Evaluation of Corn Grit Quality from Farmer-Scale Trial Production

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Abstract. Corn grit is one of the corn products can be used as staple food for rice substitution in order to support food diversification program. This research conducted to identify the quality of corn products produced from the production trial at farmer level. Corn grit production trial was conducted at corn centre production area in Kupang-East Nusa Tenggara. The research was conducted in three stages: 1) milling process of corn, 2) corn grit processing, and 3) Identification of corn product quality, including aflatoxin content, moisture content, ash content, fat content, protein, carbohydrate, dietary fibre and organoleptic properties. Two types of corn used in this research were white and yellow corn. Corn grit processing was conducted to produce 3 types of corn grit that were original corn grit, parboiled corn grit and premium corn grit. The results showed that yellow corn had higher yield and milling capacity than white corn that was 86.44% and 19.43 kg grit/hour corn. Measurement of quality corn grit products showed that the parboiled corn had the highest total aflatoxin content of 17.08 ppb in white corn and 20.95 ppb for yellow corn, although the value was still below the safe threshold for consumption. Parboiled corn grit also showed the highest of carbohydrate content, protein content and total energy of 82.87%, 8.83% and 386.49 kcal on white corn; and 85.42%, 8.74% and 392.82 kcal on yellow corn. However, based on the preference test for colour parameters, flavour, aroma and overall appearance showed no significant difference between treatments.

1. Introduction
Rice is a staple food for most Indonesians where their needs are increasing year by year along with the increasing population in Indonesia. Consumption per capita of rice in Indonesia in 2015 reached 98,0871 kg/capita/year [1]. The Government has made various efforts to reduce people's dependence on staple foods of rice, including by establishing a Local Resource-based Food Consumption Diversification policy. In addition, the Food Security Agency in 2012 has developed a Local Basic Food Development Model as a pilot project to create alternative staple foods other than rice and flour based on local resources such as cassava, sago and corn [2]. Corn is one of the sources of carbohydrates that are widely used as raw material in the feed and food industries, it is also widely used as a staple food in several regions in Indonesia. Corn production in East Nusa Tenggara in 2015 was 685,081 tons, where this number increased from 2014 with 647,108 tons of production. Citizen of East Nusa Tenggara is commonly planted corn in fields with other food crops such as paddy fields, tubers, and legumes in mixed cropping systems [3]. In addition to having a high availability of corn, East Nusa Tenggara having the highest level consumption per capita of corn that was 39.21 kg/capita/year [4].

East Nusa Tenggara’s people are actually used to consuming corn either in the form of steamed corn or porridge (it was called Bose in local society), but lately there has been a change in the pattern of
consumption of staple food some people in East Nusa Tenggara to consumption in the form of rice. The dependence on the pattern of staple food for one commodity such as rice is feared to cause food insecurity, especially in the event of crop failure. Therefore, efforts need to be made to restore the habits of the people of East Nusa Tenggara to consume corn as a staple food in the form of processed products that are more practical to be processed like rice.

The innovation of processing corn-based products is absolutely necessary so that it is easier and more practical in processing and more attractive to the community to consume them. In addition, there are several factors inhibiting or side effects if corn is directly consumed without processing it in advance, such as stomach pain. Therefore, it is necessary to do research on the processing of corn into the form of corn grit which is more practical and relatively easier in processing. Besides that, the corn grit has modified is known not cause stomach pain and is more resistant to aflatoxin infection so that the shelf life is longer. The purpose of this research was to identify the quality of processed corn grit produced from the production trial at farmer level in Kupang-East Nusa Tenggara as a dissemination program of Agricultural Postharvest Research and Development supporting acceleration of food diversification program based on local food in the east area in Indonesia.

