IMPROVEMENT OF RED RICE EATING QUALITY THROUGH ONE-TIME POLISHING PROCESS AND EVALUATION ON ITS PHENOLIC AND ANTHOCYANIN CONTENT

Zahara Mardiah
Indonesian Center for Rice Research
Indonesian Agency for Agricultural Research and Development
Email: zahara.mardiah@yahoo.com

Elis Septianingrum
Indonesian Center for Rice Research
Indonesian Agency for Agricultural Research and Development
Email: elis.septianingrum@gmail.com

Dody D. Handoko
Indonesian Center for Rice Research
Indonesian Agency for Agricultural Research and Development
Email: dodyhandoko@gmail.com

Bram Kusbiantoro
Indonesian Center for Rice Research
Indonesian Agency for Agricultural Research and Development
Email: hbram_kusbiantoro@yahoo.com

ABSTRACT

Red rice is generally consumed in the form of brown rice which the cooked rice has rather firm texture and tend to separated so that become less desirable by consumers. The polishing process can be done to improve the eating quality of red rice, but also eliminate the phenolic and anthocyanin compounds contained. This study aimed to investigate the influence of a one-time polishing process (half-aleurone removal) on eating quality and its effects on phenolic and anthocyanin compounds. The information gained from this study was expected to be valuable in helping consumers change the habit of eating white rice to red rice in their daily diet. Red rice varieties used were Inpari24 and Inpara7 obtained from Indonesian Center for Rice Research (ICRR). The analyses performed were sensory analyses including scoring test and hedonic test; and analysis on total phenolic content (TPC) and total anthocyanins content (TAC). The one-time polishing process produced rice called half polished rice (HPR). Scoring test results indicated that the cooked brown rice (BR) of Inpari24 and Inpara7 both considered by the panelists had the same firm texture. After one-time polishing process, the texture of cooked HPR of Inpari24 and Inpara7 were assessed by the panelists became very soft and soft, respectively. Furthermore, the cooked HPR was preferred by the panelist compared to cooked BR based on texture attribute. The TPC analysis showed that Inpari24 possessed higher TPC compared to Inpara7 i.e. 1,589 and 1263 mg GAE/100g DW, respectively. The one-time polishing process decreased the TPC content where the highest decreasing occured in Inpari24 followed by Inpara7 i.e. 54% (30% TAC dan 24% other phenolic compounds) and 34% (29% TAC and 5% other phenolic compounds), respectively. The one-time polishing process improved the red rice eating quality but reduced its phenolic content up to 54%. For consumers who prefer nutritional value rather than eating quality then consumed red rice without polishing process would be the beneficial choice. However, for consumers who are not accustomed with BR eating quality, then the transition period by consuming HPR might provide assistance for them to convert to red rice.

Keywords: polishing process, eating quality, red rice, sensory analysis, phenolic content.

INTRODUCTION

Rice is a staple food in many countries in the world, one of those is Indonesia. Rice has a different color, depending on their genetic. The color of the rice is formed by differences in the genes that regulate the color of aleuron, the color of endosperm, and the composition of starch in the endosperm. In general, there are 2 types of rice based on their color namely white rice and pigmented rice. The pigmented rice contains phenolic compounds especially anthocyanin that also act as a color pigment. The anthocyanin compounds in rice are in the form of cyanidin-3-O-glucoside, peonidine-3-O-glucoside and their derivatives (Escribano et al., 2004; Wang et al., 2008). There are two colors of pigmented rice; rice with reddish-grain color is commonly called red rice, while rice with a purplish grain color is called black rice. The purple color in black rice is due to aleurone and endosperm producing high-intensity anthocyanins.

White rice generally dominates the rice market, however, the consumers are now more interested in pigmented rice. Nowadays, rice is considered not only as staple food but also as a functional food that could provides health effects (Indrasari et al. 2009). Some studies have shown that anthocyanin compounds in addition to their role as a source of color pigment in rice also play as antioxidant that preventing various diseases such as diabetes (Ghosh, 2007), heart (Wang et al, 2007), and cancer (Wang & Stoner, 2008).

Pigmented rice usually consumed as brown rice because the aleurone contains phenolics and anthocyanins. Brown rice is easily become rancid since the aleurone layer contains lipids. But the main issue of brown rice is that the cooked rice has a texture that describes as firm, chewy, hard, and loose grains. As the major concern to the customer is the eating quality of rice thus cooked brown rice becomes less desirable by consumers. The eating quality of red rice makes it difficult and challenging for consumers to eat red rice every day as they eat white rice.

