Effect of The Combination of Polishing and Dry Milling Method on Black Glutinous Rice Flour Characteristics

Riezka Zuhriatika Rasyda[1], Tjahja Muhandri[2], Slamet Budijanto[2]

[1] Study Program of Food Science and Technology, Faculty of Food and Agroindustry Technology, University of Mataram, 83125, Indonesia
[2] Department of Food Science and Technology, Faculty of Agricultural Engineering and Technology, IPB University, 16680, Indonesia
riezka_rasyda@unram.ac.id

Abstract. This study aims to determine the effect of the combination of polishing and dry-milling method on the characteristics of black glutinous rice flour (BGRF) it produced. The observed parameters were total anthocyanin content, total phenolic content, DPPH and FRAP antioxidant activity, proximate content, and pasting properties. The results showed that the combination of polishing and dry-milling method produced BGRF with the highest amount of total anthocyanin (194.12±0.24 mg C3GE/100 g) and total phenolic (304.25±3.89 mg GAE/100 g) content which significantly differs with other methods, with DPPH antioxidant capacity 717.37±1.43 mg AAE/100 g and FRAP antioxidant capacity 407.29±3.23 mg AAE/100 g, indicated its potential as an ingredient in antioxidant-rich functional foods. Its proximate content consists of moisture content 12.89±0.03%, ash content 1.25±0.03%, crude protein content 10.76±0.05%, crude fat content 3.20±0.10%, and carbohydrate content 71.90±0.21%. Meanwhile, its pasting properties parameters indicated that BGRF starch granules tend to absorb water quickly and expand easily, resulting in an easily gelatinized and thickened dough when heated and stirred, with a chewy, sticky texture of the final product that remains soft even when stored for a long time due to its resistance to syneresis.

Keywords: Antioxidant, Black Glutinous Rice, Milling Method.

1 Introduction

Black glutinous rice (BGR) has a substantially higher antioxidant capacity than other varieties of glutinous rice, make it the greatest option for processing functional foods made with glutinous rice flour. BGR can be processed conventionally into black glutinous rice flour (BGRF) using the dry-milling method or the combination of soaking and dry-milling method. The dry-milling method is more practical because rice grains can be directly converted into flour without any preliminary processing [1]. The bran of glutinous rice is hard and tough, so it is difficult to crush when milled using the dry-milling method, resulting in the production of flour particles that are larger than the results of the combination of soaking and dry-milling method [2]. Larger flour particles

Q. D. Utama et al. (eds.), *Proceedings of the 7th International Conference on Food, Agriculture, and Natural Resources (IC-FANRES 2022)*, Advances in Biological Sciences Research 35,
https://doi.org/10.2991/978-94-6463-274-3_33

will influence the texture, gelatinization, and starch paste characteristics of BGRF [3]. The dry-milling method involves greater mechanical and thermal energy, thus causing a greater level of damage (14.7%) to starch granules compared to the combination of soaking and dry-milling method (9.4%) [4]. Exposure to high mechanical energy and heat will also affect the antioxidant content of BGRF because antioxidant properties are easily damaged by heat [5].

The combination of soaking and dry-milling method involves a preliminary process in the form of soaking the grains in water followed by a dewatering and milling process and then drying at the end of the process [1]. The milling process is carried out on grains in a wet state where additional water can be added during the process if needed [4][6]. This method softens the grains due to the water absorption and starch granules disintegration from the protein matrix during the soaking process, thus easing the process of crushing the grains and producing softer flour with a smaller and more uniform granule size [2]. The weakness of this method is the reduction in water-soluble nutritional components because they are washed out with the wasted water when the soaking process is complete [7]as well as exposure to heat during the drying process at the end of the process [1]. Water-insoluble phenolic compounds contribute around 26.88% to the total phenolic compound content in pigmented rice grains, while water-insoluble anthocyanin compounds only contribute 1-12% to the total anthocyanin content [8], thus the utilization of this method may cause low levels of antioxidant components in BGRF.

