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The Effects of Various Way of Processing Black Glutinous Rice (*Oryza sativa L. Processing Var Glutinosa*) on Digestibility and Energy Value of the Products

The Effects of Various Way of Processing Black Glutinous Rice (*Oryza sativa L. Processing Var Glutinosa*) on Digestibility and Energy Value of the Products

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Abstract. The aim of this research is to study about the nutritional value, digestibility, and energy value from various ways of black glutinous rice processing. This research used explorative design using five processing methods and three replications. The results showed that the highest water content was found in boiled black glutinous rice (75.61%), the highest ash content in roasted black glutinous rice (1.19%), the highest fat content in puffing black glutinous rice (10.51%), the highest protein content in puffingblack glutinous rice (11.09%), the highest starch digestibility in roasted black glutinous rice (80.12%), the highest amylose content and the lowest amylopectin in roastedblack glutinous rice (10.32% and 89,67% respectively), the highest starch digestibility in puffingblack glutinous rice(75.61%), the highest antioxidant activity in raw black glutinous rice (60.75%), and the highest energy content (408 kcal) in puffing black glutinous rice.
Keywords: Black Glutinous Rice, Digestibility, Nutritional Value, Processing

Introduction

Black glutinous rice (*Oryza sativa L Var. Glutinosa*) is widely available in Indonesia with estimated total production around 42,000 tons per year. Glutinous rice (or sticky rice) has characteristics such as not transparent, has a distinctive smell, and almost all of the starch is amylopectin. Glutinous rice is usually processed into simple foods such as steamed black glutinous rice or boiled black glutinous rice. Glutinous rice is almost completely dominated by amylopectin thus the very sticky feature. Winarno (2004) stated that glutinous rice has a high starch content consisting in 1-2% amylose and 98-99% amylopectin. The higher the amylopectin level, the stickier the rice became.

Starch digestibility means the level of the easiness of the starch to be hydrolyzed and become simpler substance (Mercier, 1988). Indrasari, Wibowo, and Darajat (2008) reckoned that measuring starch digestibility could be done by using α-amylase enzyme. This enzyme has the ability to breakdown starch into simple sugars through hydrolysis process. According to Rimbawan and Siagian (2004), the higher the starch digestibility is the easier the starch to breakdown into glucose which could lead to the increased level of blood glucose. The increase level of blood glucose will also cause the increase need of insulin to convert glucose into energy.

Processing the glutinous rice to become a variety of processed products could affect the nutritional value, starch digestibility, and energy value of the products. The methods that could be use for processing the glutinous rice are roasting, steaming, puffing, and boiling. Roasting is a cooking method which utilized heat without using oil. This method is the one that is mostly developed. This method is done to improve the flavor of the food. Steaming is a cooking method which utilize liquid or steam (moist cooking method). Basically, the food is cooked by the steam, therefore the food should not be in direct contact with the boiled water underneath the filter. Puffing is method of food processing where the food is expanded in volume as a result of temperature and pressure involvement which results in changes in the structure of the food material. Boiling is a cooking method using boiled water as a heat transfer medium. Harris and Karmas (1989) stated that the factors that affects the loss of nutrients during the boiling process are the material surface area, concentration of dissolved substances in water, and the action of stirring the water. There is still no further information about the nutritional value, starch digestibility, and energy value produced by the variety of processed black glutinous rice as yet.

2. Materials and Methods

2.1 Ingredients and Tools

The ingredient used in this research was black glutinous rice obtained from Pasar Raya Padang, West Sumatera. The chemical substances used are diethyl ether, ethanol 95%, NaOH 1N, K_2SO_4, HgO, H_2SO_4, H_3BO_3, $Na_2SO_2O_3$ 0.1 N, starch solution 0.5%, HCl 0.02 N, HCl 30%, cotton wool, aluminium foil, filter paper, iodine solution, acetic acid, boiling solvent, boiling stone, distilled water, methyl orange indicator, MM-MB indicator, phenolphthalein 1% indicator, phosphate buffer solution 0.1 M, luff schoorl solution, KI 30% solution, α-amylase enzyme solution, dinitrosalicylate acid solution, pure amylose, standard maltose, and pure starch.

