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Effect of Soaking Time on the Physicochemical Characteristics, Antioxidant Activity, and Glycemic Index of Parboiled Local Cultivar Black Rice from West Sumatra

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***Abstract*— Black rice, originating from Sariak Alahan Tigo in Solok Regency, is one of the indigenous rice varieties found in West Sumatra. Black rice is a cereal variety that has a low glycemic index and is rich in phytochemical substances called anthocyanins. These compounds act as antioxidants, helping to prevent diabetes and preserve the cardiovascular system. The procedure of parboiling involves varying the period of grain soaking in order to maximize the health advantages of anthocyanins found in black rice. The study utilized a Completely Randomized Design (CRD) consisting of 5 treatments and 3 duplicates. The treatment protocol utilized in this experiment consisted of A (control), B (grain immersion for 2 hours), C (grain immersion for 3 hours), D (grain immersion for 4 hours), and E (grain immersion for 5 hours). The data acquired were evaluated using analysis of variance (ANOVA) and subsequently subjected to Duncan's Multiple Range (DNMRT) analysis at a significance level of 5%. The study findings indicate that the duration of grain soaking has a notable impact on various factors, including water content, starch levels, amylose and amylopectin levels, antioxidant activity, starch digestibility (in vitro), glycemic index values, taste, and texture. Nevertheless, the duration of grain soaking does not have any discernible impact on the physical hue, sensory hue, and fragrance of parboiled black rice. The treatment that is most favored according to the results of the sensory study is treatment D, which has a color rating of 3.86 (like), fragrance rating of 3.91 (like), taste rating of 3.91 (like), and texture rating of 3.81 (like).**

***Keywords*— antioxidant, black rice, glycemic index, parboiled rice**

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I. INTRODUCTION

Rice is the main nutritional staple for 97% of Indonesians. This illustrates the substantial dependence of the Indonesian populace on rice. The Indonesian population's dependence on rice is due to its attributes as a filling and satisfying staple food that possesses a delightful taste, is conveniently accessible, and can be prepared with ease [1].

In modern times, people are more and more attracted to consume various types of rice in addition to white rice. The rise in degenerative diseases, such as diabetes mellitus, can be ascribed to changes in individuals' lifestyles and dietary patterns [2]. In Indonesia, the prevalence of diabetes mellitus increased to 19.5 million individuals in 2021, as opposed to 10.7 million in 2019 [3]. As the number of people with diabetes mellitus has increased, there have been simultaneous efforts to prevent the development of the condition.

One of the prevention efforts for diabetes mellitus is to choose and eat healthy and appropriate foods, namely foods that not only meet the basic needs of the body but also have functional properties. The selection of the right food can be done through the glycemic index approach of food. The glycemic index (IG) is the level of food according to its effect on blood sugar, which aims to provide an overview of the relationship between carbohydrates found in food and blood glucose levels [4]. The glycemic index of a food can be influenced by several factors, namely the type of material and how it is processed, such as the processing of parboiled rice.

Parboiling is a method of processing rice that involves soaking and heating the grains using water and hot water vapor, followed by drying [5]. Parboiled rice is the product obtained by subjecting grains to the process of soaking, heating, and drying. The objective of the parboiling procedure is to enhance the nutritional content and physical characteristics of rice, as well as increase the yield obtained [6]. Parboiling rice involves the transfer of nutritious elements from the bran layer and husk, resulting in a modification of the rice's nutritional composition and an impact on its glycemic index.

Multiple investigations have documented parboiling procedures [7,8]. The main goal of parboiling is to achieve hydration of the grain by immersing it in water and applying heat, which leads to the gelatinization of the endosperm starch. [9]. An outcome of this pretreatment is a rise in moisture content to 35% (w.b.) [10]. The parboiling technique alters the physicochemical properties of grains and enhances the quality of rice [11,12,13,14].

Parboiled rice has various benefits compared to non-parboiled rice, including enhanced kernel integrity, higher milling recovery, preservation of nutrients during milling, improved shelf-life, and avoidance of fungal and insect growth. Nevertheless, parboiling has certain unfavourable consequences. Specifically, subjecting rough rice to high temperatures and extended steaming durations during parboiling typically results in a darker and firmer end product, which is less valuable in the market [9].

Making parboiled rice consists of five stages of the process, namely cleaning/sorting, soaking, heating, drying and milling. Cleaning/sorting is done to separate empty grain and unwanted foreign objects. Soaking aims to attach the nutritional components found in the rice aleurone to the rice endosperm. Soaking is carried out using water with a certain temperature and period of time. This is due to the temperature of the water used when soaking determines the speed of increase in moisture content.

According to Ref. [15] the soaking process carried out at ambient temperature (20-30^oC) takes 36-48 hours. While soaking at a temperature of 60-65^oC only takes 2-4 hours. [16] also stated that soaking at a temperature of 60^oC can increase the moisture content of grain faster than 30^oC at the same soaking time due to the influence of hot temperatures which trigger the opening of larger husk pores so that more water enters the rice endosperm. [17] also stated that soaking at 60 is an efficient temperature for the use of time and energy in the soaking process so that the water content is absorbed at 30% so that it can facilitate gelatinization during the heating process.

Meanwhile, the heating process is carried out at a temperature of 90^oC for 20 minutes with the aim of absorbing the aleurone part of the rice endosperm through the gelatinization process. The heating process causes gelatinization of the starch granules so that the aleurone layer diffuses into the endosperm part of the rice. This process can increase the binding ability so that the texture of the resulting parboiled rice is denser and not easily broken during the milling process.

Drying is carried out with the aim of reducing the moisture content in the grain to a moisture content of around 12-14% so as to facilitate the milling process [15]. The process of losing moisture content in grain causes recrystallization of starch molecules, namely changes in the texture of the paste into crystals (solid). This change causes the texture of rice to become sturdier and not easily broken when milled. Based on this, the yield of parboiled rice produced will be high.