This study offers an alternative in the form of a dry-milling method that involves prior polishing of BGR using an abrasive polisher. The obtained flour then later mixed with its rice bran fraction. Separating the BGR endosperm fraction from the bran will make the process of crushing the BGR grains easier during milling, thereby speeding up the processing time and reducing the size of the starch granules [2]. The grain milling process in this alternative method does not involve the rice bran fraction, so its bran antioxidant contents will be retained. This alternative method needs further investigation to determine the effect of the combination of polishing and dry-milling method on the characteristics of black glutinous rice flour it produced.

2 Materials And Methods

This study was conducted in August and September 2019 at IPB University's Faculty of Agricultural Engineering and Technology. Black glutinous rice (BGR) whole grains of Setail variety were bought from local farmers in Dompu, West Nusa Tenggara, and then processed into black glutinous rice flour (BGRF) using three different methods. The first method is the dry milling method based on [9]. BGR was grounded using a pin disc mill and sieved using an 80-mesh vibrating screen (particle size ~0.177 mm) to produce BGRF I. The second method is the dry milling method with a soaking process beforehand. Modifying the method of [4], BGRF was soaked in water for 4 hours at room temperature (25°C), drained, and grounded using a pin disc mill, then dried using a cabinet dryer at 40°C for 6 hours and sieved using an 80-mesh vibrating screen to produce BGRF II.

The third method modified the dry-milling method, which involved BGR polishing process beforehand. BGR was polished using an abrasive polisher for 2 minutes to obtain BGR endosperm and bran fractions. The endosperm fraction was milled using a pin disc mill and then mixed with the rice bran fraction. The mixed flour was sifted using an 80-mesh vibrating screen to produce BGRF III. Each BGRF was extracted [10] and then analyzed for its total anthocyanin content (TAC) [11] and total phenolic content (TPC) [12]. The milling method that produced BGRF with the highest TAC and TPC then selected as the recommended method. Its produced BGRF then analyzed for antioxidant capacity using DPPH [13] and FRAP assay [14], proximate content [15], and pasting properties using Rapid Visco Analyzer (RVA) [9].

The experimental design used in this study was a completely randomized design consisting of 3 treatments (dry-milling, combination of soaking and dry-milling, combination of polishing and dry-milling) with 2 replications. The experimental data were processed with SPSS 23.0 software subjected to one-way analysis of variance (ANOVA) at 95% confidence level ($P<0.01$). Significantly different treatment results were further tested with Duncan's Multiple Range Test (DMRT). The data in all Tables reported as mean±standard deviation.

3 Results and Discussions

3.1 Total Anthocyanin Content (TAC) and Total Phenolic Content (TPC)

Each BGRF had significant differences ($p<0.05$) in terms of TAC (see Fig. 1) and TPC (see Fig. 2). Each milling method produces BGRF with different antioxidant component content caused by the differences in the required shear force for quick mechanical changes from large particles to smaller particles during its process, where the greater shear force resulted in the increase of heat generated [2]. Exposure to mechanical energy and heat can affect the content of antioxidant components in BGRF due to the nature of these components which are susceptible to heat damage. Degradation of anthocyanins by heat can occur through covalent bond cleavage and deglycosylation mechanisms [5], while degradation of phenolic compounds by heat can occur through decarboxylation and polymerization mechanisms [16].

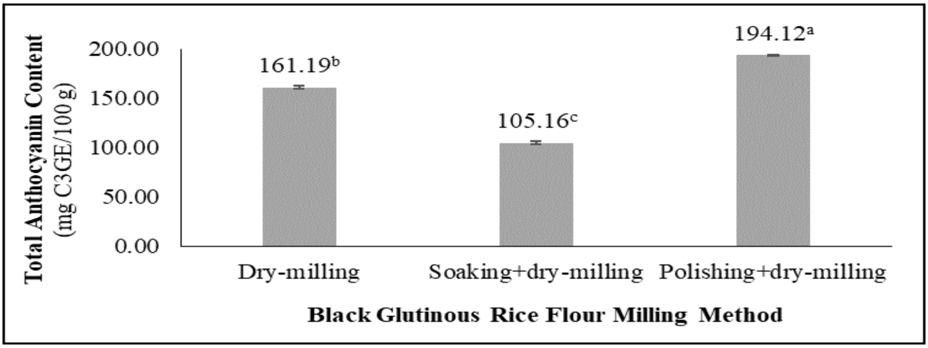

Fig. 1. Effect of milling method on total anthocyanin content of black glutinous rice flour.