2. Materials and Methods

2.1. Materials

The study was conducted in 2016 in Kupang, East Nusa Tenggara and Agricultural Postharvest Research and Development in Bogor. The main material used in this study were two type of corn (yellow and white corn) and traditional starter from traditional market in Indonesia which was contains of many microorganism such as fungi (Amylomyce rouxii, mucor sp, Rhizopus sp), yeast (Saccharomycopsis fibuligera, Saccharomycopsis malanga, Pichia burtonii, Saccharomyces cerevisiae, Candida utilis), and bacteria (Pediococcus sp, Bacillus sp). The equipment needed were polisher, soaking tube and siever machine.

2.2. Methods

The research was conducted in three stages: 1) milling process of corn, 2) corn grit processing, and 3) Identification of corn product quality. Firstly, milling process of corn was conducted to break the corn kernels that the small corn grit (diameter 3-4 mm) produced, furthermore, corn grit were sorted and sieved to obtain clear and suitable size of corn grit which was ready used for the fermentation process. Furthermore, corn grit processed through many stages that was soaking for 24 hours, steaming for 2 hours, sun-drying and packaging. Ratio of corn grit and water used in the fermentation process was 1:2. There were two kinds of fermentation process used in this research that were natural fermentation and microbial fermentation. Natural fermentation was did by soaking of corn grit in water, while microbial fermentation was did by soaking of corn grit in mixed of water and traditional starter. Fermentation was did by soaking of corn grit at room temperature in neutral pH conditions.

2.3. Experimental Design

The experimental design used was completely randomized design with two factors, ie the type of corn grain (yellow and white corn) and fermentation treatment (no fermentation, natural fermentation and fermentation using microbe starter). Then experimental data were analyzed using ANOVA and continued with Duncan Multiple Range Test.

2.4. Analysis Method

Analysis conducted on the corn grit included analysis of chemical and organoleptic properties. The chemical properties of corn grits were observed: yield, aflatoxin content, dietary fibre, moisture content, ash, fat, protein, carbohydrate and total energy. Analysis of organoleptic properties were conducted using preference test on the colour, flavour, appearance, and size of corn grit using 100 panelists. The sample used in this test was steamed corn grit.
3. Result and Discussion

3.1. Milling process of corn

The result of corn grit produced from farmer scale trial production was shown in Table 1. The result showed that capacity of the corn milling machine was 17.36 kg of corn kernels/hour for white corn and 22.37 kg of corn kernels/hour for yellow corn. Based on that capacity, the yield of corn grit produced in every hour was 15 kg for white corn and 19.43 kg for yellow corn. Yields of corn grit produced between two type of corn used (yellow and white corn) were not significantly different. The average number of corn grit can be produced by farmer’s milling machine assuming 8 hours/day was ±120 kg of corn kernels/day for white corn, and 150 kg of corn kernels/day for yellow corn. This differences caused by the threshing level of both type of corn used. Performing of corn milling machines used by farmers was not optimal so the production capacity of the milling machine was relatively small. The input hole for the corn inlet into the milling component was small, so the corn input must be carried out slightly to avoid blockage in the filtration process in the machine between corn grit, corn bran and impurities.

Table 1. Yield on milling process of corn

| Type of corn | Milling Capacity | Yield of corn grit | Corn bran | Impurity |
|--------------|------------------|--------------------|-----------|----------|
|              | Corn kernels/hour| Corn grit/hour     | %         |          |
| White        | 17.36±0.08 *     | 15.00±7106 *       | 86.44±0.06 * | 1.17±0.24 * | 5.40±0.01 * |
| Yellow       | 22.37±0.10 b     | 19.43±0.04 b       | 86.87±0.03 b | 8.96±0.04 b | 4.17±0.01 b |

Note: Mean values in each column with the same letter are not significantly different (p = 5%)

The output that comes out of the process of corn milling consists of three products, namely corn grit, bran and impurity. The corn grit produced was various sizes that are still mixed with some of the husks which was not separated in the screening process in a milling machine. The bran produced had the quite high of mesh size around 80 mesh. The brain produced was not significantly different between white corn and yellow corn. The impurities consist of corn husk, spill, and a small portion of corn husk which was left. The number of impurities produced from the corn milling process was quite low within 5.40% in white corn and 4.17% in yellow corn. The impurities produced as a by-product of this milling process was used to feed pigs and poultry by the farmer. As feed, it was processed through the cooking process using a large drum for approximately 1 hour at a boiling water temperature of around 100ºC.