Tools used were pots, stoves, frying pan, ignition plates, hot plates, furnaces, cup saucer, pipette dropper, water bath, desiccator, spectrophotometer, test tube, volumetric flask 250 ml, soxhlet complete with the condenser, oven, filter paper, cotton, centrifuge, spoon, steam bath or electric heater, Kjeldahl heater connected to a steam absorber through an aspirator, Kjeldahl flask, burette, Erlenmeyer 500 ml, fat flask, vortex, bomb calorimeter, and analytical scales.

2.2 The Research Design

This research used explorative design consists of three replications. This research uses steaming, roasting, boiling, puffing and control as methods of processing.

2.3 Implementation of Research

2.3.1 Boiled Black Glutinous Rice. Boiling the black glutinous rice is done by following these steps:

1. 750 ml of water is boiled (100^{o}C) in a pan within ± 10 minutes over medium heat
2. Put 200gr of black glutinous rice into the boiling water for about ± 15 minutes
3. Remove the cooked black glutinous rice from the boiling water and drained the excess water
4. Boiled black glutinous rice is ready to be analyzed

2.3.2. Steamed Black Glutinous Rice. Steaming the balck glutinous rice is done by following these steps:

1. Clean wash the black glutinous rice and let it soak for about 2 hours
2. Boil (100^{o}C) 1 L of water in the steam pan for about ± 10 minutes over medium heat
3. Put 200 gr of soaked black glutinous rice into the steaming pan for about ± 15 minutes
4. Remove the cooked black glutinous rice from the boiling water and drained the excess water
5. Steamed black glutinous rice is ready to be analyzed

2.3.3. Roasted Black Glutinous Rice. Roasting black glutinous rice is done by following these steps:

1. Soak 200 gr of black glutinous rice and drain the excess water
2. Mash the soaked black glutinous rice to size 75 mesh
3. Put the mashed black glutinous rice into the pan and roast it in medium heat
4. During the roasting process, stir the black glutinous rice evenly
5. The roasting process is carried out at 100-120^{o}C in temperature for 30 minutes
6. Roasted black glutinous rice is ready to be analyzed

2.3.4 Puffing Black Glutinous Rice. Puffing black glutinous rice is done by following these steps:
1. Put 5 gr margarine into a pre-heated pan (60ºC) and wait until it melts
2. Wash clean 10 gr of black glutinous rice (water content 13.5-14%), drained the excess water, and put it in the pan from step 1.
3. Close the pan with a lid and shake the pan once in a while in order to make all of the black glutinous rice exposed to margarine evenly
4. This process will make the black glutinous rice give out a popping sound. Leave it for ± 5 minutes (90-110ºC) until the popping sound stops.
5. Puffing black glutinous rice is ready to be analyzed

2.4 Observation
In this study, chemical observations were carried out, i.e., observation of the water content (Gravimetric), ash content, fat content, protein content, starch digestibility, amylose content, amylopectin content, energy value, and antioxidant activity.

3. Results and Discussion

3.1 Water Content (Gravimetric)
Based on the results of this study, the water content of various processed black glutinous rice products could be seen in Table 1.

Table 1. Water Content of Various Processed Black Glutinous Rice (BGR)

Treatment	Water Content(%) ± SD
Control BGR	12.53 ± 0.2738
Boiled BGR	73.26 ± 0.7673
Steamed BGR	67.37 ± 0.8129
Roasted BGR	10.27 ± 0.5175
Puffing BGR	7.77 ± 0.4221

SD: Standard Deviation

The water content of the control black glutinous rice and the four processed black glutinous rice ranges from 7.77-73.26 %. The water content of the control black glutinous rice (12.53%) is higher than the ones from the Directorate of Nutrition, Health Departement of Indonesia (2001) which was 12%. This difference is caused by the difference of variety and the place of growth. The water content from the roasting process and the puffing process are decreased compared to the control.