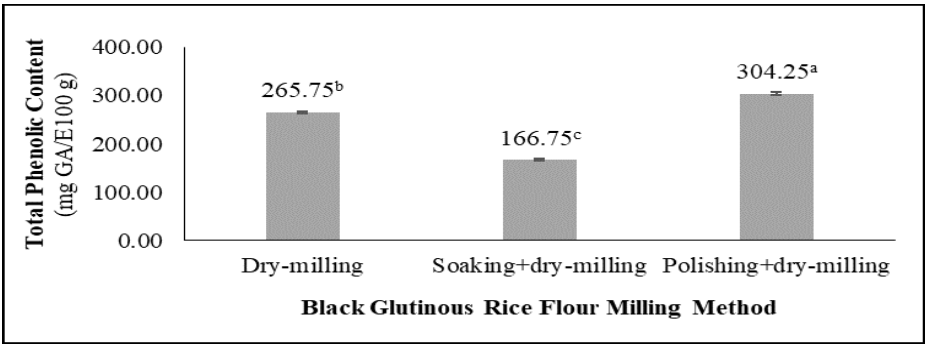

Fig. 2. Effect of milling method on total phenolic content of black glutinous rice flour.

The TAC and TPC of BGRF produced by the combination of soaking and dry-milling method were the lowest among all milling methods, which are 105.16 ± 2.07 mg Cyanidin-3-Glucoside Equivalent (C3GE)/100 g and 166.75±2.47 mg Gallic Acid Equivalent (GAE)/100 g, respectively. The soaking process causes the dissolution of anthocyanins and phenolic compounds into water that is later lost along the wasted water during the draining process so that the TAC and TPC at the end of the crushing process become much lower. Water-insoluble phenolic compounds contribute about 26.88% to the TPC of pigmented rice grains, while water-insoluble anthocyanins contribute 1-12% to the TAC [8]. This milling method also involves drying at the end of the process, which causes additional heat exposure to the BGRF, thus further reducing its TAC and TPC.

The TAC and TPC of BGRF produced by the combination of polishing and dry-milling method were the highest among all milling methods, which are 194.12±0.24 mg C3GE/100 g and 304.25±3.89 mg GAE/100 g, respectively. These high contents proved that the prior polishing process could minimize the loss of TAC and TPC due to the milling process. The separation of BGRF endosperm fraction from its bran facilitates the grains crushing process during milling, thus minimizing the mechanical energy and heat generation. BGR bran contains most parts of BGR antioxidant components, so the milling process without the bran fraction involvement can prevent damage to the antioxidant components, resulting in a high content of TAC and TPC. The combination of polishing and dry-milling method produced BGRF with the highest TAC and TPC, thus it was selected as the recommended method and its flour underwent further analysis.

3.2 Antioxidant Capacities of Recommended Flour

The antioxidative activities of anthocyanins and phenolic compounds of BGRF could be indicated by BGRF antioxidant capacities tested using DPPH (*2,2-diphenyl-1-picrylhydrazyl*) and FRAP (*ferric reducing antioxidant power*) assays. The DPPH method indicated the ability of antioxidants to capture DPPH free radicals, while the FRAP method indicated the ability of antioxidants to prevent oxidation reactions through single electron donation [10].

The antioxidant capacities of BGRF were 717.37±1.43 mg Ascorbic Acid Equivalent (AAE)/100 g and 407.29±3.23 mg AAE/100 g, resulting from FRAP and DPPH assay respectively (see Fig. 3). These results were higher than results from other prior studies [9]. The slight differences that may have occurred were presumably due to differences in varieties, harvest age, harvest location, milling method, and sample preparation [17].