One of the important stages in the process of parboiling is the soaking process [16]. Soaking serves to introduce water into the intercellular space of the starch cells of the rice endosperm starch. During soaking, water will be absorbed by the starch cells of the rice endosperm to a certain degree and sufficient for the gelatinization process [15]. According to Ref. [3], in the parboiling process, about 30% of the grain moisture content is needed for the gelatinization process to occur. Suppose the moisture content of the grain exceeds 30-32%. In that case, the husk skin can split due to the continuous gelatinized endosperm and a spike in water absorption, which can cause the nutritional components to dissolve out of the grain. Based on research conducted by [17], the parboiling process by soaking grain for 4 hours can reduce the glycemic index value of brown rice. However, soaking it for 4 hours produces brown rice with a low protein content. Therefore, soaking must be done optimally in order to produce parboiled rice with good nutritional characteristics and quality.

One of the local rice cultivars from West Sumatra is black rice originating from Sariak Alahan Tigo, Solok Regency [18]. Pigmented rice, such as black rice, contains a number of bioactive components, such as flavonoid compounds that can act as antioxidants.

Black rice is one type of cereal that has a low glycemic index value of 42.3 [19]. The low IG value of black rice is due to its high fibre content. In addition, black rice also contains phytochemical compounds in the form of anthocyanins found in the aleurone part of rice. Anthocyanins are one of the natural antioxidants that are very beneficial for the body, preventing diabetes and protecting the cardiovascular system [5]. Based on the description above, the author conducted a study. The purpose of the study was to determine the effect of long soaking of grain on the physicochemical characteristics, antioxidant activity, and glycemic index of parboiled black rice and to determine the length of grain soaking that produces the most preferred parboiled black rice product in terms of sensory.

II MATERIAL AND METHODS

A. Material

The raw material used in this study was dry-milled black rice grain obtained from Talang Babungo, Alahan Panjang. Other materials used for analysis are HCl 30%, boiling stone, NaOH 4 N, concentrated acetic acid solution, distilled water, luff school solution, KI solution 30%, H_2SO_4 25%, $Na_2S_2O_3$ 0.1 N, starch indicator 0.5%, ethanol 95%, NaOH 1 N, acetic acid 1N, iodine solution, phosphate buffer pH 7, alpha-amylase enzyme, DNS solution (dinitro salicylic acid), pure maltose, methanol, DPPH and glucose.

B. Methods

The design used in this study was a simple, Completely Randomized Design (CRD) with 5 levels of treatment and 3 repeats. The observational data were analyzed using variance analysis (ANOVA) with the F test and Duncan's New Multiple Range Test (DNMRT) at a real level of 5%.

The treatment used in this study was the length of grain soaking which was detailed as follows:

Treatment A : Soaking time for 0 hours (control)
Treatment B : Soaking time for 2 hours
Treatment C : Soaking time for 3 hours
Treatment D : Soaking time for 4 hours
Treatment E : Soaking time for 5 hours

C. Research Implementation

Making parboiled black rice (modified from [4]

Making Parboiled black rice starts with the process of cleaning dry milled black rice grain from unnecessary materials such as straw, gravel, and soil. Next, the grain is soaked in water at a temperature of 60-65°C using an electric pan. Then, the grain is heated for 20 minutes at 90oC using a water bath. After that, the grain is dried at a temperature of 90°C for 1.5 hours using a *food dehydrator*. The parboiled grain is then ground using *a husker* until it becomes broken rice skin and then tested for physicochemical properties, antioxidant activity, glycemic index, and sensory analysis.

Observation

Observations made on parboiled black rice are physical properties in the form of colour analysis [20] and chemical properties, including water content [21], starch content [22], amylose and amylopectin levels [23], antioxidant activity [4], and organoleptic [24]. Other observations on the best-treated products are starch digestibility (*in vitro*) [25] and glycemic index analysis [22].

III RESULT AND DISCUSSION

A. Color

Colour is one of the important quality attributes of food products. Color is also one of the first organoleptic attributes seen by consumers in buying and consuming a product. The determination of the color of parboiled black rice was carried out using the Hunterlab colorflex Ez spectrophotometer, which produced 3 color parameters with L*, a*, and b* notations. The results of the color analysis of parboiled black rice can be seen in **Table 1**.

TABLE 1
RESULTS OF COLOR ANALYSIS OF PARBOILED BLACK RICE

Treatment	L*	Hue° ± SD	Color
C (soaking 3 hours)	17.87	17.86 ± 0.17	*Red-purple*
D (soaking 4 hours)	18.39	18.39 ± 0.25	*Red-purple[-1]*
B (soaking 2 hours)	18.87	18.86 ± 0.92	*Red-purple[-2]*
A (control)	18.94	18.93 ± 0.17	*Red-purple[-3]*
E (soaking 5 hours)	19.00	18.99 ± 0.50	*Red-purple[-4]*
CV = 0.53%			

Description: The numbers in the same lane followed by different lowercase letters differ markedly according to DNMRT at the level of 5%.

The L* notation indicates the light of the panel resulting in white, gray and black. The a* notation indicates red (positive) and green (negative) chromatic values. The b* notation indicates the chromatic colors yellow (positive) and blue (negative). °Hue indicates the proportion of color in the material.

According to Ref [4], °hue values are grouped as follows.

°hue 18-24 = Red
°hue 54-90 = Yellow red
°hue 90-126 = Yellow
°hue 126-162 = Yellow green
°hue 162-198 = Green
°hue 198-234 = Blue purple
°hue 234-270 = Blue
°hue 270-306 = Blue purple
°hue 306-342 = Purple
°hue 342-18 = Red purple

Based on Table 1, it can be seen that the °hue value of Parboiled black rice ranges from 17.86 – 18.99%, which means that the color of Parboiled black rice has red-purple and red colors. The highest brightness value (L*) was found in treatment E (soaking, 5- hours) which was 19.00% while the lowest brightness value was found in treatment C (3-hour immersion) which was 17.87%. The color brightness value of parboiled black rice decreased with the increase in grain soaking time, but increased brightness again after soaking the grain for 4 hours. The physical color of parboiled black rice can be seen in **Fig. 1**.

