Chemical and Physical Characterization of Cereal Flakes Formulated with Broken Rice and Banana Flour

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Abstract. Broken rice is a by-product of the rice milling process. In Indonesia, the price of broken rice is very low and most of it, is only used as animal feed. In this study, broken rice were further processed into food products, that was cereal flakes which composited with banana flour. The aim of this study was to determine the chemical and sensory characteristics of cereal flakes made from a mixture of broken rice flour and banana flour. The broken rice, obtained from rice milling in Bandar Lampung and milled into flour to be further processed into cereal flakes with the addition of banana flour as a composite flour. There are three formulations of broken rice and banana flour to make that cereal flakes, that was 1: 3, 1: 1, and 3: 1. Each formulation of cereal flakes, then dried at 40°C, 60°C, and 80°C for 3h. The raw materials and all cereal flakes are then carried out with chemical characterization and physical characteristics. The results of this study, showed that the different ratio of broken rice flour and banana flour had significantly affect (p<0.05) the chemical characteristics.

1. Introduction
Rice is the main agricultural commodity produced in Indonesia, which due to the fact that most of people in Indonesian consume rice as the main food. Until 2016, rice production in Indonesia had reached 79.1 tons, which was an increase of 11.7% from the previous production [2]. One of the regions in Indonesia, namely Lampung Province is one of the largest rice producing centers in Sumatra. Data from Indonesia Central Bureau of Statistic Agency (BPS) shows that, until 2015 rice production in Lampung had reached 3.6 million tons and its production increase from year to year [4].
In its production, rice is produced from several steps of rice milling processes, which in the process also produce some by-products such as husks (15-20%), rice bran (8-12%), and broken rice (± 5%) [22]. Broken rice is a kind of rice consisting of grains broken in the milling process [9]. According to Silva et al in Carvalho AV et al (2012) [6], during the grinding process 14% of the milled rice will break into broken rice or broken rice, which is commercially classified as a low value product even though it has the same proximate content as rice (unbroken rice). Generally, these menir rice is used more as livestock feed and many people do not like to consume menir rice because it tastes bad and is considered low quality, as a result the economic value of broken rice is low. Therefore, this rice needs to be processed further to increase its added value. Until now, broken rice is generally processed further into rice flour which is used as a raw material for making several types of food products through an extrusion process [6].
Many food products that can be made from broken rice flour and in this study cereal flakes products will be developed. Cereal flakes are one of the ready to eat food products that are commonly used as a breakfast menu, especially for children. In this era, the most popular breakfast food is ready to eat cereals because it does not take a long time to serve [17]. Flakes is one type of ready to eat breakfast cereal with low water content and crunchy texture [17]. Actually there are two classes of breakfast cereals, the first is breakfast cereals that need cooking before eating, and the second is breakfast cereals which can be eaten with the addition of water or milk [16].

For the fulfillment of nutrients in cereal flakes, composite flour is usually used from other ingredients such as from legum or other tubers and in this study, banana flour was used as composite flour. The use of this banana flour is to add or enrich the nutrients and flavor of the cereal flakes products. In addition, bananas are one of the main agricultural products in Lampung Province, where one of their derivative products is banana flour.

Based on the description, further processing of broken rice which are a by-product of the rice milling process, can be a solution to increase the economic value of the rice so that it does not only become waste which doesn’t utilized properly.

2. Material and Methods

2.1. Broken Rice Flour Production

One of the raw materials used in this study was broken rice which is a byproduct of rice milling process. That broken rice was obtained from Puji Rahayu Rice Milling Industry, Way Kandis, Lampung. In this study, the making of broken rice flour was based on Suksomboon and Onanong (2006) Methods [19], that was dry milling method with soaking treatment before the milling process. Broken rice were ground with rice grinder into rice flour with a particle size 60 mesh. Broken rice flour, stored in PE plastic with a thickness of 0.15 mm at room temperature for further processing.

