microorganisms will break down the sugar in rice and convert it into energy. The growth of microorganisms can be seen with changes in the rice, such as the runny/slimy appearance of the rice, and the emission of an unpleasant (rotten) aroma.

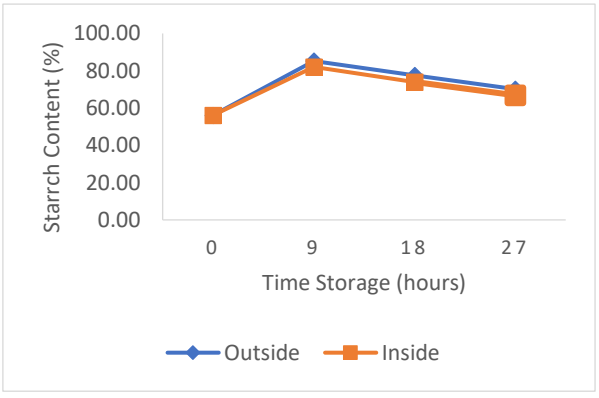
Based on the results of ANOVA and further tests with the Duncan method, in the Inpari 43 GSR variety, there were two treatments that had no significant difference in total sugar levels, namely the total sugar content at 9 hours' storage in rice cooker and 18 hours outside the rice cooker. At the same time, among the Sembada Hitam varieties, there were also two treatments with not significant difference in total sugar content, namely, the total sugar content stored in rice cooker for 9 hours and outside rice cooker for 27 hours.

3.5. Effect of storage methods on total starch

The starch content of Sembada Hitam and Inpari 43 GSR varieties in different ways and for different storage times is shown in Figure 3.



(a)



(b)

Figure 3. Effect of storage methods on total starch (a) white rice and (b) black rice.

Starch is the main component of rice, making up 90% of the total weight of the rice grain [10]. Based on Figure 3, it can be seen that the storage process in the two rice varieties can increase the starch content in the 9 hours of storage, both inside and outside the rice cooker, but then the starch content will decrease until the 27 hours. The highest starch content of the two varieties was the 9-hour storage time outside of rice cooker. The increase in starch content during storage for 9 hours was caused by the retrogradation process. According to [22], retrogradation is the process in which the starch gelatinized molecules begin to recombine to form a structure, and it is a process in which the linear polysaccharide chains dissolve and the molecular solubility decreases.

The retrogradation phenomenon is the result of hydrogen bonding between starch molecules that have a hydroxyl group and a hydrogen receiving side. In the early stages, two or more chains of starch molecules from simple bonds can expand in an orderly manner to form crystalline regions. By increasing the retrogradation process, it will also make the starch content even higher. The retrogradation process operates quickly and efficiently at low temperatures, so the increase in starch content in rice stored outside of magic corn will be higher.

The 18th and 27th hours of storage time, both on the outside and inside of rice cooker, reduced starch content. This event is due to continuous heating during storage in rice cooker. Alternative: The Prolonged heating at higher temperatures can revert the retrograded starch to gelatinized starch [23], in which case the starch polymers will be hydrolyzed and broken, causing damage to the carbohydrates. With increasing temperature, the amylose content and the number of short amylopectin decreased, while the intermediate amylopectin increased, resulting in an increase in starch gelatinization temperature and enthalpy [11]. The decrease in starch content along with the increase of storage duration can also be caused by the growth of microbes in the rice. The presence of microbial activity will make the stored rice undergo a change of carbohydrates from starch to simple sugars. The monosaccharide will then be used by the microbes for energy to develop and survive.

Based on the results of statistical analysis with ANOVA and further tests with the Duncan method, in the Inpari 43 GSR variety, there were two treatments that had no significant difference in starch content, namely the starch content at 0 hours storage and 27 hours storage outside the rice cooker. On the other hand, in Sembada Hitam variety, it was found to be significantly different for all storage treatments.

3.6. Sensory evaluation

An organoleptic test was performed on all samples with storage times of 0, 9, 18 and 27 hours. The test was carried out by 30 panelists which included aroma, color, texture, taste and overall parameters were carried out on cooked rice Inpari 43 GSR and Sembada Hitam varieties. The results of the sensory analysis showed a very significant difference when stored for 27 hours. The results of the sensory analysis are sown in Figure 4.

According to aroma parameter, Inpari 43 GSR cooked rice before storage, is preferred by panelists, compared to Sembada Hitam cooked rice. However, the aroma preference level for Inpari 43 GSR cooked rice which is stored inside and outside rice cooker decreased after 27 hours Sembada Hitam rice only slightly decreased the level of preference for aroma for 27 hours storage. High temperature storage causes volatile compounds such as aldehydes, ketones, and furans increase, so that the aroma of rice decreases during storage [24].