The highest water content is found in the boiled black glutinous rice (73.26%) due to the involvement of water in the process. On the other hand, steamed black glutinous rice was processed using hot steam (moist heat), which basically used convection heat transfer, thus resulted in lower water content (67.37%) compared to boiled glutinous rice.The lowest water content is found in roasted black glutinous rice and puffing black glutinous rice (10.27% and 7.77% respectively) since the processing was done in dry environment. The roasted black glutinous rice was processed by mashing it and roasting it in high temperature which made the water content evaporates. This founding is in line with the research by Ravi et al., (2015) which stated that the roasting proses would result in water evaporation and decrease the water content after the process is done.

3.2 Ash Content
From the results of this study, the ash content of various processed black glutinous rice can be seen in Table 2.

Table 2. Ash Content of Various Processed Black Glutinous Rice (BGR)

Treatment	Ash Content(%) ± SD
Control BGR	0.59 ± 0.3436
Boiled BGR	0.26 ± 0.1131

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Steamed BGR	0.39 ± 0.0002
Roasted BGR	1.19 ± 0.0023
Puffing BGR	0.79 ± 0.0036

SD: Standard Deviation

The ash content of the control black glutinous rice and the four processed black glutinous rice ranges from 0.26-1.19%. The highest ash content is found ini roasted black glutinous rice (1.19 %), higher compared to research by Refdi and Prima (2017) which is 0.68 %. This shows that the roasting process resulted in the increase in ash content. This happens due to the interaction between the metal equipments that were used during the process. This founding is in line with the research by Faria et al., (2012) which stated that the possible interaction between the metal equipments couldn't be ignored. The ash content of puffing black glutinous rice is 0.79%, which shows an increase compred to the control. This was caused by the puffing processing that used margarine. The existence of sodium in the margarine will cause the increasing ash content since sodium is one of the main salt group (Deman,1997).

Boiled and steamed black glutinous rice shows a decrease value of ash content compared to roast and puffing black glutinous rice. This was due to the dissolving of salt mineral in water during the boiling process, which was in accordance with Chen et al., (1999), whom stated that the treatment of soaking in water could causes the dissolution of some minerals, water-soluble vitamins, albumin, and sugar. According to, Sediaoetama (1993), the act of processing food could decrease the mineral content of the food due to the damage done by pH, oxygen, light, and heat or any combination of said components during the process. In accordance with Santoso et al., (2006) that stated that the chemical structure of minerals contained in food could change due to the act of processing or the interaction with other materials, thus resulting in the increase or decrease level of mineral solubility depending on the process.

3.3 Fat Content

From the results of this study, the fat content of various processed black glutinous rice can be seen in Table 3.

Table 3. Fat Content of Various Processed Black Glutinous Rice (BGR)

Treatment	Fat Content (%) ± SD
Control BGR	2.19 ± 0.3302
Boiled BGR	0.49 ± 0.4088
Steamed BGR	0.35 ± 0.0400
Roasted BGR	1.92 ± 0.3308
Puffing BGR	10.51 ± 0.4765

SD: Standard Deviation

The fat content of the control black glutinous rice and the four processed black glutinous rice ranges from 0.35-10.51%. The highest fat content is found in puffed black glutinous rice (10.51%) while the lowest in steamed black glutinous rice (0.35%). The increase of fat content in the puffed black glutinous rice is due to the addition of margarine that contains fat during the process.

Boiling and steaming process resulted in fat content of 0.49% and 0.35% respectively, which are lower compared to the control (2.19%). The decrease in fat content is due to the treatment of washing and soaking during the process resulting in the loss of the epidermis of the black glutinous rice that contains fat. This also causes the high water content in boiled and steamed black glutinous rice. Mastuti (2008) stated that the high water content found in end products is usually the cause of the low fat content. Besides, the water content in the final product it is also influenced by the hydrolysis process. Ketaren (1986) stated that fat hydrolysis will form free fatty acids and glycerol, where the higher the temperature used, the higher the level of fat damage.

3.4 Protein Content

From the results of this study, the protein content of various processed black glutinous rice can be seen in Table 4.