2.2. Cereal Flakes Processing

The process to making cereal flakes were based on the research of Carvalho et al (2012) [6]. Broken rice flour obtained from the previous stage, then mixed with banana flour with three types of formulations of broken rice flour and banana flour. The product formulation was prepared by mixing 1:3, 1:1, and 3:1 of broken rice flour and banana flour. Then each formulation were made by mixing 2% vanilla, 2% sugar, and water until the appropriate mixture is formed. Flakes dough that have been formed are then flattened using roller and then moulded. That flakes, then dried using an oven dryer with a variation of the drying temperature at 40, 60, and 80 °C for 3 hours. All cereal flakes that obtained are then stored in plastic at room temperature for further analysis.

2.3. Chemical and Physical Charactrization of Flours and Cereal Flakes

Broken rice flour and banana flour as well as cereal flakes products that obtained were characterized for water content, ash content, fat content, protein content, and their amylose content based on AOAC (2006) methods [1], and carbohydrates content that calculated by the difference between 100 and the sum of the percentage of water, proteins, lipids, and ash (by difference methods). In addition, broken rice flour, banana flour and cereal flakes products were also characterized for their color, and for the cereal flakes product, the hardness value was also characterized. For hardness, that analyzed using Universal Testing Machine (UTM) Zwick ZO.5 (USA) and color (L a b) were analyzed using Chromameter Konica Minolta. The L* value indicates the lightness. The a* value give the degree of red-green color, with a higher positive of a* value indicating more red. The b* value indicates the degree of yellow-blue color, with a higher positive of b* value indicating more yellow.
2.4. Statistical Analysis

All statistical analyzes were performed using SPSS 16.0 software with analysis of variance (ANOVA) method and tukey test (p < 0.05).

3. Result and Discussion

3.1. Chemical and Physical Characterization of Raw Material

Chemical Characterization

Chemical characterization of raw material that carried out in this study included analysis of the proximate content (water content, ash, fat, protein and carbohydrate) and amylose content. The proximate analysis was carried out to determine the nutritional composition which contained in the raw material. As shown in Table 1, it can be seen that carbohydrates are the main chemical component of broken rice flour (80.95%) and banana flour (88.12%). It also shows that banana flour can be used as an alternative source of carbohydrates other than wheat, rice, and corn.

Then, the value of broken rice flour was obtained at 6.303% (wb), where this value was in accordance with SNI 3549: 2009 for rice flour product with maximum moisture content is 13% (wb). That result shows that broken rice flour in dry conditions and can be stored at room temperature. The same result is also shown from the value of banana flour moisture content where the value of banana flour moisture content is 7.213% (wb) which is in accordance to SNI 01-3841-1995 for banana flour with maximum value is 12%. According to Buckle KA et al via Yani A et al (2013) [20], the moisture content of a food product can affect the shelf life of that product, so that if neither broken rice flour nor banana flour are not dry (> 13%), it can cause damage to the flour during the storage process.

|                              | Broken Rice Flour | Banana Flour  |
|------------------------------|-------------------|---------------|
| Moisture Content (%wb)       | 6.303 ± 0.055     | 7.213 ± 0.214 |
| Ashes (%db)                  | 0.264 ± 0.008     | 0.295 ± 0.009 |
| Lipids (%db)                 | 4 ± 0.233         | 1.307 ± 0.1   |
| Proteins (%db)               | 8.480 ± 0.377     | 3.066 ± 0.199 |
| Total Carbohydrates (%db)    | 80.953 ± 0.618    | 88.119 ± 0.315|
| Amyloses (%db)               | 17.551 ± 0.127    | 26.43 ± 0.187 |

*Average and standard deviation of three replicates of each analysis

Then the ash content in broken rice flour is known as 0.264% (%db) which that value is in accordance with SNI of rice flour, with maximum value is 1% (%wb). In addition, the value of ash content in banana flour is 0.295% (%db). The ash content of banana flour is very low, which caused by the loss of some mineral components during process of making banana flour such as during the process of soaking, drying, and grinding. According to Chiang and Yeh (2002) [7], during the process of soaking, proteins, lipids, and ash (minerals) will dissolve in the soaking water.