3.2. Chemical Properties

The results of the trial of the production of several corn grit products showed that the yield was quite high with values above 80% and significantly different in all treatments. The yield of natural fermented white corn showed the highest value compared to other products with an average value of 94.63%. The yield of non-fermented corn grit both of white and yellow corn showed a lower value compared to other products because it was calculated based on the yield of corn milling, where in the production process there were some missing components namely skin, pile and some impurities. Generally, the yield of white corn grit showed a higher value than the yellow one. The difference of the final yield of corn grit products was probably caused by differences in the level of loss during the production process, especially the process of soaking corn grit. Yield and chemical properties of fermented corn grit were shown in Table 2. The aflatoxin content of corn grit was shown in Table 3.

Analysis of the proximate content of corn grit products was conducted on a number of parameters including dietary fibre content, moisture content, ash content, carbohydrate, fat, protein and total energy. The analysis results of dietary fibre on corn grain used as raw materials showed that the value was not significantly different between white corn and yellow corn, ie 5.30% and 5.93%. Generally, the dietary fibre of fermented corn was both in natural fermentation and fermented using microbe tend to decrease, and its value was lower than unfermented corn grit. Measurement of corn grit moisture content showed below 10% in all product. The moisture content of microbial fermented corn grit showed lower moisture
content compared to other products, namely 5.57% in white corn and 3.48% in yellow corn. The low water content in the microbial fermented corn grit probably due to over-drying in its sun drying process. The steaming process of microbial fermented corn grit caused the structure to be softer and more porous so that it releases water more quickly during the drying process. Moisture content is a very important factor because it affects the product’s shelf life. Water content was known to be very influential on the growth of microbes and fungi in corn. According to [5], the moisture content in food material determines the freshness and long-term durability of this food material, the high water content results in easy bacteria, mould and yeast to multiply, so there will be changing in food. The overall moisture content of the corn grit showed that it was still below the 14% safe moisture level. According to SNI 4483: 2013 the maximum limit of moisture content required for storage corn as a raw material of feed is 14%.

Table 2. Yield and chemical properties of corn grit produced in farmer level in Kupang, East Nusa Tenggara

| Type of product | Yield (%) | Fiber (%) | Moisture content (%) | Ash (%) | Fat (%) | Protein (%) | Carbohydrate (%) | Energy (kcal) |
|-----------------|-----------|-----------|----------------------|---------|---------|-------------|-----------------|--------------|
| A               | 5.30±0.07e | 7.41±0.16d | 1.34±0.04d           | 2.37±0.04d | 9.12±0.03d | 79.78±0.01d | 376.85±0.06d     |
| B               | 4.85±0.01b | 5.57±0.04b | 0.55±0.07ab          | 2.19±0.08a | 8.83±0.04de | 82.87±0.04f | 386.49±0.06f     |
| C               | 4.73±0.04a | 6.57±0.03c | 0.62±0.03b           | 2.64±0.06b | 8.70±0.06c | 81.48±0.03f | 384.46±0.05c     |
| D               | 5.39±0.04b | 9.12±0.03c | 0.65±0.03bc          | 2.15±0.07b | 8.52±0.03b | 79.24±0.06b | 371.67±0.24b     |
| E               | 5.93±0.04f | 8.84±0.06e | 1.41±0.06d           | 3.15±0.07c | 8.38±0.03b | 78.22±0.03a | 374.75±0.06c     |
| F               | 5.41±0.01d | 3.48±0.03a | 0.57±0.04b           | 1.80±0.07b | 8.74±0.06ed | 85.42±0.03b | 392.82±0.13f     |
| G               | 5.64±0.06e | 9.49±0.08f | 0.44±0.06a           | 1.55±0.01b | 8.13±0.04e | 80.40±0.07e | 368.03±0.72a     |
| H               | 5.97±0.03f | 9.04±0.06f | 0.74±0.06c           | 2.12±0.01b | 8.71±0.06c | 79.40±0.06c | 371.46±0.06b     |