Fig. 1 The physical color of parboiled black rice

The decrease in color brightness value in treatment C (3-hour soaking) is caused by the soaking process which results in more aleurone layers adhering to the rice endosperm. The aleurone layer in black rice has anthocyanin compounds that can give it a red, orange, purple or blue color. Black rice has aleurones and endosperm that produce anthocyanin pigments with high intensity so that rice is solid purple close to black [26]. While the increase in brightness value in parboiled black rice is caused by a soaking process that lasts long enough so that the anthocyanin color pigments contained in rice dissolve back in water.

Color changes can also be influenced by the sugar and amino acid content resulting from enzyme activity during the soaking process [27]. Reducing sugars react with amino acids during the soaking process, causing a non-enzymatic browning reaction that results in a darker color of parboiled black rice. This reaction takes place quickly at a temperature of 100°C with the moisture content of the material at 10-15%. The higher the given temperature, the browner the color will be because the formation of intermediate compounds is faster [28].

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B. Chemical Analysis

Water Content

Water is an important component of various foodstuffs. Water content in food determines the acceptance and durability of these foods [29]. Rice with high moisture content will be easily damaged and degraded during storage. The results of the moisture content analysis of parboiled black rice can be seen in Table 2.

Table 2 shows the length of grain soaking has a significant effect on the moisture content of parboiled black rice. The moisture content of Parboiled black rice ranges from 10.13 – 12.87%. The highest value is treatment A (control), which is 12.87%, and the lowest value is treatment B (2 hours immersion), which is 10.13%. The moisture content of parboiled black rice increases along with the increase in the length of the soaking grain.

TABLE 2
PARBOILED BLACK RICE WATER CONTENT

Treatment	**Water Content (%) ± SD**
B (soaking 2 hours)	10.13 ± 0.12 a
C (soaking 3 hours)	10.47 ± 0.12 b
D (soaking 4 hours)	10.73 ± 0.12 c
E (soaking 5 hours)	11.07 ± 0.12 d
A (control)	12.87 ± 0.31 e
CV = 0.31%	

Description: The numbers in the same lane followed by different lowercase letters differ markedly according to DNMRT at the level of 5%.

The soaking process causes an increase in water content during parboiling, which results in more water being absorbed and bound so that the water content of rice increases. The hot temperature during soaking triggers the opening of the pores of the husk to become larger so that more water enters the rice endosperm [30]. Ref [30] mentioned that immersion with high temperatures can cause disruption of hydrogen bonds and weaken the micellar structure of starch granules so that water more easily penetrates into the endosperm. Water absorption into the endosperm during soaking aims to meet the minimum moisture content for the gelatinization process at the grain heating stage, which is limited to 35%.

The water content of parboiled black rice is lower than that of black rice without Parboiled. This is due to the higher levels of amylose in parboiled black rice compared to black rice without parboiled rice. Gelatinization of starch causes starch granules to break and amylose molecules come out which then the amylose hydroxyl group will bind to water thus affecting the water content in parboiled black rice. The higher the amylose content, the more water is absorbed and bound to rice starch because the amylose hydroxyl group is hydrophilic [29, 34].

The difference in the percentage of moisture content can also be affected by the fiber content in a material. The higher the fiber content, the higher the moisture content of a material. This is due to the large content of fiber hydrophilic groups and large water-binding capacity. According to Ref. [21], the maximum moisture content in rice is 14%; this means that the water content of Parboiled black rice has met the requirements.

Starch Content
Starch is the largest component contained in carbohydrates. Starch is a homopolymer of glucose with alpha-glycosidic bonds. Starch consists of two fractions that can be separated with hot water. The dissolved fraction is called amylose and the undissolved fraction is called amylopectin [4]. The results of the analysis of Parboiled black rice starch levels can be seen in **Table 3.**

TABLE 3
STARCH CONTENT OF PARBOILED BLACK RICE

Treatment	Starch (%) ± SD
A (control)	70.55 ± 0.52 a
B (soaking 2 hours)	70.92 ± 0.47 b
C (soaking 3 hours)	71.29 ± 0.47 c
D (soaking 4 hours)	72.23 ± 0.18 d
E (soaking 5 hours)	73.18 ± 0.11 e
CV = 0.11%	

Description: The numbers in the same lane followed by different lowercase letters differ markedly according to DNMRT at the level of 5%.

Based on Table 3, it can be seen that the length of grain soaking has a significant effect on the starch content of Parboiled black rice. The longer the soaking time, the higher the starch content of Parboiled black rice. The starch content of parboiled black rice ranges from 70.55 – 73.18%. The highest value was found in treatment E (soaking 5 hours), while the lowest value was found in treatment A (control). The increase in starch levels is caused by a heating process that results in the breaking of the amylopectin branch chain into straight chains such as amylose. During the heating process, there is a random breaking of alpha-1,4 bonds on the inside of starch molecules in either amylose or amylopectin resulting in short-chain oligosaccharides. The starch formed is modified starch obtained from the process of partial hydrolysis of starch using heat. This increase is also affected by changes in starch structure after undergoing gelatinization during grain heating. The structure of starch changes to a crystalline structure that causes starch not to dissolve easily during heating [31].

In addition, changes in starch levels can be influenced by a decrease in the nutritional value of foods such as protein in boiled black rice due to the soaking process using heat for a long period of time. The longer the processing time, the more nutritional value will decompose and dissolve in water and water evaporation will also increase [33]. Based on the results of Newton et al.'s research in Ref. [27] that the starch formed in parboiled rice is influenced by the interaction between varieties and the conditions of the parboiled process.

Amylose and Amylopectin
Starch consists of two components, namely amylose and amylopectin. Amylose is a linear (straight) glucose polymer connected by alpha-1,4-glycosidic bonds, while amylopectin is a linear glucose polymer connected by alpha-1,4-glycosidic bonds and forms branching on alpha-1,6-glycosidic bonds. Amylose and amylopectin are always found simultaneously in foodstuffs, but in different ratios [29]. According to Ref. [27], the Parboiled process can increase the amylose content in rice. The results of amylose content analysis of parboiled black rice can be seen in **Table 4.**

TABLE 4
AMYLOSE LEVELS OF PARBOILED BLACK RICE

Treatment	Amylose (%) ± SD
A (Control)	27.07 ± 1.31 a
B (Soaking, 2 hours)	39.66 ± 1.72 b
C (Soaking, 3 hours)	45.38 ± 0.99 c
D (Soaking, 4 hours)	51.39 ± 1.31 d
E (Soaking, 5 hours)	57.68 ± 2.58 e
CV = 0.76%	

Description: The numbers in the same lane followed by different lowercase letters differ markedly according to DNMRT at the level of 5%.