Furthermore, the protein content of broken rice flour is 8.480% db, that not too different from the protein content of rice where the protein content of rice is ± 7-10% [10]. Then, the protein content of banana flour is 3,066% db as reported by [23]. That protein value is affected by the type of banana and their processing to banana flour.
Then, lipid content of rice flour is 4% db, while the lipid content of banana flour is 1.307% db. That results indicate that, the lipid content of banana flour is quite lower than broken rice flour, so that banana flour can be used as a diet menu [23]. But the value of broken rice flour lipid content is quite high when compared with some of the results of other studies such as the results of the study of Carvalho, et al [6].

In this study, the analysis of amylose content from broken rice flour and banana flour were measured using a spectrophotometric method at a wavelength of 625 nm. Amylose content analysis were carried out to determine the effect of amylose content on the texture of cereal flakes products. As shown in Table 1, it is known that the amylose content of broken rice flour was 17.551% db, while the amylose content of banana flour is 26.043% db which is higher than broken rice flour. The amount of their amylose content are affected by the their each cultivar and their processing become flour.

As the result, the amylose content of broken rice flour was 17.551% db. It has been reported that flour from rice containing less than 20% amylose is desirable to use in bread without gluten formulas since it produces much less retrogradation, but other authors have shown that the use of rice varieties, having medium and high amylose content (18–27%), gave good results for gluten-free bread [8].

Physical Characterization

In addition, physical characterization of raw materials is also carried out in this study, that was color analysis. The color analysis was performed using chromameter which expressed of L a b value . The L* value indicates the lightness. The a* value give the degree of red-green color, with a higher positive of a* value indicating more red. The b* value indicates the degree of yellow-blue color, with a higher positive of b* value indicating more yellow. As shown in Table 2, it can be seen that broken rice flour has an average value of lightness (L) of 83.495, appearance (a) of 4.82, and blueness (b) of 4.645. That result, indicates that broken rice flour had bright white color.

| Table 2. Color Characteristics of Raw Material. |
|-------------------|------------------|------------------|
|                  | L (Lightness)    | a (appearance)   | b (blueness)    |
| Broken Rice Flour | 83.495±0.049     | 4.82±0           | 4.645±0.063     |
| Banana Flour      | 75.125±0.049     | 6.36±0.042       | 8.96±0.042      |

When compared to the color of broken rice flour, the banana flour had a darker color or more brown than broken rice flour. That indicated by the L (lightness) value of banana flour which smaller than L value of broken rice flour. The banana flour had a light brown color. Banana flour had a darker color than rice flour, due to an enzymatic browning process [23]. Therefore, when the processing becomes flour, the banana had an enzymatic browning process, so the color becomes more brown.

3.2. Chemical and Physical Characterization of Cereal Flakes

Chemical Characterization

In this study, there were 9 samples of cereal flakes with variations in the formulation of raw materials and drying temperatures. All samples of cereal flakes were also analyzed for proximate content (moisture, ash, fat, protein and carbohydrate) and amylose content.

As shown in Table 1, it can be seen that carbohydrates are the main chemical content of these cereal flakes product. This is due to the raw material of these product, which is broken rice flour and banana flour had carbohydrate as a main component. Then it can be seen that the increasing of temperature did not provide a significant difference in carbohydrate content, as well as the difference in the formulation of raw
The drying process applied to the production of cereal flakes aims to produce cereal with a certain amount of moisture content. The moisture content that contained in the cereal flakes affects the crispness of the final product. When compared to samples A, B, and C that are different at the drying temperature, it was known that, the value of the moisture content of samples A, B, and C are significantly different (p <0.05). Increasing of drying temperature, made the cereal flakes products will dry out more. That was indicated by the value of the moisture content which decreases with increasing drying temperature. Then the difference in the formulation of raw materials, does not provide a significant difference in the water content value of cereal flakes.