There are several factors that affect the eating quality i.e. rice variety, cultivation condition, postharvest handling, and milling degree (Morrison & Azudin, 1987). Champagne et al. (1997) and Park et al. (2001) indicated that cooked rice flavor attributes, as determined by a sensory panel, were influenced by milling degree. Instrumental firmness and hardness of cooked rice decreased as the milling degree increased (Mohapatra & Bal, 2006; Saleh & Meullenet, 2007).

Rice undergoes milling process to improve its eating quality, physical characteristics, as well as to improve its storage stability (Monks et al., 2013). Milling process is a process involving mainly two steps namely dehusking process and polishing process. In dehusking process, the outermost layer of rough rice is removed which will generate brown rice. Afterwards, the aleurone attached to endosperm of brown rice will be completely removed from grain surface, this process is known as polishing. In small scale milling company normally brown rice will go through polisher twice to completely remove the aleurone.

In the case of red rice, polishing process raises polemic. Thorough polishing process certainly will eliminate all anthocyanins since aleurone is the layer where anthocyanins accumulated. On the other hand, the eating quality of red rice becomes less favored if without polishing. For people who are used to eat red rice may assume the eating quality is not an issue when compared to the nutritional content. But for those who are not used to eat it then the improvement of red rice eating quality is needed. A one-time polishing process by which the polishing done only once may improve the eating quality of pigmented rice while minimizing the loss of anthocyanin. Cooper and Siebenmorgen (2007) concluded that milling rice to lesser degrees means allowing more bran on rice grain, can lead to a better nutritional value

This study aimed to evaluates the influence of one-time polishing process to the eating quality of red rice and its effects on the content of phenolic and anthocyanins content. Information obtained from the results of this study was expected to be useful in assisting consumers to convert to red rice from white rice.

MATERIALS AND METHODS

Material

The research was conducted in Flavor Laboratory of Indonesian Center for Rice Research (ICRR), Indonesia. The materials used were two popular red rice varieties in Indonesia namely Inpari24 and Inpara7 obtained from ICRR. Those varieties were grown in Sukamandi Experimental Station and harvested in 2016. Both varieties were prepared as Brown Rice (BR) and Half Polished Rice (HPR) and analyzed at least 3 months after harvest.

Sample Preparation

The husk of dry paddy (14% moisture content) was removed using a small scale milling company husker machine (Agrindo) to obtain brown rice (BR). Afterwards, brown rice undergone one-time polishing process using commercial polisher (ICHI N70) to obtain half polished rice (HPR). Samples were then analyzed for sensory, total phenolic content (TPC), and total anthocyanin content (TAC)

Sensory Analyses

The sensory analyses includes hedonic test and scoring test. All rice samples were cooked with household rice cooker with ratio of rice and water 1: 2. Rice was served to 30 semi-trained panelists. Panelists were required to assess each sample based on some attributes including color, aroma, texture, translucency and taste. The rating scales for hedonic test were 1 (very like), 2 (like), 3 (medium), 4 (dislikes), and 5 (very dislike), while the rating scales for the scoring test started from 1 to 5 with the number definition depend on each attribute. Drinking water was provided for the panelists to neutralize their tongue before switched to other samples. Sensory data processing was based on the Mode or number that most often appears on the assessment in each test attribute.

Sample extraction for TPC and TAC analyses

As much as 5 grams of rice grain was extracted with 10 mL MeOH absolute then placed in ultrasonic bath for 30 minutes. The mixture was centrifuged at 10,000 rpm for 30 min at 15 °C. The supernatant was collected.

Total Phenol Content (TPC)

Total phenolic content was analyzed by the *Folin–Ciocalteu* colorimetric method. A total of 80 µl of supernatant was pipetted into tube containing 2 ml miliQ water and then added with 200 µl of *Follin-Ciocalteu* reagent 0.25 N. The sample was allowed to stand for 3 minutes then 1 ml of Na_2CO_3 7.5% was added. Afterwards, the solution was incubated in dark place for 2 hours at room temperature and finally the absorbance was measured at 765 nm using spectrophotometer (UV-Spektrofotometer 1800 Shimadzu). TPC was calculated using standard curve of gallic acid and expressed as Gallic Acid Equivalent (GAE) per 100 gr dry weight.