Table 4. Protein Content of Various Processed Black Glutinous Rice (BGR)

Treatment	Protein Content (%) ± SD
Control BGR	9.45 ± 0.7663
Boiled BGR	2.95 ± 0.3669
Steamed BGR	2.55 ± 0.3689
Roasted BGR	8.33 ± 0.2010
Puffing BGR	9.04 ± 0.0556

SD: Standard Deviation

The protein content of the control black glutinous rice and the four processed black glutinous rice ranges from 2.55-9.45%. The control black glutinous rice protein content is 9.45%, which is higher compared to the data from the Nutrition Directorate, Health Department of Indonesia, (2001) which is 6.7% and research by Zulaikah, (2002) which is 8.0%. The highest protein content is found in the control black glutinous rice (9.45%) and the lowest in steamed black glutinous rice (2.55%). This was due to the water content, where the lower the water content, the higher the protein content found. According to Riansyah et al., (2013), the decrease of water content in a food material will cause the increase of protein content. The use of heat in the process could reduce the water content which resulted in the increase of protein content. The drier the food, the higher the protein content found, which is in accordance with Albert's (2013) whom stated that by decreasing the water content, the food would have higher content of protein, carbohydrate, fat, and other minerals. According to Buckle, Edwars, Fleet and Wotton (1987), the protein content is inversely proportional to the water content. The higher the water content, the lower the protein content found and vice versa.

3.5 Starch Content

From the results of this study, the starch content of various processed black glutinous rice can be seen in Table 5.

Table 5. Starch Content of Various Processed Black Glutinous Rice (BGR)

Treatments	Starch Content (%) ± SD
Control BGR	71.75 ± 0.1371
Boiled BGR	31.59 ± 0.1640
Steamed BGR	54.83 ± 0.6967
Roasted BGR	80.12 ± 0.1569
Puffing BGR	67.36 ± 0.1569

SD: Standard Deviation

The starch content of the control black glutinous rice and the four processed black glutinous rice ranges from 31.59-80.12%. The highest starch content is found in roasted black glutinous rice (80.12%), which is allegedly caused by the mashing treatment and the absence interaction with water during the process resulted in the increase of starch content. The starch content in boiled black glutinous rice was decreased (40.16%), which is in accordance with Rauf (2015), which stated that starch does not dissolve in cold water but in hot water instead where the starch granules became dissolved. Decrease in starch content was also found in puffing black glutinous rice (67.36%). In steamed black glutinous rice, the starch content also decreased significantly (16.92%), which was due to the use of hot steam during the process, resulted in the decrease of starch content.

3.6 Amylose and Amylopectin

From the results of this study, the amylose content of various processed black glutinous rice can be seen in Table 6.

Table 6. Amylose content of Various Processed Black Glutinous Rice (BGR)

Treatment	Amylose Content (%) ± SD

Control BGR	10.12 ± 0.5446
Boiled BGR	6.80 ± 0.6364
Steamed BGR	8.28 ± 0.1790
Roasted BGR	10.32 ± 0.6013
Puffing BGR	9.41 ± 0.0184

SD: Standard Deviation

The amylose content of the control black glutinous rice and the four processed black glutinous rice ranges from 6.8-10.32%. The highest amylose content was found in boiled black glutinous rice (10.32%), while the lowest was found in roasted black glutinous rice (6.80%), which was allegedly due to the soaking and steaming treatment that used heat. Rauf (2015), stated that starch granules dissolved in hot water. Amylose is easier to become a water soluble component compared to amylopectin when heated. This is due to the molecular weight of both types of starch. Amylose has a smaller molecule compared to amylopectin, while the higher the solubility of the starch, the greater the swelling became. Since amylose has a greater solubility in hot water compared to amylopectin, amylose has a greater swelling power.

The decrease in amylose content is due to the increase in temperature resulted in the decrease of amylose constituent component in starch. The increase of starch solubility due to the increase heating of the starch suspension is caused by the amylose depolymerization. High temperature could cause the depolymerization of starch molecules (Yuliasih, Irawadi, Sailah, Pranamuda, Setyowati and Sunarti, 2007). This resulted in a simpler amylose molecule, which has a shorter chain thus easily dissolves in water. Amylose is a starch component that has a straight chain and is water soluble (Ben, Zulianis, and Halim, 2007). The amylopectin content of various processed black glutinous rice can be seen in Table 7.