It can be seen that the length of grain soaking has a significant effect on the amylose levels of parboiled black rice. The longer the soaking time, the amylose levels of parboiled black rice increase (Table 4). Based on the table above, the amylose content of Parboiled black rice ranges from 27.07 – 57.68%. The increase in amylose levels in parboiled black rice is influenced by the heating process which results in gelatinization and changes in starch structure. The heating process causes the breaking of hydrogen bonds in the amylopectin fraction from branched structures to linear or unbranched structures such as amylose [28].

The highest amylose levels were found in treatment E (5-hour soaking) while the lowest amylose levels were found in treatment A (control). According to Ref. [32], based on its amylose content rice can be classified into rice with high amylose (25 – 33%), rice with medium amylose (20 – 25%), rice with low amylose (9 – 20%), and rice with very low amylose (<9%). Based on this, parboiled black rice can be classified as rice with high amylose.

The ratio of amylose and amylopectin in rice is the most important factor in determining the quality of taste and texture of rice. The higher the amylose content, the larger the volume of rice obtained without a tendency to deflate. This is due to the greater retrogradation ability of amylose compared to amylopectin. Retrogradation is the recrystallization of starch granules that have undergone gelatinization when stored, dried or cooled [29]. The results of the analysis of amylopectin levels of parboiled black rice can be seen in **Table 5.**

TABLE 5
AMYLOPECTIN LEVELS OF PARBOILED BLACK RICE

Treatment	**Amylopectin (%) ± SD**
E (soaking, 5 hours)	15.49 ± 2.61 a
D (soaking, 4 hours)	20.84 ± 1.20 b
C (soaking, 3 hours)	25.91 ± 0.66 c
B (soaking, 2 hours)	31.26 ± 1.54 d
A (control)	43.49 ± 0.82 e
CV = 1.12%	

Description: The numbers in the same lane followed by different lowercase letters differ markedly according to DNMRT at the level of 5%.

Based on Table 5, it can be seen that the longer the soaking time, the lower the amylopectin levels. The highest amylopectin levels were found in treatment A (control) while the lowest amylopectin levels were found in treatment E (5-hour soaking). This is in accordance with the results of amylose levels of Parboiled black rice obtained. The higher the amylose level, the lower the amylopectin level.

The digestibility of starch (in vitro)
The digestibility of starch is the level of ease with which starch can be hydrolyzed by the alpha-amylase enzyme into simpler units and can be absorbed by the body [34]. Determination of starch digestibility was carried out *in vitro* on Parboiled black rice with the best treatment, namely soaking grain for 3 hours and compared to treatment A, namely black rice without Parboiled (control). Treatment C (soaking 3 hours) is determined as the best treatment based on the results of organoleptic analysis by taking into account the results of physicochemical analysis. The results of the digestibility analysis of Parboiled black rice starch can be seen in **Table 6.**

TABLE 6
RESULTS OF STARCH DIGESTIBILITY ANALYSIS OF PARBOILED BLACK RICE

Treatment	***Starch digestibility* (%)**
A (Control)	15.46
C (soaking, 3 hours)	5.46

Table 6 shows that treatment A (control) has a higher digestibility of 15.46% compared to treatment C (3-hour immersion) which is 5.46%. This occurs due to retrogradation of starch after undergoing gelatinization and structural changes during the soaking and heating process. According to Ref. [28] resistant starch found in parboiled rice is resistant starch formed due to starch retrogradation after gelatinization. Retrogradation causes amylose and amylopectin that previously had an amorphous structure to change to a crystalline structure that is more resistant to digestive enzymes.

During the heating process, starch also undergoes complexation of lipid-amylose. The formation of complexes occurs due to the interaction between the lipid hydrocarbon chain with the hydrophobic part of the amylose chain and meets the central cavity of the single amylose helix. This complexation causes starch to become resistant to hydrolysis of digestive enzymes (amylolytics**) [35]**. Tetens et al. (1997) in [27] stated that parboiled rice has more resistant *starch* compared to rice without Parboiled.

Based on its speed to be digested, starch is divided into 3 groups, namely rapidly digestible starch (*RDS),* slowly digestible starch (*SDS) and resistant* starch (RS). Resistant starch is starch that is resistant to hydrolysis by digestive enzymes. Some resistant starches exist naturally and some are formed by the processing process. Resistant starch can reduce the digestibility of starch and have a positive impact on the colonic environment, which can be food for probiotics. Therefore, it can be said that the low digestibility of starch from Parboiled black rice is due to the high content of rice resistant starch.

Differences in digestibility of starch can be affected by fiber. During the parboiling process, fiber dispersion occurs from the aleurone layer and institutions into the rice endosperm so that the digestibility of parboiled black rice starch becomes low. Dietary fiber can physically block the work of the alpha-amylase enzyme, thereby reducing the ability of the enzyme to digest starch. In addition, the digestibility of rice starch can be affected by its amylose and amylopectin content. Rice that has a high amylose content will be slower to digest because of the straight-chain amylose structure so that the bond is stronger and more difficult to gelatinize [36].

Antioxidant activity

Antioxidant activity is the process of inhibition of free radicals by antioxidant compounds [26]. Antioxidant compounds found in black rice are anthocyanins that give dark purple color to black rice [37]. The results of the analysis of the antioxidant activity of parboiled black rice can be seen in **Table 7.**

TABLE 7
ANTIOXIDANT ACTIVITY ANALYSISI OF PARBOILED BLACK RICE

Treatment	Antioxidant activity (%) ± SD
E (soaking, 5 hours)	50.70 ± 0.23 a
D (soaking.4 hours)	52.69 ± 0.12 b
C (soaking. 3 hours)	54.99 ± 0.36 c
B (soaking. 2 hours)	57.40 ± 0.49 d
A (control)	61.22 ± 0.23 e
CV = 0.11%	

Description: The numbers in the same lane followed by different lowercase letters differ markedly according to DNMRT at the level of 5%.