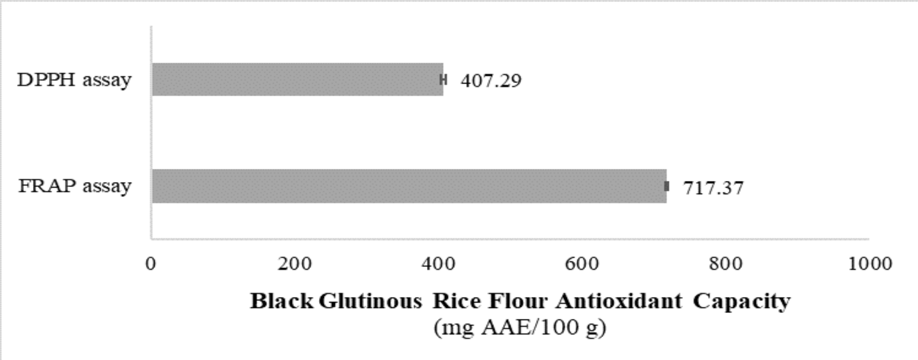

Fig. 3. Antioxidant capacity of black glutinous rice flour from the polishing+dry-milling method.

3.3 Proximate Contents of Recommended Flour

Proximate contents analysis was conducted on the BGRF produced by the selected method to determine its general chemical composition characteristics (see Tab. 1). The analysis showed similar results to other prior studies [9][16]. The slight differences that may have occurred were presumably due to differences in varieties, harvest age, harvest location, and milling method.

Table 1. Proximate contents of black glutinous rice flour from the polishing+dry-milling method.

Parameter	Proximate contents (%)
Moisture content	12.89±0.03
Ash	1.25±0.03
Crude protein	10.76±0.05
Crude fat	3.20±0.10
Carbohydrate	71.90±0.21

3.4 Pasting Properties of Recommended Flour

Pasting properties analysis was conducted on the BGRF produced by the selected method to estimate the functional characteristics of BGRF using RVA graph with parameters consisted of peak viscosity (PV), hot paste viscosity (HPV), breakdown viscosity (BD), final viscosity (FV), setback viscosity (SB), cold paste viscosity (CPV), peak time (Pt), and pasting temperature (PT). These parameters act as a specific indicator of each step of the gelatinization process, and each parameter has a specific method of determining its value [18]. Pasting properties analysis results of the selected BGRF were illustrated on the RVA graph (see Fig. 4) and then summarized (see Tab. 2). These results indicated that BGRF starch granules tend to absorb water quickly and expand easily, resulting in an easily gelatinized and thickened dough when heated and stirred, with a chewy, sticky texture of the final product that remains soft even when stored for a long time due to its resistance to syneresis. The description of each parameter results discussed in the following paragraphs.

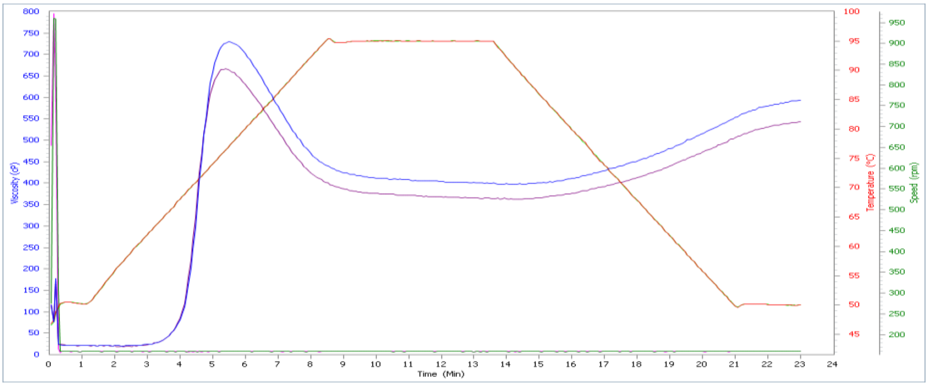

Fig. 4. RVA graph of black glutinous rice flour from the polishing+dry-milling method.

Table 2. Pasting properties of black glutinous rice flour from the polishing+dry-milling method.

Parameter	Pasting Properties Value
Peak viscosity (cp)	2095.50±133.64
Hot paste viscosity (cp)	87.00±28.28
Breakdown viscosity (cp)	955.50±61.52
Final viscosity (cp)	1704.00±106.07
Setback viscosity (cp)	564.00±33.94
Cold paste viscosity (cp)	114.00±12.73
Peak time (minutes)	5.47±0.09
Pasting temperature (°C)	68.45

The PV value of 2095.50±133.64 cp indicated the water absorption ability and expandability of starch paste. The PV value is determined from the maximum viscosity of BGRF during the heating cycle. The higher the PV value, the greater the water absorption ability and expandability of BGRF starch granules, thus increasing BGRF paste thickness.