Table 7. Amylopectin content of Various Processed Black Glutinous Rice (BGR)

Treatment	Amylopectin Content(%) ± SD
Control BGR	89.87 ± 0.5446
Boiled BGR	93.19 ± 0.6364
Steamed BGR	91.71 ± 0.1790
Roasted BGR	89.67 ± 0.6013
Puffing BGR	90.58 ± 0.0184

SD: Standard Deviation

The amylopectin content of the control black glutinous rice and the four processed black glutinous rice ranges from 89.67-93.19%, while amylopectin content in control black glutinous rice or without processing is 89.87%. Haryadi (2008) stated that the low amylose content (0-2) and the high amylopectin content (98-99%) found in glutinous rice are responsible for the sticky and shiny characteristics of the glutinous rice.

3.7 Starch Digestibility

Based on the results of this study, the starch digestibility of various processed black glutinous rice can be seen in Table 8.

Table 8. Starch digestibility of Various Processed Black Glutinous Rice (BGR)

Treatment	Starch Digestibility (%) ± SD
Control BGR	39.29 ± 0.1171
Boiled BGR	75.61 ± 0.6925
Steamed BGR	62.54 ± 0.2177
Roasted BGR	43.32 ± 0.1738
Puffing BGR	40.69 ± 0.3059

SD: Standard Deviation

The starch digestibility of the control black glutinous rice and the four processed black glutinous rice ranges from 39.29-75.61%. The lowest starch digestibility is found in black glutinous rice without processing or control (39.29%). Increased starch digestibility is found in boiled and steamed black glutinous rice (75.61% and 62.54% respectively). This is allegedly caused by the long amount of time spent during the process that used water (Thornburn, Brand and Truswell, 1986 in Amalia, Rimbawan, and Dewi, 2011). Cooking process could cause the different levels of starch digestibility. The starch gelatinization process caused the changes in the structure of amylose from crystalline into amorphous, thus the increase in starch digestibility (Harlampu, 2000).

The factor that affects the starch digestibility is the amylose content. The result is in accordance with the literature that stated the higher the amylose content, the lower the starch digestibility. This is supported by Frei, Siddhuraju, and Becker (2003) whom stated that amylose content is one of the factors that affect the starch digestibility. Amylose is a glucose polymer that has a non-branching structure with a more crystal like feature and a more extensive hydrogen bond. The hydrogen bond in amylose is also stronger compared to amylopectin, therefore is harder to be hydrolyzed by digestive enzymes (Behall and Hallfrisch, 2002). This non-branching structure strongly tied the amylose and making it hard to digest (Rimbawan and Siagian, 2004). Other factors that affects starch digestibility is the presence of anti-nutrition and anti-amylase (food fiber and tannin), and the chemical structure of the starch (starch resistance).

In correlation to the level of food fiber, which is part of a food that cannot be digested by digestive enzymes, it could increase the food mix viscosity inside the intestine thus inhibits the food and enzyme interaction (starch). According to Winarno (2004), the fiber content in black glutinous rice is 1.3%. Therefore, the other factor that affects the starch digestibility is food fiber. Food that contains a high level of fiber will be tougher to digest or has a lower digestibility.

3.8 Antioxidant Activity

Based on the results of this study, the antioxidant activity of various processed black glutinous rice can be seen in table 9.

Table 9. Antioxidant activity of Various Processed Black Glutinous Rice (BGR)

Treatments	Antioxidant activity (%) ± SD
Control BGR	60.75 ± 0.244
Boiled BGR	14.05 ± 0.904
Steamed BGR	5.66 ± 0.417
Roasted BGR	39.39 ± 0.36 4
Puffing BGR	46.73 ± 0.315

SD: Standard Deviation

Antioxidant activity of control and puffing black glutinous rice is measured in the concentration of 1000 ppm while boiled, steamed, and roasted black glutinous rice was measured in the concentration of 100 ppm. Antioxidant activity of the control black glutinous rice and the four processed black glutinous rice ranges from 5.66% - 60.75%. The highest antioxidant activity is found in control black glutinous rice (60.75%) and the lowest was in steamed black glutinous rice (5.66%). Antioxidant activity found in boiled and steamed black glutinous rice was significantly decreased (14.05% and 5.66% respectively) compared to the control. This is allegedly caused by the use of water as the heat transfer medium during the process. Furthermore, the act of soaking the black glutinous rice caused the antioxidant to dissolve during the process of steaming.