Table 3. Proximate and Amylose Content of Cereal Flakes.

| Sample | Moisture Content (%wb) | Ashes (%db) | Lipids (%db) | Protein (%db) | Total Carbohydrate (%db) | Amyloses (%db) |
|--------|------------------------|-------------|--------------|--------------|--------------------------|----------------|
| A (1:3) | 5.2±0.10 | 0.2±0.01 | 4.7±0.06 | 2.4±0.01 | 86.8±0.06 | 20.6±0.07 |
| A (1:1) | 5.2±0.10 | 0.3±0.01 | 4.4±0.06 | 3.5±0.12 | 86.4±0.15 | 19.1±0.33 |
| A (3:1) | 6.2±0.16 | 0.3±0.01 | 5.9±0.15 | 4.4±0.05 | 83.7±0.25 | 15.5±0.07 |
| B (1:3) | 4.3±0.03 | 0.3±0.01 | 2.5±0.01 | 4.4±0.21 | 90.3±0.23 | 18.9±0.13 |
| B (1:1) | 4.4±0.30 | 0.2±0.01 | 1.8±0.22 | 4.23±0.04 | 89.01±0.30 | 20.1±0.04 |
| B (3:1) | 4.9±0.04 | 0.2±0.02 | 4.5±0.05 | 4.2±0.44 | 85.7±0.43 | 18±0.14 |
| C (1:3) | 3.7±0.29 | 0.3±0.01 | 2.4±0.05 | 3.06±0.49 | 88.5±0.53 | 19.5±0.15 |
| C (1:1) | 2.9±0.12 | 0.2±0.01 | 4.4±0.03 | 4.6±0.44 | 88.6±0.47 | 14.6±0.21 |
| C (3:1) | 2.2±0.16 | 0.2±0.01 | 4.6±0.05 | 4.2±0.20 | 90.8±0.29 | 13.9±0.19 |

*Average and standard deviation of three replicates of each analysis.

Furthermore, on the results of the ash content analysis, it was known that the ash content of cereal flakes products from samples A, B, and C are around 0.2 - 0.3% db, where the value is not much different from the ash content of the raw material. This shows that the processing of raw materials into cereal flakes products does not cause changes in ash content. The difference in drying temperatures of cereal flakes and raw material formulations, does not provide a significant difference in the ash content of cereal flakes.

On the results of lipid level analysis, it was known that the increasing of drying temperatures can cause a significant decrease in the lipid content of cereal flakes products. This is due to the higher drying temperatures used in the process, so that the lipid components contained in the product break down into simpler components such as fatty acid and gliserol [17]. Then the results of this study also showed that, if more broken rice flour are used, so the value of the lipid content was more higher. That was caused of the lipid content of rice flour as raw material is also quite high. If the results are compared with the SNI 01-4270-1996 as standard for cereal products, so the lipid content of cereal flakes product are below from 7% as a minimum value for the lipid content of cereal products. Therefore, this product is suitable for diet menu to people who are obese.
Then, based on the table 3, it is also known that cereal flakes products are obtained in this study has a protein content of 3 - 4.5% db. The value of protein content is very low when compared with the results of flakes products in the study of Carvalho, et al (2012) [6]. In addition, when compared to SNI 01-4270-1996, the protein content of the cereal product is still below from the minimum requirement of cereal protein commonly, that is 5%. That was caused banana flour as a composite flour in the production of cereal flakes contains low protein, while flakes products in the Carvalho et al (2012) [6] study are high in protein due to the use of nut flour as composite flour which containing 20.2% protein. Then it was also known that the differences in the composition of broken rice flour and banana flour caused significant differences in the protein content of cereal flakes products. The more composition of broken rice flour is used, then the protein content of cereal flakes products will increase. That was caused broken rice flour has a higher protein content than banana flour, so the use of broken rice flour which will increase the protein content of cereal flakes. While the increase in drying temperature by 20°C does not significantly affect the protein content of cereal flakes products.

Furthermore, the cereal flakes products were also analyzed for their amylose content to determine the effect on texture of the cereal flakes that produced in this study. According to Juliano, B.O via Gonzalez, R. J (2013) that Amylose content affects quality and texture of product. In addition, according to Setiaji B (2012) Starch has an important role in producing flakes because its can affect their texture that caused by the ratio of amylose and amylopectin in starch. Therefore, in this study, amylose content from cereal flakes products was also analyzed. Based on the results shown in table 3, it can be seen that the average cereal flakes product contains amylose 13-20%. Then it can be seen that the more banana flour is used, the amylose content of cereal flakes will also increase. This can be caused by banana flour which has a higher amylose content than broken rice flour.