Table VII shows that the length of soaking of grain has a significant effect on the antioxidant activity of parboiled black rice. The average antioxidant activity of parboiled black rice ranges from 50.70 – 61.22%. The highest value was found in treatment A (control) while the lowest value was found in treatment E (soaking 5 hours). The decrease in antioxidant activity is caused by the process of pratzing using heat over a relatively long span of time. This suggests that antioxidants are susceptible to the heating process.

Anthocyanins which play an important role as antioxidant compounds in black rice have water-soluble properties and undergo *leaching* during the soaking process, resulting in decreased antioxidant activity of Parboiled black rice. The grain drying process also causes a decrease in antioxidant activity because drying is carried out at a temperature of 90°C, resulting in antioxidant compounds in rice degrading. According to Hernawan et al., (2008) in [38] the higher the the heating temperature, the lower total anthocyanin.

Glycemic index (in vivo)

The glycemic index (IG) is the level of food according to its effect on blood sugar levels. Foods that raise blood sugar quickly have a high glycemic index, while foods that raise blood sugar slowly have a low glycemic index [39]. The glycemic index can also be defined as the ratio between the area of the food glucose response curve equivalent to 50 g of carbohydrates to the area of the glucose response curve after consuming 50 g of pure glucose. The test is carried out in the morning after fasting for 12 hours and the determination of blood sugar levels is determined for 2 hours. The wider the area under the curve, the higher the glycemic index. The glycemic index of rice is generally used as a dietary guideline for people with type II diabetes [1] The results of the glycemic index analysis of Parboiled black rice can be seen in **Table 8.**

TABLE 8.
RESULTS OF GLYCEMIC INDEX ANALYSIS OF PARBOILED BLACK RICE

Respondent	Area Curve (Parboiled Black Rice)	Area Curve (Pure Glucose)	IG
1	15	3660	0.41
2	645	1800	35.83
3	1185	3315	35.75
4	1260	3945	31.94
5	705	4200	16.79
6	330	3675	8.98
7	1065	2475	43.03
8	750	5100	14.71
9	2505	8280	30.25
10	15	1965	0.76
Score IG			21.85

Table 8 shows the area under the curve of 10 respondents after consuming steamed rice from Parboiled black rice with grain soaking for 3 hours (best treatment) and pure glucose. Based on the results of the analysis, it is known that the glycemic index of Parboiled black rice of 21.85 is included in the low category. According to the results of research by Ref. [19], black rice has a glycemic index value of 42.3. This shows that the Parboiled process has an effect on the glycemic index value of black rice. The Parboiled process results in a starch structure crystallization process that increases resistant starch levels which has an impact on decreasing the glycemic index value [40]. The decrease in glycemic index in this study was supported by data on increased amylose levels and decreased digestibility of starch in *vitro*.

Some factors that affect food IG include the processing process, the ratio of amylose and amylopectin, sugar content, digestibility of food, fiber content, fat, protein and food antinutrition [39]. Different amylose and amylopectin structures cause different digestibility. Amylose has an unbranched structure so that amylose is bound more firmly. Starch granules containing a lot of amylose have a more crystalline structure. This makes amylose difficult to gelatinize and difficult to digest. In addition, amylose easily crystallizes and undergoes retrogradation which is difficult to digest. Amylopectin has a branched structure with a larger and open molecular size so that it is easier to gelatinize and digest. Starch that is digested and absorbed by the body will cause an increase in blood sugar levels. High digestibility of starch will accelerate the breakdown of carbohydrates into glucose which affects the glycemic response in metabolic processes [41].

The glycemic index is also affected by resistant starch. Consumption of foods containing resistant starch results in a decreased blood glucose response resulting in a decrease in the glycemic index. Resistant starch found in parboiled black rice is type III resistant starch formed due to retrogradation of starch after gelatinization. Retrogradation causes amylose and amylopectin to undergo a structural change from amorphous to crystalline which is more resistant to digestive enzymes [17].

C. Sensory

Color

Color is the first sensory property that can be assessed directly by panelists [42]. A product can be judged nutritious and tasty through the color of the product. Attractive colors will also make the product more liked and in demand by panelists. The results of fingerprints at the level of 5% showed that the treatment of variations in the length of grain soaking had no significant effect on the organoleptic color of rice from the resulting parboiled black rice. The results of organoleptic assessment of boiled rice color from parboiled black rice can be seen in **Table 9.**

TABLE 9.
AVERAGE VALUE OF FAVORABILITY FOR BOILED RICE COLOR FROM PARBOILED BLACK RICE

Treatment	Color ± SD
A (Control)	3.52 ± 1.08
B (soaking 2 hours)	3.67 ± 0.86
C (soaking 3 hours)	3.81 ± 0.75
D (soaking 4 hours)	3.86 ± 0.48
E (soaking, 5 hours)	3.91 ± 0.54
CV = 3.95%	

Description: 1=strongly dislike, 2=dislike, 3=ordinary, 4=like, 5=very like

Based on Table 9, it can be seen that the average assessment of panelists on the color of rice from Parboiled black rice ranges from 3.52 – 3.91. The lowest value of 3.52 was found in treatment A (control) while the highest value of 3.91 was found in treatment E (soaking 5 hours). The color of boiled rice from parboiled black rice is preferred compared to the color of rice from black rice without Parboiled. The final boiled rice yield of parboiled black rice can be seen in **Fig. 2.**