Total Anthocyanin Content (TAC)

1 mL of supernatant was diluted with pH 1.0 buffer KCl to 10 mL final volume. In different tube, another 1 mL of supernatant was diluted with pH 4.5 buffer Na-asetat to 10 mL final volume. The absorption of both diluted sample was measured at 510 nm and 700 nm. The results were expressed as mg of cyanidin-3-O-glucoside (cy-3-glu) equivalents per 100 gr dry weight. Total anthocyanin content (TAC) was calculated using formula:

$$TAC = \frac{A \times MW \times DF \times 1000}{\varepsilon \times 1}$$

Error! Digit expected.
where:
$A = (A_{510\ m} - A_{700\ nm})_{pH\ 1.0} - (A_{510\ nm} - A_{700\ nm})_{pH\ 4.5}$
MW represents molecular weight of cyanidin-3-glucoside (449.2). DF is dilution factor, ε is molar extinction of cyanidin-3-glucoside (26,900 L/mol cm).

RESULTS AND DISCUSSION

The polishing process undertaken in small scale rice milling company. Usually pigmented rice such as red rice and black rice are eaten as brown rice. However, since it has an issue on eating quality thus in this research brown rice was inserted to polisher only once to remove half of its aleurone, so called one-time polishing process. The rice generated from one-time polishing process is called half polished rice (HPR). The difference between milled rice and HPR is on the milling degree. According to Indonesian National Standard of Rice Quality no.6128-2015, the meaning of milling degree is the amount of losing pericarp, testa, and aleurone layers from rice grain stated in percentage (National Standardization Agency of Indonesia, 2015). It means that brown rice (rice without polishing) has milling degree 0% while milled rice has milling degree 100%.

In regard to Indonesian National Standard, the milling degree of HPR was calculated by comparing the weight of aleurone loss after the one-time polishing process with the total aleurone weight. Based on these calculations, it was known that the milling degree of HPR varies depend on the rice varieties. The milling degree of HPR Inpari24 was 56% while on Inpara7 was 46%. The formula used in calculating the milling degree of HPR was as follows:

$$Milling\ Degree\ (\%) = \frac{Weight\ of\ BR - Weight\ of\ HPR}{Weight\ of\ BR - \ Weight\ of\ MR}\ x\ 100$$

Where :
BR : Brown rice
HPR : Half polished rice
MR : Milled rice (two times polishing)

The eating quality of cooked rice is influenced by several factors such as varieties, milling degree, and methods of processing. The sensory analysis is one method to evaluate a commodity subjectively which commonly used to determine the eating quality. The sensory analyses performed in this study were scoring and hedonic test. The scoring test aims to provide value based on the preferred choice of panelist while the hedonic test is to evaluate the acceptances and preferences of the panelist on the rice samples. Sensory analyses were performed on cooked rice of BR and HPR using assessments of approximately 30 semi-trained panelists.

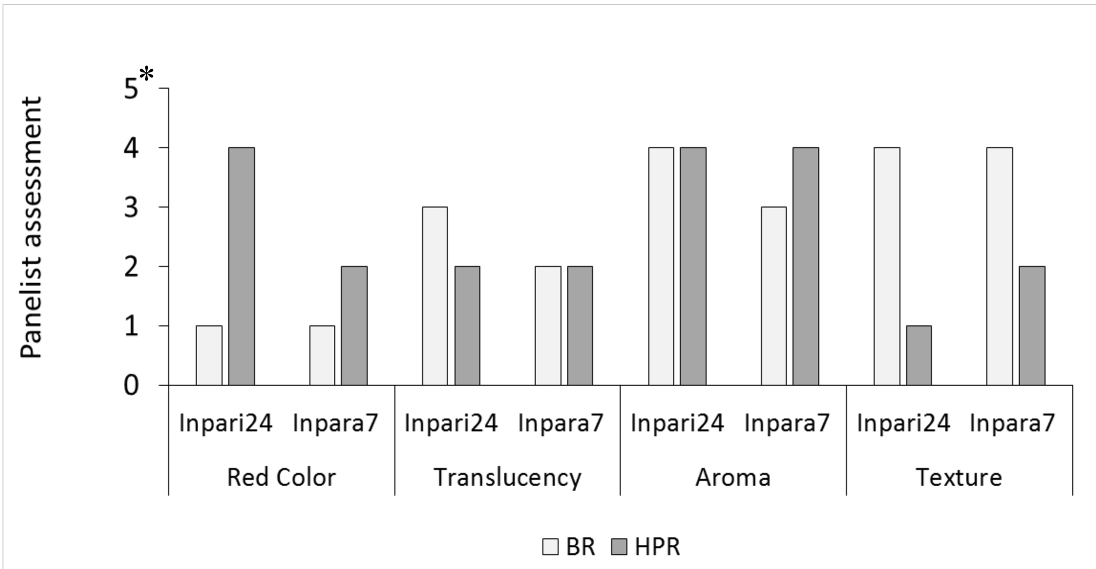
The scoring test performed for attributes color, translucency, aroma, and texture. Scoring test results showed that cooked BR of both Inpari24 and Inpara7 had the same very red color. After one-time polishing process, panelists assessed the red color of the HPR of both varieties was lesser in which red color of Inpari24 HPR more faded than that of Inpara7 (Figure 1). This results confirmed the statement that degree of milling can affect the color of rice milled because only the surface of brown rice contains pigments (Chen & Siebenmorgen, 1997; Champagne et al., 2004). Polishing caused removal of the aleurone layer and since anthocyanin that acts as red pigment of rice accumulates in the aleurone layer hence the red color of red rice also decreases.