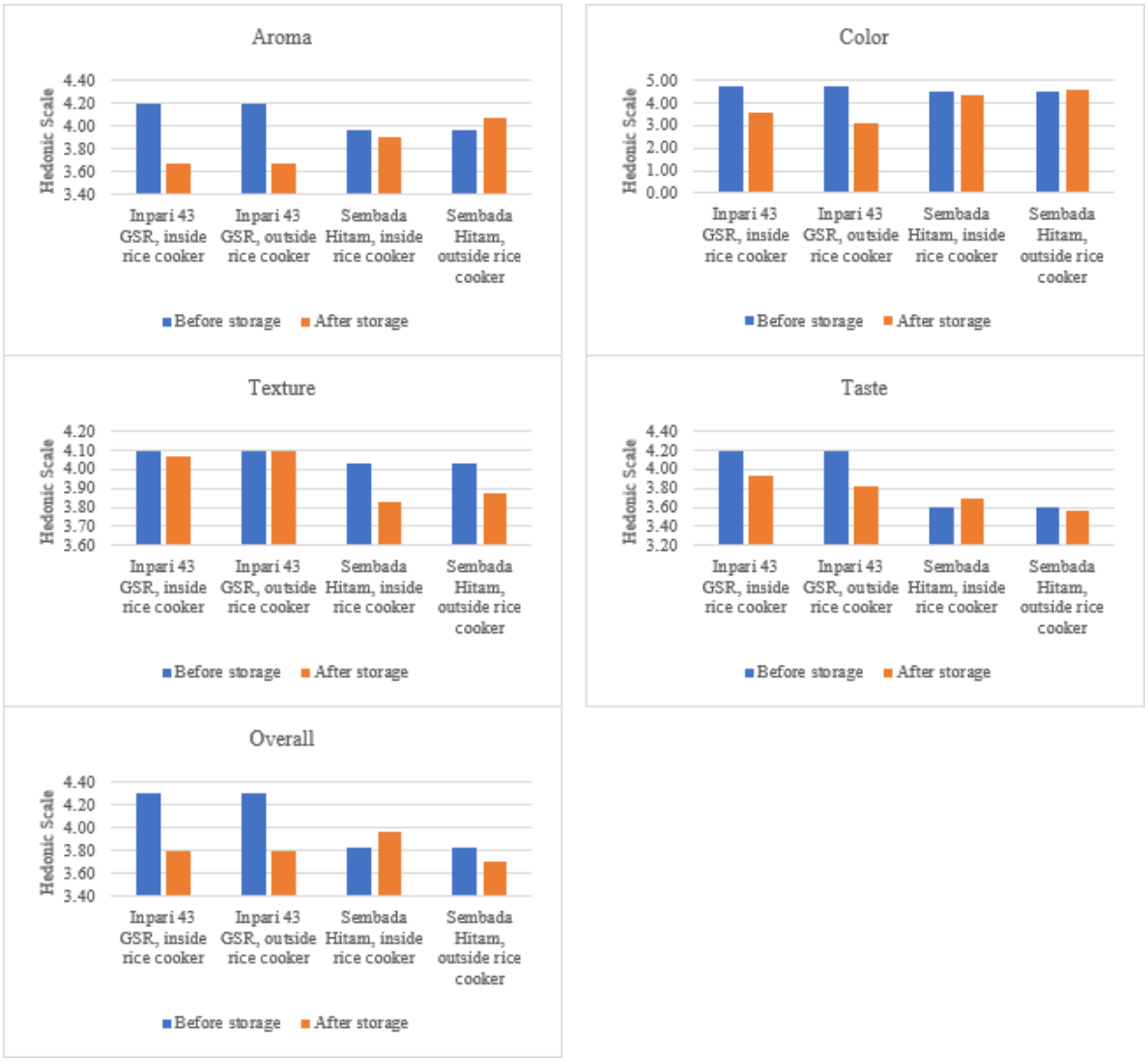


Figure 4. Sensory test of Inpari 43 GSR and Sembada Hitam cooked rice.

Panelists prefer Inpari 43 GSR to Sembada Hitam cooked rice. Inpari 43 GSR cooked which is stored outside rice cooker more decrease in color preference than that stored inside rice cooker. This means that the storage in rice cooker retains the color of the rice. Sembada Hitam cooked rice only slightly decreased its color preference level for 27 hours storage.