### Physical Characterization

Beside the chemical characteristics, cereal flakes products that obtained in this study also analyzed of their physical characteristics. The physical characteristics of cereal flakes products that observed in this study were color and texture. The results of each analysis are shown in Table 4 and figure 1.

| Sample | Colour Index | Colour Profile of Cereal Flakes. |
|--------|--------------|----------------------------------|
|        | L  | a   | b     |
| A (1:3) | 69.805 | 5.830 | 9.025 |
| A (1:1) | 69.620 | 5.405 | 8.100 |
| A (3:1) | 72.535 | 4.975 | 8.040 |
| B (1:3) | 74.375 | 5.505 | 8.860 |
| B (1:1) | 75.955 | 4.860 | 8.465 |
| B (3:1) | 78.710 | 4.555 | 8.170 |
| C (1:3) | 74.905 | 5.165 | 8.580 |
| C (1:1) | 76.815 | 4.905 | 9.435 |
| C (3:1) | 80.37  | 4.425 | 8.340 |

*Sample A (Dried Flakes at 40°C), sample B (Dried Flakes at 60°C), sample C (Dried Flakes at 80°C)

Based on the results of the color index measurements on the cereal flakes products, both in samples A, B, and C, it is known that the more concentration of rice flour is used, so the color of the cereal flakes product will incline to be close to white. This is indicated by the value of Lightness (L) which is getting
bigger or closer to the value of 100. This result can be caused by the rice flour has a whiter color than banana flour, so the more rice flour is used, the color of the cereal flakes product will also close to white. Then the higher the drying temperature, the color of the cereal flakes will tend to be white. This is indicated by the value of lightness (L) in sample C which is greater than samples A and B. It was also appears visually which seen in sample A whose the color is still brown like the color of the initial dough after the drying process has finished. This can be caused because 3 hours of the drying process with a temperature 40 ° C for sample A, is not enough to make cereal flakes to be cooked. According to Setiaji, B (2012), the drying temperature greatly affects the maturity level of the product that produced. The drying temperature also affects the time that needed by the dough which becomes the product as desired. Whereas between samples B and C, there were no significant color differences (p <0.05). This showed that with a temperature of 60 ° C in the drying process of cereal flakes for 3 hours was enough to made product to be cooked with a low moisture content.

Besides color, the physical characteristics that determine the quality of cereal flakes are the texture of the cereal flakes. The texture parameters that analyzed in this cereal flakes product are the hardness values that indicate the crispness of the cereal flakes products which produced in this study. The results of the analysis of the hardness of the cereal flakes products are shown in Figure 1.

![Figure 1. Hardness of Cereal Flakes Product. Sample A (Dried Flakes at 40°C), sample B (Dried Flakes at 60°C), sample C (Dried Flakes at 80°C)](image)

Based on the results shown in Figure 1, it is known that the higher the drying temperature, the hardness value of cereal flakes will be greater. It can also be seen from sample A which is still very fragile when compared with samples B and C. This can be caused by the use of 40 ° C for 3 hours on drying A sample, not enough for the gelatinization process to occur in the starch component. Then it can be seen that sample C (1: 3), the hardness value is higher than other samples. This can be caused by sample C which has a high amylose content because it uses more banana flour and this sample is dried at a higher temperature than samples A and B. According to Muchtadi et al via Setiaji B (2012), high amylose content, incline to produce the harder flakes.
4. Conclusion

Broken rice flour as a waste from rice milling industry that obtained in this study can be used as raw material for making cereal flakes and appropriate with SNI quality requirements. Then, The temperature difference of 20 °C in the drying process can cause significant color and texture differences in cereal flakes products from composite rice flour and banana flour. The difference in formulation of rice flour and banana flour also gives a significant difference in the color and texture of cereal flakes. The difference in drying temperature and raw material formulation does not provide a significant difference in the proximate content of cereal flakes. Carbohydrates are a major component of cereal flakes. Beside that, Fat and protein content is still quite low when compared to SNI quality requirements for cereal products. So, that cereal flakes product still needs to add other composite flour such as nuts flour to enrich nutrition, especially protein in these cereal flakes.

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