Panelist assessed cooked BR of Inpara7 had a slightly fragrant aroma however its cooked HPR had neutral aroma. In the meantime, the panelist assessed the aroma of inpari24 BR and HPR was the same as neutral aroma (Figure 1). Rice grain has more than 200 volatile compounds nevertheless 2-acetyl-1-pyrroline (2-AP) is believed to be the most eminent aroma compound in rice (Buttery et al., 1982). 2-AP has a popcorn-like aroma and has a much lower threshold value (< 0.1 ppb in water) than other volatile compounds found in the aromatic rice varieties (Adams and Kimpe, 2006). According to some reports, the aleurone layer of rice contains higher amounts of 2-AP than the endosperm (Buttery et al., 1983; Buttery et al., 1986). In this study, we found that the aroma of rice perceived by the panelist changed from fragrant to neutral after the aleuron layer partially removed. The loss of this fragrant led to the hypothesis that instead of the entire aleurone part, the aromatic compounds may accumulate only or mostly in its outer part.

Red rice usually consumed in a form of BR that has harder texture compared to milled rice thus make red rice less desirable (Rafael et al., 2014). The BR cooked rice texture of both Inpari24 and Inpara7 was considered by the panelists as Firm (chewy, separated and not sticky). After one-time polishing process, the texture of HPR cooked rice of Inpari24 and Inpara7 were assessed by the panelists changed to very soft and soft, respectively. (Figure 1).

The level of texture improvement was different on Inpari24 and Inpara7. The texture of cooked BR Inpari24 improved from skor 4 (firm) to skor 1 (very soft) while the texture of cooked BR Inpara7 improved from skor 4 (firm) to skor 2 (soft). It seems that the extent of the milling degree effect on cooked rice texture was dependent on rice variety. The improvement of cooked rice texture in HPR might be due to the reduction or loss of fiber along with the loss of aleurone layer. The increase in cooked rice stickiness with increasing milling degree was attributed to an increase in starch leaching during cooking because of the greater starch granule swelling associated with a better water uptake (Saleh & Meullenet, 2007). Desikachar et al. (1965) stated that water absorption into brown rice is hindered as a result of fat and wax in the bran. Specifically, a component of the outer surface of bran namely hydrophobic waxy cuticle could create a physical barrier to water absorption (Champagne et al., 2004). The loss of bran layer will make the water more easily absorbed into the rice grain allowing it to create a better texture of rice. This result was in line with Mohapatra & Bal (2006) that reported the milling degree influenced the instrumental hardness and adhesiveness of cooked rice.

Figure 1. The scoring test of brown rice (BR) and half polished rice (HPR) of Inpari24 and Inpara7



*Numbers meaning:

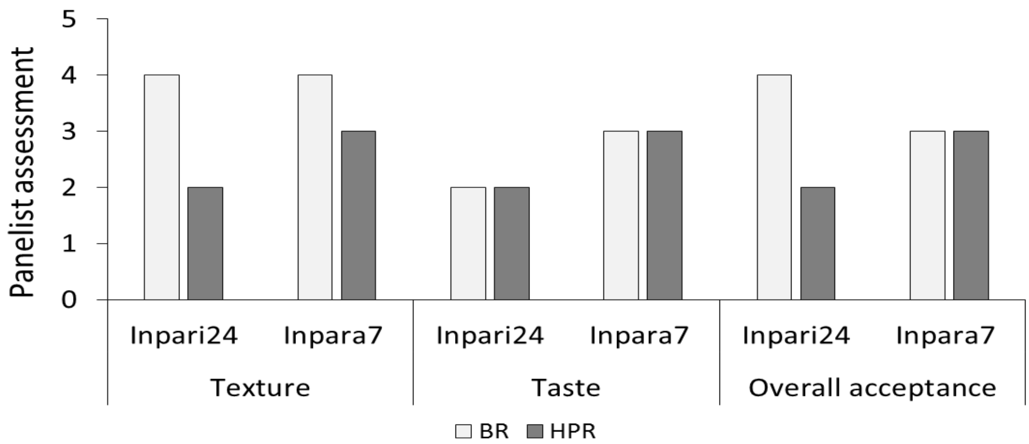
Red color	**Translucency**	**Aroma**	**Texture**
1 : Very red	1 : Very translucent	1 : Very fragrant	1 : Very Soft
2 : Red	2 : Translucent	2 : Fragrant	2 : Soft
3 : Slightly red	3 : Slightly translucent	3 : Slightly fragrant	3 : Slightly soft
4 : Fade	4 : Dull	4 : Neutral	4 : Firm
5 : Very fade	5 : Very dull	5 : Unpleasant	5 : Very firm