Panelists prefer the texture of Inpari 43 GSR to Sembada Hitam cooked rice, this means that the panelists prefer cooked rice with high starch content. Inpari 43 GSR cooked rice slightly decreased the level of texture preference for 27 hours storage. Storage temperature also has an important effect on the fraction of starch molecules in rice, related to the process of retrogradation or re-association in a regular/crystal form [25]. Meanwhile, Sembada Hitam cooked rice more decreased the texture preference level for 27 hours of storage. Storage of Sembada Hitam cooked rice in rice cooker further reduces the level of preference texture parameters, because the texture becomes softer.

The taste of Inpari 43 GSR cooked is preferred to Sembada Hitam cooked rice, this is because the panelists usually consume white rice so they do not like the taste of black rice. The taste of Inpari 43 GSR rice decreased during storage, especially if it was stored outside of rice cooker, the decrease

in taste was sharper than that stored inside rice cooker. Based on taste parameter, the level of preference of Sembada Hitam cooked rice increases after being stored 27 hours inside rice cooker and slightly decreases when stored outside rice cooker.

According to the overall parameters, Inpari 43 GSR rice is also preferred to Sembada Hitam rice. However, during 27 hours of storage inside and outside of the rice cooker, the preference level decreased. This means that Inpari 43 GSR cooked rice, after cooking or before storage is preferred over after storage. Meanwhile, Sembada Hitam cooked rice is preferred after being stored for 27 hours inside the rice cooker compared to freshly cooked or before storage. The process of cooking will affect the overall preference of rice, which is related to the cultural background and personal preferences of consumers [1,23,25].

4. Conclusions

The rice cooking process by using a rice cooker can affect the sugar levels and starch levels. Inpari 43 GSR cooked rice has a higher sugar content and starch content than that of Sembada Hitam. The method of storing cooked rice (inside and outside) of Inpari 43 GSR and Sembada Hitam varieties had no significant effect on total sugar content. Whereas the method of storing the cooked rice (inside and out) had a significant effect on the starch content of Sembada Hitam, while in the outside rice cooker had no significant effect on Inpari 43 GSR. The storage time generally reduces the preference level, Sembada Hitam cooked rice stored for 27 hours which is stored outside the rice cooker is more preferable over Inpari 43 GSR according to color and aroma parameters. Future research should investigated the effect of storage time and methods on the anthocyanin/flavonoid brown and black rice.

Acknowledgments

The authors express their gratitude to the Indonesian Agency for Agricultural Research and Development that has supported funding for this work through research project entitled Management of Specific Plant Genetic Resources in Yogyakarta Special Region and Dorotea Diaz Hapsari who has helped data collection and implementation of research activities.

Conflict of interest

No potential conflict of interest was reported by the authors.

References

1. Aalim H, Wang D, Luo Z (2020) Black rice (*Oryza sativa* L.) processing: Evaluation of physicochemical properties, in vitro starch digestibility, and phenolic functions linked to type 2 diabetes. *Food Res Int* 141: 109898. https://doi.org/10.1016/j.foodres.2020.109898
2. Batubara I, Maharani M, Sadiah S (2017) The potency of white rice (*Oryza sativa*), black rice (*Oryza saliva* L. Indica), and red rice (Oryza nivara) as antioxidant and tryosinase inhibitor. *J Phys: Conf Ser* 824: 012017. https://doi.org/10.1088/1742-6596/824/1/012017