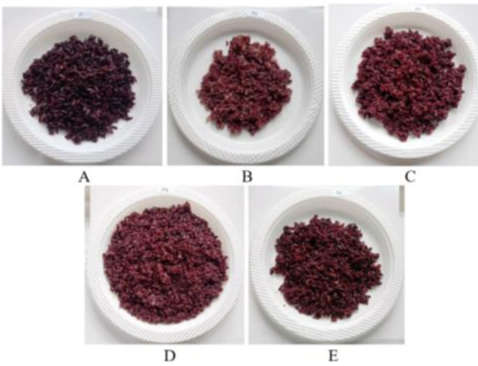

Fig. 2. The final rice yield of Parboiled black rice

This color difference is caused by the Parboiled process in rice, namely soaking and heating the grain using heat which results in the aleurone layer adhering to the rice endosperm [4]. The more layers of aleurone attached to the endosperm, the browner the color of the rice. In addition, soaking temperature also affects the formation of rice color because high temperatures result in the amino acid content of lysine or proteins containing lysine will more easily react to form intermediate compounds and produce melanoidin pigments [28]. The longer the soaking time of the grain, the darker the color of the rice from the resulting Parboiled black rice.

Aroma

Aroma is a determining factor for the acceptability of panelists because a product with a distinctive and attractive aroma will affect the interest of panelists. The results of organoleptic assessment of rice aroma from Parboiled black rice can be seen in **Table 10.**

TABLE 10
AVERAGE VALUE OF FAVORABILITY FOR RICE AROMA FROM PARBOILE BLACK RICE

Treatment	Aroma ± SD
A (Control)	3.52 ± 0.68
E (Soaking, 5 hours)	3.76 ± 0.83
C (Soaking, 3 hours)	3.86 ± 0.57
B (Soaking, 2 hours)	3.91 ± 0.63
D (Soaking, 4 hours)	3.91 ± 0.63
CV = 21.91%	

Description: 1=strongly dislike, 2=dislike, 3=ordinary, 4=like, 5=very like

Table 10 shows that the length of soaking has non-significantly effect on the aroma of parboiled rice. The average panelists' rating of the aroma of rice from Parboiled black rice ranged from 3.52 – 3.91 (likes). Treatment D (4-hour immersion) had the highest value while treatment A (control) had the lowest value. This shows that panelists can still receive the aroma of the resulting Parboiled black rice. Rice from black rice Parboiled has almost the same aroma as rice from black rice without Parboiled. This is caused by the soaking and heating process during Parboiled, resulting in nutrients contained in the husk will enter the rice endosperm and make the parboiled rice have a slight husk aroma. Rice from broken Parboiled black rice has a slight husk aroma because the bran layer is still attached to the endosperm [4].

Taste

Taste is an important organoleptic attribute and can influence a consumer's final decision to accept or reject a product. Taste assessment is more determined subjectively which is influenced by region, environment, education and group level [29]. The results of organoleptic assessment of the taste of Parboiled black rice can be seen in Table 11.

TABLE 11
AVERAGE VALUE OF LIKING FOR THE TASTE OF RICE FROM BLACK RICE PARBOILED

Treatment	Taste ± SD
A (control)	3.14 ± 0.91a
E (soaking, 5 hours)	3.57 ± 0.87ab
B (soaking, 2 hours)	3.67 ± 0.80b
C (soaking, 3 hour	3.76 ± 0.89b
D (soaking,4 hours)	3.91 ± 0.70b
CV = 3.95%	

Description: - 1=strongly dislike, 2=dislike, 3=ordinary, 4=like, 5=very like. The numbers on the same strip are followed by unequal lowercase letters, differing markedly according to DNMRT at the level of 5%.

The data presented in Table 11 indicates that the average evaluation of the taste of parboiled black rice by the panelists ranged from 3.14 to 3.91. The treatment with the highest value was D, where the soaking time was 4 hours, with a score of 3.91 (likes). Conversely, the treatment with the lowest value was A, which served as the control, with a score of 3.14 (usual). The mean participant exhibited a preference for the flavor of Parboiled black rice over black rice without Parboiled. Rice derived from non-Parboiled black rice exhibits a relatively mild flavor in contrast to rice derived from Parboiled black rice. The rice obtained from black rice is parboiled, with cracked skin and no breakage. The parboiled skin has a subtle bitter flavor. This occurs because the bran layer is connected to the rice endosperm. According to Ref [4], rice bran contains saponin compounds that can cause a bitter taste. This difference in taste can also be influenced by non-enzymatic browning reactions and is related to the higher nutritional components attached to the rice endosperm [43].

Texture

The texture of rice is divided into pera rice and fluffy rice. Pera rice is rice that has a hard and dry texture after cooling, is not sticky and has a larger volume than fluffy rice. Fluffy rice is rice that has a soft texture even though it is cold, stickier than pera and shiny rice [29]. The results of organoleptic assessment of rice texture from Parboiled black rice can be seen in Table 12

TABLE 12
. AVERAGE VALUE OF LIKING FOR THE TEXTURE OF RICE FROM PARBOILED BLACK RICE

Tratment	**Texture ± SD**
A (control)	2.67 ± 0.91a
E (soaking, 5 hours)	3.43 ± 0.93b
C (soaking, 3 hours)	3.67 ± 0.86b
B (soaking, 2 hour)	3.76 ± 0.94b
D (soaking, 4 hours)	3.81 ± 0.87b
CV= 4.66%	

Description: 1=strongly dislike, 2=dislike, 3=ordinary, 4=like, 5=very like. The numbers on the same strip are followed by unequal lowercase letters, differing markedly according to DNMRT at the level of 5%.

Based on the Table 12, it can be seen that the panelists' assessment of the rice texture of parboiled black rice ranged from 2.67 – 3.81. The highest value was found in treatment D (soaking 4 hours) while the lowest value was found in treatment A (control). The average panelist preferred the texture of rice from black rice Parboiled compared to rice from black rice without Parboiled. The texture of rice from black rice parboiled is harder and drier after cold and more fluffy compared to rice from black rice without Parboiled. The amylose content of rice will affect the texture of the resulting rice. Rice with high amylose content will produce pera rice [4]. The higher the amylose content, the easier retrogradation will occur because hydrogen bonds in amylose are easier to form compared to amylopectin [28].