The hedonic test results showed that the preference of panelists on cooked rice texture of Inpari24 before and after one-time polishing process increased from dislike to like while for Inpara7 the preference of panelists on cooked rice texture increased from dislike to average. One-time polishing process proved increase the preference of the panelists based on texture attribute. The magnitude of preference increasing on HPR rice texture varied each rice variety. This finding in agreement with Lyon et al. (1999) that stated postharvest factors affected sensory properties are rice type (distinguished from each other by variety and location in which rice was grown) and milling degree.

Surprisingly, the taste of cooked rice of BR and HPR of both varieties assessed by the panelists was unchanged (Figure 2). Billiris et al. (2012) stated that the cooked brown rice taste was significantly more bitter than the cooked milled rice. However, in this study the aleurone layer was removed only partially and not entirely as on milled rice. Apparently, the taste of HPR was close to BR instead of milled rice. These results exhibited that one-time polishing process only affected the texture and not the taste of cooked rice.

The overall acceptance of Inpari24 cooked rice after one-time polishing process improved from dislike to like while the overall acceptance of Inpara7 cooked rice remained the same. Since the taste kept unchanged, it was likely that the assessment of panelists on overall acceptance was mainly based on texture. This is in line with the results of Rousset et al. (1999) which stated that consumers consider the texture of cooked rice to be its major quality attribute.

Figure 2. The hedonic test of brown rice (BR) and half polished rice (HPR) of Inpari24 and Inpara7

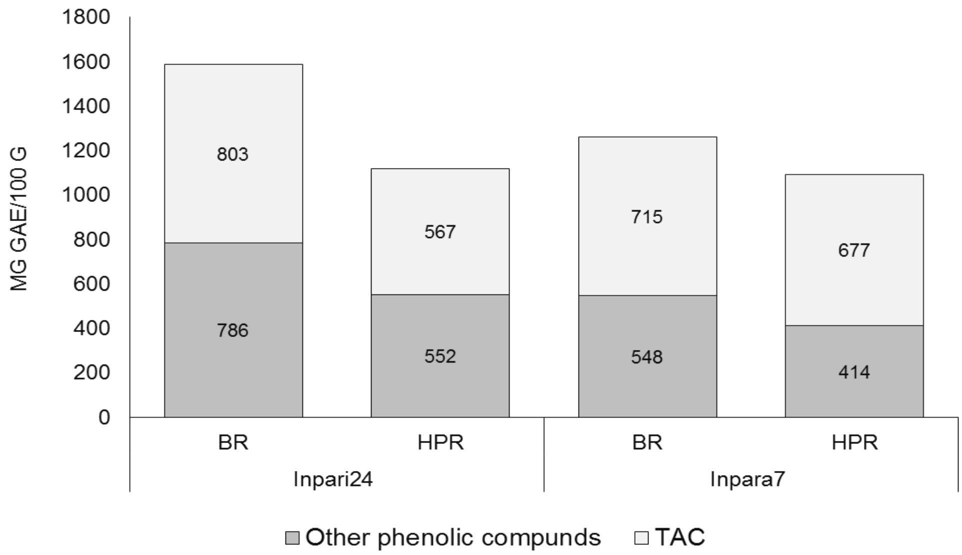


*Numbers meaning: 1 : Very like 2 : like 3 : Average 4 : dislike 5 : Very dislike

Phytochemical compounds normally accumulate in pericrap and aleurone (Muntana & Prasong, 2010), furthermore, phenolic compounds that may act as antioxidants are present in aleuron layer (Dar & Sharma, 2011). Phenolic compounds in rice are include phenolic acids, flavonoids, anthocyanins and proantosianidins (Goufo & Trindade, 2014). Determination of TPC content was done using *Follin-Ciocalteu* reagent. This method is based on the reduction strength of the phenolic hydroxy group. The *Follin-Ciocalteu* reagent will change the color of the sample to blue color that is directly proportional to the concentration of phenolic ions formed, therefore, the greater the concentration of phenolic compounds the more concentrated the blue color of the tested sample solution (Singleton & Rossi, 1965).