The HPV value of 87.00±28.28 cp indicated the stability of the BGRF paste in the heating phase. The HPV value is determined from the difference in BGRF viscosity before and after holding in the heating phase (95°C). The higher the HPV value, the lower the heat-resistant ability of BGRF starch granules, thus increasing its tendency to thicken more when heated.

The BD value of 955.50±61.52 cp indicated the stability of BGRF during the heating process accompanied by stirring. The BD value is determined from the difference between the PV value and the viscosity of starch paste at 95°C before holding begins. The higher the BD value, the lower the resistance of BGRF starch granules to the changes caused by the combination of heating and stirring process.

The FV value of 1704.00±106.07 cp indicated the final texture of BGRF-based food products after cooling. The FV value is determined from BGRF viscosity at the end of the cooling phase. The higher the FV value, the higher the BGRF-based food product's texture tendency to be denser and stickier. In retrospect, the lower the FV value, the higher the BGRF-based food product's texture tendency to be softer and more elastic.

The SB value of 564.00±33.94 cp indicated the ability of starch retrogradation in BGRF-processed products during storage. The SB value is determined from the difference between the PV and FV values. The higher the SB value, the higher the BGRF-based food product's tendency to become denser and harder during storage.

The CPV value of 114.00±12.73 cp indicated the stability of BGRF against the agitation process. The CPV value is determined from the difference in BGRF viscosity before and after the holding process in the cooling phase (50°C). The higher the CPV value, the lower the resistance of BGRF starch granules to the changes caused by the agitation process, thus increasing its tendency to thicken more when stirred.

The Pt value of 5.47±0.09 minutes, just like the PV value, indicated the water absorption ability and expandability of BGRF. The Pt value is determined as the time when the starch granule breaks. The higher the Pt value, the greater the ability of water absorption and expandability of BGRF because its starch granules have a longer time to absorb water before finally breaking.

The PT value of 68.45°C indicated the resistance of BGRF to the heating process. The PT value is determined from the required temperature to start the gelatinization process indicated by the start of the BGRF viscosity increase. The lower the PT value, the lower the heating temperatures required to break the bonds between BGRF starch granules and start the gelatinization process.

Conclusions

The combination of polishing and dry-milling method produced BGRF with the highest amount of total anthocyanin (194.12±0.24 mg C3GE/100 g) and total phenolic (304.25±3.89 mg GAE/100 g) content which significantly differs with other methods, with DPPH antioxidant capacity 717.37±1.43 mg AAE/100 g and FRAP antioxidant capacity 407.29±3.23 mg AAE/100 g, indicated its potential as an ingredient in antioxidant-rich functional foods. Its proximate content consists of moisture content 12.89±0.03%, ash content 1.25±0.03%, crude protein content 10.76±0.05%, crude fat content 3.20±0.10%, and carbohydrate content 71.90±0.21%. Meanwhile, its pasting properties parameters indicated that BGRF starch granules tend to absorb water quickly and expand easily, resulting in an easily gelatinized and thickened dough when heated and stirred, with a chewy, sticky texture of the final product that remains soft even when stored for a long time due to its resistance to syneresis.