A recapitulation of the sensoric assessment of rice from Parboiled black rice can be seen in **Fig. 3.**

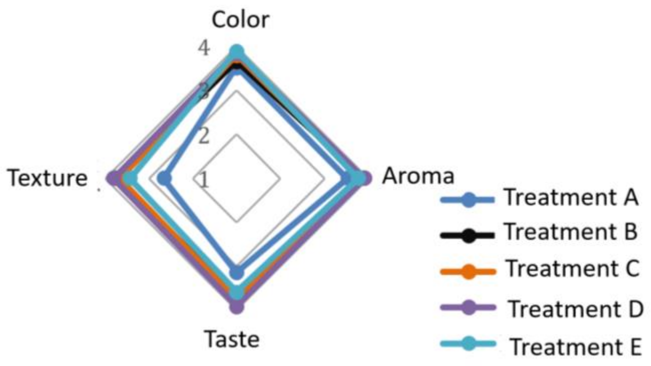

Fig. 3 Sensoric assessment of steamed rice from Parboiled black rice

Based on the chart above, it can be seen that the most preferred rice from parboiled black rice is rice from Parboiled black rice with grain soaking treatment for 4 hours. Panelists' overall preference for rice from parboiled black rice was color = 3.86; aroma = 3.91; taste = 3.91; and texture = 3.81

IV. CONCLUSION

The length of soaking of grain has a significant effect on the characteristics of parboiled black rice such as moisture content, starch content, amylose and amylopectin levels, starch digestibility, antioxidant activity, glycemic index, taste and texture. But it does not exert a noticeable influence on the characteristics of color and aroma. The most preferred parboiled black rice based on organoleptic analysis is parboiled black rice with a soaking duration of 4 hours with average values, namely: color 3.86 (like), aroma 3.91 (like), taste 3.91 (like), and texture 3.81 (like).

Based on the research that has been done, the author suggests that further researchers should conduct further studies on the physical quality of parboiled black rice and changes in the quality of parboiled black rice during storage, and research needs to be done to reduce the aroma of husks in parboiled black rice.

REFERENCES

[1] Novalina, Efrianti, R., & Sari, Y. (2022). The Effect Of Intensification of Rainfed Paddy Rice on the Production of Rainfed Paddy Rice in Martapura Sub-District, East OKU Regency. *AJARCDE (Asian Journal of Applied Research for Community Development and Empowerment)*, *7*(1), 123-131. https://doi.org/10.29165/ajarcde.v7i1.230

[2] Indrasari, S. D., Purwani, E. Y., Wibowo, P., & Jumali. 2008. Nilai Indeks Glikemik Beras Beberapa Varietas Padi. Penelitian Pertanian Tanaman Pangan, 27, 127–134

[3] Mahdi, M. Ivan. 2022. Penderita Diabetes Indonesia Terbesar Kelima di Dunia. https://dataindonesia.id/ragam/detail/penderita-diabetes-indonesia-terbesar-kelima-di-dunia. [07 October 2023].

[4] Marsela, G. 2019. Karakteristik Sifat Fisik-Kimia, Indeks Glikemik dan Profil Sensori Beras Ungu Parboiled. [Skripsi]. Padang: Fakultas Teknologi Pertanian. Universitas Andalas. 72 hal.

[5] Patria, D. G., Sukamto, & Sumarji. 2021. Rice Science and Technology. Malang: Literasi Nusantara Abadi. 155 p.

[6] Binalopa, T., Hasbullah, R., & Ahmad, U. 2019. Proses Parboiled dan Teknik Penggilingan untuk Mempertahankan Mutu Beras Merah (Oryza nivara). September.

[7] Oli P, Ward R, Adhikari B, Torley P. Parboiled rice: understanding from a materials science approach. J Food Eng. 2014;124:173–83.

[8] Buggenhout J, Brijs K, Celus I, Delcour JA. The breakage susceptibility of raw and parboiled rice: a review. J Food Eng 2013;117:304–15.].

[9] Ebrahim Taghinezhad, Mohammad Hadi Khoshtaghaza*, Saeid Minaei and Asefeh Latifi Effect of Soaking Temperature and Steaming Time on the Quality of Parboiled Iranian Paddy Rice.

[10] Das I, Das SK, Bal S. Specific energy and quality aspects of infrared (IR) dried parboiled rice. J Food Eng 2004;62:9–14.].

[11] Islam MR, Shimizu N, Quality KT. Evaluation of parboiled ricewith physical properties. Food Sci Technol Res 2001;7:57–63.

[12] Bhattacharya KR. Parboiling of rice. In Juliano BO, editor. In rice chemistry and technology. Minnesota: American Association of Cereal Chemists, Inc, 1985:289–348.

[13] Bhattacharya S. Kinetics on colour changes in rice due to parboiling. J Food Eng 1996;29:99–106.

[14] Wu D, Shu Q, Wang Z, Xia Y. Effect of gamma irradiation on starch viscosity and physicochemical properties of differentrice. Radiat Phys Chem 2002;65:79–86.]

[15] Hasbullah, R., Fadhallah, E. G., Almada, D. P., Koswara, S., & Surahman, M. 2016. Teknologi Pengolahan dan Pengembangan Usaha Beras Parboiled. 339–353.

[16] Fadhallah et al., (2016) also stated that soaking at a temperature of 60oC can increase the moisture content of grain faster than 30oC at the same soaking time due to the influence of hot temperatures which trigger the opening of larger husk pores so that more water enters the rice endosperm.

[17] Nurdjannah, R., Apriliani, S. A., & Widowati, S. 2018. Penurunan Indeks Glikemik Beras Parboiled dengan Bahan Baku Gabah Kering Panen (GKP). Jurnal Penelitian Pascapanen Pertanian, 15(2), 106–114.

[18] Indra Dwipa, Irfan Suliasyah, Auzar Syarif, and Etti Swasti. Exploration and Characterization of Brown Rice Germplasms in West Sumatra IJASEIT Vol.4 (2014) No. 3).