The results showed that TPC and TAC of Inpari24 BR was higher compared to those of Inpara7 BR i.e. 1,589 mg GAE/100g and 1,263 mg GAE/100g, respectively. One-time polishing process decreased the TPC and TAC where the highest decreasing was Inpari24 HPR i.e. 54% TPC (30% of those were anthocyanins) followed by Inpara7 HPR i.e. 34% TPC (29% of those were anthocyanins) (Figure 3). This indicates that the decreasing of TPC and TAC due to the one-time polishing process was different for each variety.

Figure 3. Total Phenolic Content (TPC) of brown rice (BR) and half polished rice (HPR) of Inpari24 and Inpara7



Walter & Marchesan (2011) and Paiva et al. (2015) reported that polishing process significantly decreased the total phenolic content as well as anthocyanin content. The differences in the amount of TPC loss after one-time polishing process between Inpari24 and Inpara7 may be due to the ease of aleurone to be detached is varied for each rice variety. Therefore the amount of the decreasing may not the same for every rice varieties. The results was consistent with the sensory analyses results where the panelist assessed the color of HPR Inpari24 was more faded compared to the color of HPR Inpara7 (Figure 1). The aleurone of Inpari24 was easier to remove compared to the aleuron of Inpara7.

Phenolics in the grain has been positively linked with human health. Phenolics act as antioxidant and provide beneficial effects on health such as reduction of oxidative stress, aid in prevention of cancer, help regulate blood lipids and related diseases, and may help in the prevention of cardiovascular problems (Zhang et al., 2006; Hu et al., 2003, Chen et al., 2006; Ling et al., 2001). The decreasing of phenolics content in rice is a drawback that occurs as a side effect of the one-time polishing process.

One that need to be take into account is the dietary intake of phenolics. Scalbert and Williamson (2000) reported that the daily intake of phenolics is 1 g/day. Using a French cohort and a phenolic content in foods database, Perez-Jimenez and colleagues confirmed polyphenol daily intake of about 1 g/day. Nevertheless, the quantity can be higher due to inadequate data on food contents for more complex polyphenols (Perez-Jimenez et al., 2011). Based on data from Statistics Indonesia (2015), rice consumption per capita in Indonesia is 233 g/day. The HPR of Inpari24 and Inpara 7 contain ± 1,100 mg /100g or 1.1 g/100 g of rice. Referring to the rice consumption data, HPR may provide about 2.5 g of phenolics per day where the amount has more than enough to cover the daily intake. Even so, the phenolic concentrations in rice will certainly decrease during meal preparation such as rice washing and cooking. Hiemori and colleagues (2009) found that black rice lost about 21-35% anthocyanins after cooking. Therefore the concentration of phenolics in cooked HPR must be lower than cooked BR.

CONCLUSIONS

The higher the milling degree the greater stickiness, glossiness, inner moisture, dan sweet taste. Rice with the lower milling degree were weaker in intactness of grains (separated), raw rice flavor and wet cardboard smell (Park et al., 2001). The results of the present study confirmed that one-time polishing process had significant effect on red rice eating quality improvement. Sensory analysis results indicated that one-time polishing increased the cooked red rice texture and, therefore, increased the panelist preference. Nonetheless, the increasing level of cooked rice texture after one-time polishing varied depending on the variety of red rice. To confirm the effect of one-time polishing process on the sensory characteristics of cooked rice, further descriptive analysis of cooked rice with more pigmented rice varieties is needed.

It can be inferred that one-time polishing process enhanced the eating quality of red rice yet brought down its phenolics up to 54% depending of the rice variety For consumers who are concerned with nutrition rather than eating quality then surely would think better to consume red rice without polishing. But for consumers who are not used to eat red rice in the form of BR, it is necessary to have a transition period for them to be able to consume red rice every day. Regardless of the intake amount of phenolics or other nutritional value to be met, what needs to be underlined from the purpose of this study is in bridging transformation on diet from white rice to red rice.

ACKNOWLEDGEMENTS

The authors would like to acknowledge the financial assistance provided by Indonesian Agency for Agricultural Research and Development (IAARD), Indonesian Ministry of Agriculture. We thank our colleagues who provided insight and expertise that greatly assisted the research.