*Mean values in each column with same letter are not significantly different (p = 5%)

A: White corn, grain  
B: White corn, fermentation using traditional starter  
C: White corn, natural fermentation  
D: White corn, no fermentation

E: Yellow corn, grain  
F: Yellow corn, fermentation using microbe starter  
G: Yellow corn, natural fermentation  
H: Yellow corn, no fermentation

Table 3. Aflatoxin of corn grit produced in farmer level in Kupang, East Nusa Tenggara

| Type of product | Aflatoxin B1 (ppb) | Aflatoxin B2 (ppb) | Aflatoxin G1 (ppb) | Aflatoxin G2 (ppb) | Aflatoxin Total (ppb) |
|-----------------|-------------------|-------------------|-------------------|-------------------|-----------------------|
| A               | 3.55±0.07c        | 3.37±0.10c        | 5.11±0.01d        | 5.48±0.06d        | 17.84±0.06d           |
| B               | 3.81±0.10d        | 3.25±0.07b        | 4.97±0.03d        | 5.05±0.07c        | 17.08±0.06c           |
| C               | 2.76±0.04e        | 2.45±0.07a        | 5.55±0.07c        | 6.00±0.15d        | 16.76±0.08d           |
| D               | 2.09±0.13f        | 3.21±0.01b        | 3.88±0.11b        | 4.15±0.07e        | 13.33±0.04e           |
| E               | 3.88±0.11f        | 5.05±0.07e        | 3.54±0.06d        | 4.78±0.01b        | 17.24±0.06d           |
| F               | 2.80±0.14c        | 4.05±0.04d        | 7.15±0.21f        | 6.95±0.07e        | 20.95±0.06h           |
| G               | 2.48±0.06b        | 3.26±0.08b        | 4.36±0.08c        | 5.07±0.01e        | 15.16±0.08b           |
| H               | 3.13±0.18d        | 3.46±0.08c        | 4.26±0.08a        | 4.70±0.14b        | 15.54±0.06c           |

*Mean values in each column with the same letter are not significantly different (p = 5%)

A: White corn, grain  
B: White corn, fermentation using traditional starter  
C: White corn, natural fermentation  
D: White corn, no fermentation

E: Yellow corn, grain  
F: Yellow corn, fermentation using microbe starter  
G: Yellow corn, natural fermentation  
H: Yellow corn, no fermentation

The analysis results of ash content indicate that the three corn grit products have lower ash content than corn kernels. However, overall the ash content of fermented corn grit in this study was higher than the result of fermented corn grit were soaked using mixture solution using α-amylase and CaCl₂ [7]. Ash content is often associated with the representation of the mineral content of a product [6], so it can be said that the ash content of corn grit that was smaller than corn kernels due to the mineral content located in the corn husk and the corn germ had been released during the milling process. The ash content of
fermented and unfermented white corn grit was not significantly different, but the ash content in natural and microbe fermented yellow corn grit showed less value than the non-fermented corn grit.

The measurement results on the fat content of three corn grit products showed that the fermented and non-fermented white corn grit showed no significantly different with corn kernels with a value range of 2.15-2.64%. However, the fat content of both fermented and nonfermented yellow corn grit showed a smaller value than corn kernels with an average value of 1.5-2%. Generally, the fat content of microbial fermented corn grit in this study was higher than fat content of fermented corn grit soaked using mixture solution using α-amylase and CaCl₂ that was 0.36% [7]. According to [8], the fat content in corn kernels varies between 1.2 to 5% and is majority stored in germ, which is about 83% of total fat. Corn fats are mainly in the form of triglycerides and many contain essential unsaturated fatty acids, especially linoleic. Fat content and fatty acid composition in corn are influenced by agronomic and genetic factors [8].