3. Ok CJ, Jeong RH, Othani K, et al. (2001) Non-starch polysaccharides of cell walls in Glutinous rice, rice and black rice. *J Korean Home Econ Assoc* 39: 91–102.
4. Zhu L, Zhang H, Wu G, et al. (2020) Effect of structure evolution of starch in rice on the textural formation of cooked rice. *Food Chem* 342: 128205. https://doi.org/10.1016/j.foodchem.2020.128205.
5. Abraha B, Admassu H, Mahmud A, et al. (2018) Effect of processing methods on nutritional and physico-chemical composition of fish: A review. *MOJ Food Process Technol* 6: 376–382. https://doi.org/10.15406/mojfpt.2018.06.00191
6. Chavan P, Sharma SR, Mittal TC, et al. (2018) Effect of parboiling technique on physico-chemical and nutritional characteristics of Basmati rice. *Agric Res J* 55: 490–499. https://doi.org/10.5958/2395-146X.2018.00089.3
7. Zhou Z, Robards K, Helliwell S, et al. (2007) Effect of storage temperature on cooking behaviour of rice. *Food Chem* 105: 491–497. https://doi.org/10.1016/j.foodchem.2007.04.005
8. Wiruchi P, Naruenartwongsakul S, Chalermchat Y (2019) Textural properties, resistant starch, and in vitro starch digestibility as affected by parboiling of brown Glutinous rice in a retort pouch. *Curr Res Nutr Food Sci* 7: 555–567. https://www.foodandnutritionjournal.org/download/9414
9. He M, Qiu C, Liao Z, et al. (2018) Impact of cooking conditions on the properties of rice: Combined temperature and cooking time. *Int J Biol Macromol* 117: 87–94. https://doi.org/10.1016/j.ijbiomac.2018.05.139
10. Sofyan (2008) Changes in Glucose levels in Brown Rice and White Rice During Storage in a Heater. Treatise is not published. Teaching and Educational Sciences, University of Tadulako. Central of Sulawesi.
11. Chun A, Lee HJ, Hamaker BR, et al. (2015) Effects of ripening temperature on starch structure and gelatinization, pasting, and cooking properties in rice (Oryza sativa). *J Agric Food Chem* 63: 3085–93. https://doi.org/10.1021/jf504870p
12. Tembo DT, Holmes M, Marshall LJ, et al. (2022) Bioactive contents, antioxidant activities, and storage stability of commercially-sold baobab fruit (Adansonia digitata L) juice in Malawi. *J Food Chem&Nanotechnol* 7: 68–77. https://doi.org/10.17756/jfcn.2021-115
13. Mansouri-Nasrabadi R, Milani JM, Nazari SSJ (2018) Optimization of washing and cooking processes of rice for Ochratoxin A decrement by RSM. *Food Sci Nutr* 6: 2523–9. https://doi.org/10.1002/fsn3.860
14. Maldaner V, Coradi PC, Nunes MT, et al (2021) Effects of intermittent drying on physicochemical and morphological quality of rice and endosperm of milled brown rice. *LWT-Food Sci Technol* 152: 112334. https://doi.org/10.1016/j.lwt.2021.112334
15. Coradi PC, Müller A, André G et al. (2021) Effects of cultivars and fertilization levels on the quality of brown and polished rice. *Cereal Chem* 98: 1238–1249. https://doi.org/10.1002/cche.10476
16. Yu L, Turner MS, Fitzgerald M, et al. (2017) Review of the effects of different processing technologies on cooked and convenience rice quality. *Trends Food Sci Technol* 59: 124–38. https://doi.org/10.1016/j.tifs.2016.11.009
17. Thiranusornkij L, Thamnarathip P, Chandrachai A, et al. (2019) Comparative studies on physicochemical properties, starch hydrolysis, predicted glycemic index of Hom Mali rice and Riceberry rice flour and their applications in bread. *Food Chem* 283: 224–31. https://doi.org/10.1016/j.foodchem.2019.01.048

18. Bhavadharini B, Mohan V, Dehghan M, et al. (2020) White rice intake and incident diabetes: A study of 132,373 participants in 21 countries. *Diabetes Care* 43: 2643–50. https://doi.org/10.2337/dc19-2335
19. Adebamowo SN, Eseyin O, Yilme S, et al. (2017) A mixed-methods study on acceptability, tolerability, and substitution of brown rice for white rice to lower blood glucose levels among Nigerian adults. *Front Nutr* 4: 1–9. https://doi.org/10.3389/fnut.2017.00033
20. Aminudin M, Habib I (2009) The effect of storage time on bacterial growth in rice cooked in a rice cooker with steamed rice. *J Kedokt dan Kesehat* 9: 18–22.
21. Novianti M, Tiwow VMA, Mustapa K (2017) Analysis of glucose levels in white rice and corn rice using the 20 spectronic method. *J Akad Kim* 6: 107. https://doi.org/10.22487/j24775185.2017.v6.i2.9241
22. Iftikhar SA, Dutta H (2019) Status of polymorphism, physicochemical properties and in vitro digestibility of dual retrogradation-annealing modified rice starches. *Int J Biol Macromol* 132: 330–9. https://doi.org/10.1016/j.ijbiomac.2019.03.206
23. Syafutri MI, Pratama F, Syaiful F, et al. (2016) Effects of varieties and cooking methods on physical and chemical characteristics of cooked rice. *Rice Sci* 23: 282–6. https://doi.org/10.1016/j.rsci.2016.08.006
24. Zhao Q, Yousaf L, Xue Y, et al. (2020) Changes in flavor of fragrant rice during storage under different conditions. *J Sci Food Agric* 100: 3435–44. https://doi.org/10.1002/jsfa.10379
25. Pellegrini N, Vittadini E, Fogliano V (2020) Designing food structure to slow down digestion in starch-rich products. *Curr Opin Food Sci* 32: 50–7. https://doi.org/10.1016/j.cofs.2020.01.010

AIMS Press