On the other hand, antioxidant activity in roasted and puffing black glutinous rice slightly decreased (39.39% and 46.73% respectively) compared to control. This is allegedly caused by the short amount of time spent during the process. This founding is in accordance with the research by Suhartatik (2013), which stated that the heating process also affects the antioxidant activity of the food. The longer heating process could damage the antioxidant activity. According to Gordon, et al., (2001) antioxidant activity is affected by factors such as lipid content, antioxidant concentration, temperature, oxygen pressure, and the general chemical component of the food i.e., protein and water.

Anggarini et al., (2015) stated that antioxidant activity in black glutinous rice ranges from 30%-55% measured in the concentration of 1000 ppm. One of the antioxidant found in black glutinous rice is anthocyanin and it could be damage by high temperature. According to Nugraheni (2014), high temperature could induce damage towards the logarithmic pigment with heating time at constant temperature. Anthocyanin extracted from the black glutinous rice was damaged after processing at 80-100°C. This damage happened because anthocyanin sustain an increase in oxidation reaction at high temperature (Hou, et al., 2013). This is also in line with the research by Suhartatik (2013), the higher the heating temperature, the more anthocyanin is damaged. Similarly, the longer the heating process the more number of anthocyanin was degraded.

3.9 Total Energy

Based on the results of this study, the total energy of various processed black glutinous rice can be seen in Table 10.

Table 10. Total Energy of Various Processed Black Glutinous Rice (BGR)

Treatment	**Total Energy(kcal) ± SD**
Control **BGR**	351 ± 0.1331
Boiled BGR	142 ± 0.2769
Steamed BGR	233 ± 0.0987
Roasted BGR	379 ± 0.1263
Puffing BGR	408 ± 0.1197

SD: Standard Deviation.

Total energy of the control black glutinous rice and the four processed black glutinous rice ranges from 351-408 kkal. The highest total energy is found in puffing black glutinous rice (408 kkal), which was caused by the use of margarine during the process. The higher fat content it has the higher energy value it has since margarine contains 80% of fat and contains energy 9 kkal per gram (Winarno, 2004). Total energy found in control black glutinous rice is 351 kkal, which is lower compared to the research by Soeharto (2004) that stated the total energy was 356 kkal.

The lowest total energy is found in boiled boiled black glutinous rice (142 kkal). The use of water as the heat transfer medium caused the fat to be taken out, thus the higher water content found in boiled and steamed black glutinous rice. According to Mastuti (2008), the high water content found in the end productusually resulted in a low fat content.

Fat is one of the main content found in food and also the main energy source. According to Andarwulan et al., (2011), fat has an important role in the increase calorie of food due to the higher total energy it has compared to other nutrition substances. Every burning process of 1 gram carbohydrate and protein will produce 4 kkal energy, while the burning process of 1 gram fat will produce 9 kkal (Apriyantono, 1989).

4. Conclusion

The results of this research shows that the highest water content is found in boiled black glutinous rice (73.26%), the highest ash content is found in roasted black glutinous rice (1.19%), the highest fat content is found in puffing black glutinous rice (10.51%), the highest protein content is found in puffing black glutinous rice (11.09%), the highest starch content is found in roasted black glutinous rice (80.12%), the highest amylose and the lowest amylopectin content is found in roasted black glutinous rice (10.32% and 89.67% respectively),the highest digestibility is found in boiled black glutinous rice (75.61%), the highest antioxidant activity is found in control black glutinous rice (60.75%), and the highest total energy is found in puffing black glutinous rice (408 kkal).

Based on these findings, we can conclude that the best way of processing the black glutinous rice is by puffing it, which resulted in high fat content and high total energy produced. Meanwhile, the best digestibility is found in boiled black glutinous rice.

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