The test results on the protein content of corn grit showed that the microbial fermented corn grit showed a higher value than the natural fermented and non-fermented corn grit. Generally, the protein content both in corn kernels and white corn grit showed a higher value than yellow corn grit. The average value of protein both in corn kernels and corn grit ranged 8-9%. This was in line with the results of previous studies which stated that corn kernels were known to contain approximately 10% of protein, where the protein contained in corn kernels was prolamin (zein) 47.2%, gluten 35.1%, albumin 3.2% and globulin 1.5%. Prolamin is a protein that is soluble in ethanol 70-80%, gluten dissolves in alkaline and dilute acids, albumin dissolves in dilute salts and globulins dissolve in water [8]. This result also inlines with the protein content of fermented corn grit using mixture solution using α-amylase and CaCl₂ that was 8.59% [7].

Carbohydrates are the biggest component in corn, where the main component is starch composed of amylose and amylopectin. Carbohydrates in corn except starch are sugar, pentosan and crude fibre. The carbohydrate content of microbial fermented corn grit showed the highest value among other products, both in white and yellow corn. Generally, natural fermented and microbial fermented corn grit has a higher carbohydrate than non-fermented corn grit. Generally, carbohydrate of corn grit in this study (more than 80%) was quite higher than fermented corn grit soaked using mixture solution using α-amylase and CaCl₂ that was 79% [7]. The results on the total energy of corn grits showed a fairly high value (370-390 Kcal) with a significant difference between them. The microbial fermented corn grit had the highest energy value compared to other corn grit products, both in white and yellow corn. The lowest energy was shown by fermented corn grit with an average value of ± 371 kcal.

One of the biggest problems of corn products is aflatoxin contamination which is very toxic to the body. According to [9], aflatoxin is a natural contamination produced by several species of Aspergillus fungi which are widely found in tropic and humid climates, especially at temperatures of 27-40 °C (80-104 °F) and relative humidity of 85%. It is known more stable and resistant during food processing. Nowadays there are 4 kinds of aflatoxin, namely aflatoxin B1, aflatoxin B2, aflatoxin G1, and aflatoxin G2 which are the main aflatoxins which are naturally known and found in nature [10].

The results of measurement on the aflatoxin content of corn grain and corn grit in Table 3 showed that the content of aflatoxin B1, B2, G1 and G2 were quite low with values under 9%. Generally, the content of aflatoxin B1 and B2 in grain corn and corn grit showed a lower value than the content of its aflatoxin G1 and aflatoxin G2, except in yellow corn grain which showed higher levels of aflatoxin B1 and aflatoxin B2. Aflatoxin B1 is the most toxic of aflatoxin, whereas aflatoxin B2, aflatoxin G1 and aflatoxin G2 have low toxicity, only 1/60-1/100 times compared to aflatoxin B1 and they are not too dangerous [10]. Besides being carcinogenic, aflatoxin is also genotoxic, hepatoxic in humans, and nephrotoxic and immunosuppressive in animals [11].

Table 3 showed that fermented corn grit could decrease aflatoxin content both in the yellow and white type of corn. The total content of aflatoxin in white and yellow corn kernels showed almost the same value of around 17 ppb, while the total aflatoxin content of unfermented, microbial fermented and natural fermented of yellow corn grit, showed lower values than the total aflatoxin content in white corn grit products with a value range of 13-17 ppb. Generally, total aflatoxin content of yellow corn products showed values above 20 ppb where microbial fermented corn grit had a total aflatoxin content of 20.95
ppb, the naturally fermented corn grit of 26.11 ppb and unfermented corn grit of 22.43 ppb. The total aflatoxin content in corn kernels, microbial fermented corn, naturally fermented corn grit and unfermented corn grit were higher than the limit value of total aflatoxin content in corn according to Indonesian National Standard of corn grain and corn product. According to the Indonesian National Standard (SNI 7385:2009) the total contamination of aflatoxin in corn and its product is 20 ppb. Whereas according to Indonesian Food and Drug Control Agency [12], the limit of total aflatoxin content on food product that contain corn is 35 ppb. According to Europe Union Regulation of 165 : 2010, the limit of total aflatoxin content in corn product is 10 ppb while the limit of aflatoxin B1 content in the same product is 5 ppb. Many countries in Europe and some others determination specific maximum levels of B1 aflatoxins, while Indonesia has a maximum limit of aflatoxin aimed to total aflatoxins content (aflatoxin B1, aflatoxin B2, aflatoxin G1, and aflatoxin G2 [11].