REFERENCES

Adams, A. & Kimpe, N. D. E. (2006). Chemistry of 2-Acetyl-1-pyrroline, 6-Acetyl-1,2,3,4-tetrahydropyridine, 2-Acetyl-2-thiazoline, and 5-Acetyl-2,3-dihydro-4H-thiazine: Extraordinary Maillard Flavor Compounds. *Chemical Reviews*, 106 (6), 2299–2319

Buttery, R. G., Ling, L. C., Juliano, B. O. & Mon, T. R. (1986). Quantitative analysis of 2-acetyl-1-pyrroline in rice. *J. Agric. Food Chem*, 34, 112–114.

Buttery, R. G., Ling, L. C., Juliano, B. O. & Turnbaugh, J. C. (1983). Cooked rice aroma and 2-acetyl-1-pyrroline. *J. Agric. Food Chem*, 31, 823–826.

Buttery, R. G., Ling. L. C. & Juliano, B. O. (1982). 2-acetyl-1-pyrroline: an important aroma compound of cooked rice. *Chem. Ind.* 958–959.

Champagne, E.T., Karen L. B., Bryan T. V., Bill, D. W., Anna, M. M., Franklin, E. B., Brenda, G. L., Karen, M., Steve, L., & David, K. 1997. Effects of drying conditions, final moisture content, and degree of milling on rice flavor. Cereal Chemistry 74 (5), 566–570.

Champagne, E.T., Wood, D.F., Juliano, B.O., & Bechtel, D.B. (2004). The rice grain and its gross composition. In: Champagne, E.T. (Ed.), Rice. Chemistry and Technology, 3 ed. American Association of Cereal Chemists, Inc, St. Paul, Minnesota, U.S.A., 77–107.

Chen, H. & Siebenmorgen, T. J. (1997). Effect of rice kernel thickness on degree of milling and associated optical measurements. *Cereal Chemistry*, 74, 821–825.

Chen, P.; Kuo, W.; Chiang, C.; Chiou, H.; Hsieh, Y., & Chu, S. 2006. Black rice anthocyanins inhibit cancer cells invasion via repressions of MMPs and u-PA expression. *Chem-Biol Interact*. 163, 218-229.