[19] Agustina, A. W., & Anjani, G. 2017. Cookies Tepung Beras Hitam dan Kedelai Hitam sebagai Alternatif Makanan Selingan Indeks Glikemik Rendah. Journal of Nutrition College, 6, 128–137.

[20] Kaemba, A., Suryanto, E., & Mamuaja, C. F. 2017. Karakteristik Fisiko-Kimia dan Aktivitas Antioksidan Beras Analog dari Sagu Baruk (*Arenga microcarpha*) dan Ubi Jalar Ungu (*Ipomea batatas* L. Poiret). *Jurnal Ilmu dan Teknologi Pangan*, *5*(1).

[21] BSN. 2015. SNI 6128:2015 Beras.

[22] Yenrina, R. 2015. *Metode Analisis Bahan Pangan dan Komponen Bioaktif*. Padang: Andalas University Press. 158 hal.

[23] Muchtadi, T. R., Sugiyono, & Ayustaningwarno, F. 2010. *Ilmu Pengetahuan Bahan Pangan*. Bandung: Alfabeta. 324 hal.

[24] Suryono, C., Ningrum, L., & Dewi, T. R. 2018. Uji Kesukaan dan Organoleptik terhadap 5 Kemasan dan Produk Kepulauan Seribu secara Deskriptif. *Jurnal Pariwisata*, *5*(April), 95–106.

[25] Pangastuti, H. A., & Permana, L. 2021. Pengukuran Pati Resisten Tipe 5 secara *In Vitro* pada Nasi Uduk. *Jurnal Pengolahan Pangan*, *6*(2), 42–48.

[26] Azis, A., Izzati, M., & Haryanti, S. 2015. Aktivitas Antioksidan dan Nilai Gizi dari Beberapa Jenis Beras dan Millet sebagai Bahan Pangan Fungsional Indonesia. Jurnal Biologi, 4(1), 45–61.

[27] Yulianto, W. A. 2020. Teknologi Pengolahan Beras Parboiled. Sleman: Deepublish. 108 hal.

[28] Apriliani, S. A. 2016. Karakteristik Beras Parboiled yang Terbuat dari Gabah Kering Panen dan Gabah

Kering Giling. [Skripsi]. Bogor: Fakultas Teknologi Pertanian. Institut Pertanian Bogor. 52 hal.

[29] Ummah, R. 2016. Perubahan Mutu Gizi dan Daya Cerna Pati Berbagai Varietas Padi di Sumatera Barat Melalui Proses Parboiled. [Skripsi]. Padang: Fakultas Teknologi Pertanian. Universitas Andalas. 65 hal.

[30] Fadhallah, E. G., Hasbullah, R., & Nugroho, L. P. E. 2016. Pengaruh Lama Pengukusan terhadap Mutu Fisik Beras Parboiled pada Beberapa Varietas Gabah. Jurnal Keteknikan Pertanian, 4, 187–194. Https://Doi.Org/10.19028/Jtep.04.2.187-194

[31] Wulan, S. N., Widyaningsih, T. D., & Ekasari, D. 2007. Modifikasi Pati Alami dan Pati Hasil Pemutusan Rantai Cabang dengan Perlakuan Fisik/Kimia untuk Meningkatkan Kadar Pati Resisten pada Pati Beras. Jurnal Teknologi Pertanian, 8(2), 80–87.

[32] Koswara, S. 2009. Teknologi Pengolahan Beras (Teori Dan Praktek). eBookPangan.com

[33] Rusda. 2019. Perbedaan Nilai Indeks Glikemik Beras Putih (Oryza sativa) Varietas Ir-64 dengan Cara Pemasakan Menggunakan Rice Cooker dan Dandang.

[34] Nurhidajah, Astuti, M., Sardjono, Murdiati, A., & Marsono, Y. 2015. Kadar Serat Pangan dan Daya Cerna Pati Nasi Merah yang Diperkaya Kappa-Karagenan dan Ekstrak Antosianin dengan Variasi Metode Pengolahan. 207–214.

[35] Pangastuti, H. A., & Permana, L. 2021. Pengukuran Pati Resisten Tipe 5 secara In Vitro pada Nasi Uduk. Jurnal Pengolahan Pangan, 6(2), 42–48.

[36] Dewi, T. K. 2023. Penetapan Kadar Amilosa pada Beberapa Beras Hitam (Oryza sativa L.) Lokal Jawa Barat. Jurnal Teknologi Pangan dan Ilmu Pertanian, 1(2), 64–69.

[37] Sudarwati, S. 2016. Prospek Pengembangan Beras Hitam di Kabupaten Brebes, Jawa Tengah. 508–512.

[38] Bumi, S. A. P., Aminah, S., & Yusuf, M. 2020. Aktivitas Antioksidan, Kadar Serat dan Karakteristik Fisik Beras Hitam Pecah Kulit Parboiled dengan Variasi Lama Waktu Perendaman. Jurnal Pangan dan Gizi, 10(02), 85–98.

[39] Akhyar. 2009. Pengaruh Proses Parboiled terhadap Mutu Gizi dan Indeks Glikemik Berbagai Varietas Beras Indonesia. [Tesis]. Bogor: Institut Pertanian Bogor. 124 hal.

[40] Margono, Hanifah, F., Safitri, A. A., Ts, B. S., Paryanto, Waluyo, J., Susanti, A. D., & Setyono, P. 2020. Menurunkan Indeks Glikemik Beras Putih Melalui Proses Parboiled. 4(2).

[41] Hasnelly, H., Fitriani, E., Ayu, S. P., & Hervelly, H. 2020. Pengaruh Drajat Penyosohan terhadap Mutu Fisik dan Nilai Gizi Beberapa Jenis Beras. Agritech, 40(3), 182–189.

[42] Spetriani. 2019. Kajian Teknologi Proses Pengolahan Beras Parboiled (Parboiling Rice) pada Gabah Varietas Situ Bagendit. 1–67.

[43] Susilo, N., Hasbullah, R., & Sugiyono. 2013. Proses Pengolahan Beras Parboiled Memperbaiki Kualitas dan Menurunkan Indeks Glikemik Gabah Varietas Ciherang. 2, 209–219.