3.3. Organoleptic Properties
The result of the measurement in organoleptic properties was shown in Table 4 and Table 5. This measurement was conducted to determine consumer acceptance of corn grit products tested so it can be used as one of the basic considerations for product development on a wider scale. The product preference test results showed that the average values for the attributes of colour, flavour, appearance, and size of the grit were quite good (Table 4). Overall the results of statistical tests showed that the colour, flavour, appearance and size of the three types of corn grits were not significantly different. Flavour attributes was one of the important attributes in a preference test that describes the characteristics of a product based on the sense of smell.

| Product | Colour | Flavour | Appearance | Size of grit |
|---------|--------|---------|------------|-------------|
| B       | 3.81±0.77a | 3.77±0.66a | 3.66±0.76a | 3.56±0.89a  |
| C       | 3.73±0.98a | 3.63±0.90a | 3.69±1.02a | 3.52±1.12a  |
| D       | 3.93±0.83a | 3.66±0.77a | 3.84±1.01a | 3.87±0.87a  |

*Mean values in each column with the same letter are not significantly different (p = 5%)

Table 4. Scoring in preference test of processed corn grit

The number of panellists for testing products was 103 people with a composition of 61% male and 39% female, divided into 3 professional groups, namely farmers (30%), employees (61%), and students (9%). Gender differences and the type of profession of panellists in preferences test affect the preferences in the consumption of food products. Estimated there are differences in physiological performance of body organs between men and women causing differences in food requirements both in composition and portion. Likewise, the type of profession that is suspected also influences people's choices in consumption. The average value of preference test results which were categorized by the panellists gender was shown in Figure 1. Figure 1 showed that the results on the attributes of colour, aroma, appearance, and size of the grit were in the range of score 3-4 both for panellists with male and female sexes. Generally, this showed that gender did not have a significant effect on the score of panellist preference in consumption of corn grit products. Based on the results of this assessment, it can be seen that this grit corn product has the potential to be developed to meet food needs for both consumers with male and female sex.
Table 5. Characteristic of panels contributed to a preference test of processed corn grit

| Category   | Frequency | Presentation (%) |
|------------|-----------|------------------|
| Gender     |           |                  |
| Man        | 63        | 61               |
| Woman      | 40        | 39               |
| Amount     | 103       | 100              |
| Profession |           |                  |
| Farmer     | 31        | 30               |
| Employee   | 63        | 61               |
| Student    | 9         | 9                |
| Amount     | 103       | 100              |

A similar pattern was also seen in the score of preference test which was categorized based on the type of panellist profession was shown in Figure 2. The test score on the attributes of colour, flavour, appearance and size of grits was in the range of 3-4 (normal-likes) both for panellists with the type of profession as farmers, employees, and students. Panellists as farmers provide the good response with the highest score of the colour, flavour, appearance, and grit size on the natural fermented and non-fermented white corn grit (Figure 2).

Figure 1. Scoring in preference test of processed corn grit based on gender; (a) man, (b) woman

Figure 2. Scoring in preference test of processed corn grit based on profession; (a) farmer, (b) employee, (c) student

4. Conclusion

Measurement quality of the corn grit products showed that the microbial fermented corn grit had the highest total aflatoxin, carbohydrate, protein and total energy among the other product. However, based on the preference test of colour parameters, flavour, aroma and overall appearance showed no significantly differences between them.
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