Chen, X. Q., N. Nagao, T. Itani, & K. Irifune. 2012. Anti-oxidative analysis, and identification and quantification of anthocyanin pigments in different coloured rice. *Food Chem*. 135, 2783–2788.
Cooper, N. T. W. & Siebenmorgen, T.J. (2007). Correcting head rice yield for surface lipid content (Degree of milling) variation. *Cereal Chemistry,* 84 (1), 88–91.
Dar, B. N. & Sharma. (2011). Total pnenolic content of cereal beans using conventional and mocrowave assited extraction. *Am J Food Tech*, 6, 1045-1053.
Desikachar, H.S. R., Raghavendra Rao, S. N. & Ananthachar, T. K. (1965). Effect of degree of milling on water absorption of rice during cooking. *Journal of Food Science and Technology*. 2, 110–112.
Escribano-BailÓn, M.T., Santos-Buelga, C. & Rivas Gonzalo, C. (2004). Anthocyanins in cereals. *Journal of Chromatography*. 1054 (1-2), 129-141.
Ghosh, Diliph, & Tetsuya Konishi. (2007). Anthocyanins and anthocyanin-rich extracts: role in diabetes and eye function. *Asia Pacific Journal of Clinical Nutrition*. 16 (2), 200 – 208.
Goufo Piebiep & Trindade, H. (2014). Rice antioxidants: phenolic acids, flavonoids, anthocyanins,proanthocyanidins, tocopherols, tocotrienols, c-oryzanol, and phytic acid. *Food Science & Nutrition*, 2 (2), 75–104.
Hu, C.; Zawistowski, J.; Ling, W., & Kitts, D. D. 2003. Black rice (Oryza sativa L. indica) pigmented fraction suppresses both reactive oxygen species and nitric oxide in chemical and biological model systems. *J Agric Food Chem*. 51, 5271-5277.
Indrasari SD, Purwani, E. Y., Widowati, S. & Damardjati, D. S. (2009). Peningkatan nilai tambah beras melalui mutu fisik, cita rasa dan gizi. *Padi Inovasi dan Teknologi* 2, Eds: Daradjat dkk, Balai Besar Penelitian Tanaman Padi, Indonesia.
Ling, W. H.; Cheng, Q. X.; Ma, J., & Wang, T. 2001. Red and black rice decrease atheroscletoric plaque formation and increase antioxidant status in rabbits. *J Nutr*. 131, 1421-1426
Lyon, B. G., Champagne, E. T., Vinyard, B. T., Windham, W. R., Barton, F. E., & Webb, B. D. 1999. Effects of degree of milling, drying condition, and moisture content on sensory texture of cooked rice. *Cereal Chemistry*. 76(1), 56–62.
Miki Hiemori, Eunmi Koh, & Alyson E. Mitchell. 2009. Influence of Cooking on Anthocyanins in Black Rice (Oryza sativa L. japonica var. SBR). *J. Agric. Food Chem*. 57 (5), 1908-1914.
Mohapatra, D. & Bal, S. 2006. Cooking quality and instrumental textural attributes of cooked rice for different milling fractions. *Journal of Food Engineering*. 73 (3), 253–259.
Monks, J. F., Vanier, N. L., Casaril, J., Berto, R. M., Oliveira, M. de, Gomes, C. B.,Carvalho, M. P. de, Dias, A. R. G., & Elias, M. C. (2013). Effects of milling on proximate composition, folic acid, fatty acids and technological properties of rice. *Journal of Food Composition and Analysis*, 30, 73 – 79.
Morrison, W. R. & Azudin, M. N. 1987. Variation in the amylose and lipid contents and some physical properties of rice starches. *J. Cereal Sci*. 5:35-44.
Muntana, N. & Prasong, S. (2010). Study on total phenolic content and their antioxidant activities of thai white, red and black rice bran extracts. *J Biol Sci*, 13, 170-174.
National Standardization Agency of Indonesia (BSN). (2015). Indonesian National Standard (SNI) for Rice Quality. No. 6128:2015. Jakarta. Indonesia.
Paiva, F. F., Vanier, N. L., Berrios, J. D. J., Pinto, V. Z., Wood, D., Williams, T., Pan, J. & Elias, M. C. (2015). Polishing and parboiling effect on the nutritional and technological properties of pigmented rice. *Food Chemistry*, 191, 105-112.
Park, J.K., Kim, S.S., & Kim, K.O. 2001. Effect of milling ratio on sensory properties of cooked rice and on physicochemical properties of milled cooked rice. *Cereal Chemistry*. 78 (2), 151–156.
Perez-Jimenez, J., Neveu, V., Vos, F., & Scalbert, A. 2010. Systematic analysis of the content of 502 polyphenols in 452 foods and beverages: An application of the phenol-explorer database. *Journal of Agricultural and Food Chemistry*. 58, 4959–4969.
Rafael Monge-Rojas, Josiemer Mattei, Tamara Fuster, Walter Willett, & Hannia Campos. (2014). Influence of sensory and cultural perceptions of white rice, brown rice and beans by Costa Rican adults in their dietary choices. *J. Appetite*, 81, 200–208.
Rousset, S., Pons, B. & Martin, J. M. (1999). Identifying objective characteristics that product clusters produced by sensory attributes in cooked rice. *J. Texture Stud*. 30, 50-532
Saleh, M.I. & Meullenet, J. 2007. Effect of moisture content at harvest and degree of milling (based on surface lipid content) on the texture properties of cooked long-grain rice. *Cereal Chemistry*. 84 (2), 119–124.
Scalbert, A. & Williamson, G. 2000. Dietary intake and bioavailability of polyphenols. *The Journal of Nutrition*. 130, 2073–2085.
Singleton, V. L. & Rossi, J. A. (1965). Colorimetry of total phenolic with phosphomolybdic-phosphotungstic acid reagent. *American Journal Enology and Viticulture*, 16, 147
Statistics Indonesia (BPS). 2015. Average Weekly Consumption of Several Food Items Per Capita, 2007-2015. https://www.bps.go.id.
Walter, M. & Marchesan, E. (2011). Phenolic compound and antioxidant activity of rice. *Braz Arch Biol Technol,* 54, 371-377.
Wang, L. S. & Stoner, G. D. (2008). Anthocyanins and their roles in cancer prevention. *Cancer Letters,* 269, 281- 290.
Wang, Qing, Pinghua Han, Mingwei Zhang, Min Xia, Huilian Zhu, Jing Ma, Mengjun Hou, Zhihong Tang & Wenhua Ling. (2007). Supplementation of black rice pigment fraction improves antioxidant and anti-inflammatory status in patients with coronary heart disease. *Asia Pac J Clin Nutr*, 16 (Suppl 1), 295-301.
Yoshimura, Y., N. Zaima, T. Moriyama, & Y. Kawamura. 2011. Different localization patterns of anthocyanin species in the pericarp of black rice revealed by imaging mass spectrometry. *PLoS One* 7:e31285.

Zhang, M.; Guo, B.; Zhang, R.; Chi, J.; We, Z.; Xu, Z.; Zhang, Y. & Tang, X. 2006. Separation, purification and identification of antioxidant compositions in black rice. *Agric Sci China*. 5, 431-440.