References

1. Kim, M.H.: Review on rice flour manufacturing and utilization. Journal of Biosystems Engineering 38(2), 103–112 (2013). https://doi.org/10.5307/jbe.2013.38.2.103.
2. Kumar, C.S., Malleshi, N.G., Bhattacharya, S.: A comparison of selected quality attributes of flours: effects of dry and wet grinding methods. International Journal of Food Properties 11(4), 845–857 (2008). https://doi.org/10.1080/10942910701657686.
3. Hasjim, J., Li, E., Dhital, S.: Milling of rice grains: effects of starch/flour structures on gelatinization and pasting properties. Carbohydrate Polymers 92(1), 682–690 (2013). https://doi.org/10.1016/J.CARBPOL.2012.09.023.
4. Heo, S., Lee, S.M., Shim, J.H., Yoo, SH., Lee, S.: Effect of dry- and wet-milled rice flours on the quality attributes of gluten-free dough and noodles. Journal of Food Engineering 116(1), 213–217 (2013). https://doi.org/10.1016/j.jfoodeng.2012.11.017.
5. Patras, A., Brunton, N.P., O'Donnell, C., Tiwari, B.K.: Effect of thermal processing on anthocyanin stability in foods; mechanisms and kinetics of degradation. Trends in Food Science and Technology 21(1), 3–11 (2010). https://doi.org/10.1016/j.tifs.2009.07.004.
6. Liaotrakoon, W., Liaotrakoon, V., Wongsaengtham, W., Rodsiri, S.: Influence of dry- and wet-milling processes on physicochemical properties, syneresis, pasting profile and microbial count of job's tear flour. International Food Research Journal 21(5), 1745–1749 (2014).
7. Leewatchararongjaroen, J., Anuntagool, J.: Effects of dry-milling and wet-milling on chemical, physical and gelatinization properties of rice flour. Rice Science 23(5), 274–281 (2016). https://doi.org/10.1016/j.rsci.2016.08.005.
8. Goufo, P., Trindade, H.: Rice antioxidants: Phenolic acids, flavonoids, anthocyanins, proanthocyanidins, tocopherols, tocotrienols, c-oryzanol, and phytic acid. Food Science and Nutrition 2(2), 75–104 (2014). https://doi.org/10.1002/fsn3.86.
9. Nindita, D.A., Kusnandar, F., Budijanto, S.: Changes in antioxidant and physicochemical properties of Indonesian black rice flour (var. Banjarnegara and Bantul) during no-die extrusion cooking. Jurnal Teknologi dan Industri Pangan 29(2), 164–174 (2018). https://doi.org/10.6066/jtip.2018.29.2.164.
10. Zulfafamy, K.E., Ardiansyah, Budijanto S.: Antioxidative properties and cytotoxic activity against colon cancer cell WiDr of rhizopus oryzae and rhizopus oligosporus-fermented black rice bran extract. Current Research in Nutrition and Food Science 6(1), 23–34 (2018). https://doi.org/10.12944/CRNFSJ.6.1.03.
11. Sutharut, J., Sudarat, J.: Total anthocyanin content and antioxidant activity of germinated colored rice. International Food Research Journal 19(1), 215–221 (2012).
12. Chen, H.H., Chang, H.C., Chen, Y.K., Hung, C.L., Lin, S.Y., Chen, Y.S.: An improved process for high nutrition of germinated brown rice production: Low-pressure plasma. Food Chemistry 191, 120–127 (2016). https://doi.org/10.1016/j.foodchem.2015.01.083.
13. Bobo-García, G., Davidov-Pardo, G., Arroqui C., Virseda, P., Marín-Arroyo, M.R., Navarro, M.: Intra-laboratory validation of microplate methods for total phenolic content

and antioxidant activity on polyphenolic extracts, and comparison with conventional spectrophotometric methods. Journal of the Science of Food and Agriculture 95(1), 204–209 (2015). https://doi.org/10.1002/jsfa.6706.

14. Zahin, M., Aqil, F., Husain, F.M., Ahmad, I.: Antioxidant capacity and antimutagenic potential of *Murraya koenigii*. Biomed Research International 2013(1), 1-10 (2013). https://doi.org/10.1155/2013/263509.
15. AOAC International: Official methods of analysis of AOAC international, 19th ed. AOAC International, Washington DC (2012).
16. Murdifin, M., Pakki, E., Rahim, A., Syaiful, S.A., Ismail, Evary, Y.M., Bahar, M.A.: Physicochemical properties of Indonesian pigmented rice (*Oryza sativa* linn.) varieties from South Sulawesi. Asian Journal of Plant Sciences 14(2), 59–65 (2015). https://doi.org/10.3923/ajps.2015.59.65.
17. Zhang, M.W., Zhang, R.F., Zhang, F.X., Liu, R.H.: Phenolic profiles and antioxidant activity of black rice bran of different commercially available varieties. Journal of Agricultural and Food Chemistry 58(13), 7580–7587 (2010). https://doi.org/10.1021/JF1007665.
18. Kusnandar, F.: Kimia makanan komponen makro. Bumi Aksara, Jakarta (2019).