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The proposed postharvest handling method increases the quality of corn (*Zea mays* L.) grains

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Abstract

Corn (*Zea mays* L.) is a potential commodity to support food self-sufficiency in Indonesia. Some regions use corn as an alternative food to substitute rice. However, the quality is still low because of the poor postharvest handling. The objective of the present work was therefore to compare the quality of corn grains produced by the traditional method and the proposed postharvest handling method. The present work investigated the differences in postharvest handling methods in harvesting, drying, grain removal, packing, and storage steps. The observed parameters were moisture, damaged grains, broken grains, and aflatoxin level. Moisture content was measured using a moisture analyser, while damaged and cracked grains were determined after shelling. Aflatoxin levels were analysed using High-Performance Liquid Chromatography (HPLC). Grains subjected to the proposed handling method showed an increased quality. The traditional method resulted in grains with a higher level of water content and aflatoxin level, with damaged and broken grains as compared to the proposed postharvest handling method. The proposed postharvest handling method grains met the Indonesian National and International Standard's requirements for corn grains.

Introduction

Grain production is an essential component of agriculture, and significantly contributes to human and animal feeding as well as to the economy (Souri, 2016; Aslani and Souri, 2018). Corn production can support food self-sufficiency in Indonesia. In some areas in Indonesia, corn is used as an alternative food instead of rice. In addition to direct consumption, corn is used as animal feed and raw material for various industrial sectors. The Indonesian government has launched a food self-sufficiency program, and one of the essential commodities in this program is corn. To support the program, the government increased the production of corn from 18.5 million tons in 2013 to 19.6 million tons in 2015 (BPS-Statistics Indonesia, 2016). However, this increase should be accompanied by improving corn postharvest handling and processing.

The postharvest handling of corn in Indonesia is still performed using traditional methods that are relatively inefficient. Besides, many farmers pay less attention to many factors in the postharvest phase, resulting in low product quality indicated by high moisture content, damaged and broken grains, and aflatoxin contamination. There are regulatory limits on aflatoxin concentrations on foods and feeds which could cause the loss of markets for agricultural products and reduced income (Wu, 2014). The mycotoxin contamination makes serious health problems in both humans and livestock (Baranyi *et al.,* 2013). Food and Agriculture Organization (FAO) together with the World Health Organization (WHO) has set the maximum limit of aflatoxin presence in food, which is 10-15 μg/kg (Codex Alimentarius, 2015).

Some efforts have been made by the Indonesian government and farmers to address these problems. The government has conducted extensions, provided corn sheller machines, and increased the price of good-quality corn. Sadly, the farmers have limited knowledge and skills in implementing those government policies. The proper postharvest handling method considers the hygienic factors in the process, representing an important strategy to improve the produced corn quality and increase its added value, resulting in a higher income for farmers. Therefore, the present work aimed to compare the quality of corn produced by the traditional postharvest handling and proposed postharvest handling methods.

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Materials and methods

The present work was conducted in Takalar Regency, South Sulawesi, Indonesia. We used a hybrid corn species, planted by two local farmers who used the same plantation method, and the corn was harvested after 120 days. A total of 1,000 corn cobs were sampled (500 cobs for traditional postharvest handling method, 500 cobs for proposed postharvest handling method). The observation started from harvesting, corn cob drying, shelling, packaging, to storage. Table 1 shows the steps of both postharvest handling methods.

Observed parameters

Water content

Water content was measured using an electronic air moisture tester type TM-10 (Crown, PT. Rutan, Indonesia), with a minimum accuracy of 0.2%. The tester was calibrated with a standard oven method before use. Three corn grains were placed inside the tester, and the screw of the equipment was then fully rolled until the grain broke. The moisture content was shown on the display after the grain broke.

Damaged and broken grains (visualisation and gravimetry)

The determination of damaged and broken grains was manually carried out using tweezers, of 100 g samples of each postharvest method. Damaged grain was determined by observing the defective grain due to the change in colour or damage by insect attack. Broken grain was distinguished by looking at the grain in the incomplete form due to the milling process. The percentage of damaged and broken grains was determined based on the weight of each component in comparison with the analysis sample weight times 100% (Eq. 1; Codex Alimentarius, 2015):

$$A = \frac{b}{c} \times 100\% \quad \text{(Eq. 1)}$$

where, A = percentage of damaged and broken grains; b = weight of damaged and broken grains; and c = weight of the total sample.

Analysis of aflatoxin concentration using High-Performance Liquid Chromatography (HPLC)

Extraction

Briefly, 25 grains were added to 5 g of NaCl and 125 mL of methanol:water (70:30, v:v) solution. The mixture was then homogenised for 2 min. Subsequently, the sample was filtered through a Whatman paper #1, and 15 mL of the filtrate were added to 30 mL of water, and mixed. The mixture was then filtered through a glass microfiber filter.

Clean-up

The filtrate (5 mL) was placed into a reservoir syringe connected to an immunoaffinity column. The column was then washed with 10 mL of water twice at a rate of 2 drops/s, and subsequently eluted with 1 mL of methanol. Finally, the eluate was placed in a 2-mL vial, and evaporated to dryness using a stream of nitrogen gas. The eluate was re-dissolved with 2 mL of methanol:water (40:60, v:v) solution, and then vortexed for 2 min before injecting into a High-Performance Liquid Chromatography (HPLC) equipment.

HPLC

The stationary phase was a C_{18} column (150 × 4.6 mm, 5 µm), and the mobile phase was a methanol:water (40:60, v:v) solution at a flow rate of 1 mL/min. The sample injection volume was 20 mL. The detector was a fluorescence detector with ex = 365 nm, and em = 435 nm to detect the sample.

Table 1. Traditional and proposed postharvest handling methods.

Handling phase	Traditional postharvest handling	Proposed postharvest handling
Harvesting	Harvesting and then left on the field for five days	Harvesting, then transporting out of the field using a cart or a motorcycle, and then to a storage room by car
Corn cob drying	Sun-drying by putting the corn directly on the soil for four days	Sun-drying by putting it on a plastic sheet for six days
Corn grain threshing	Using a mechanical corn sheller	Using a mechanical corn sheller
Corn grain drying	Sun-drying by putting the grains directly on the soil for three days	Using a flat-bed dryer until the intended water content is reached
Packing	Using a plastic bag which was previously used for fertiliser packing	Using a new plastic bag
Storage	In the farmers' house	In the storage room

Preparation of standard solution and standard curve to determine aflatoxin

A standard aflatoxin solution containing 0.1 to 1 µg per 20 mL injection volume in a 2-mL vial was prepared, which was then subjected to the nitrogen gas. Subsequently, the sample was re-dissolved with 2 mL methanol:water (40:60, v:v) solution, and vortexed for 2 min. The aflatoxin concentration was calculated using Eq. 2:

$$\text{Aflatoxin concentration } (\frac{ng}{g}) = (C \text{ x } F/W \quad \text{(Eq. 2)}$$

where, C = aflatoxin concentration from the calibration curve (ng/g); F = dilution factor; and W = weight of the sample (g).

Statistical analysis

The samples were analysed with three replications. The data were statistically analysed by a t-test with a significance level of α = 0.05 using Microsoft Excel (Microsoft).

Results

Water content

Figure 1 shows the different water contents in two different postharvest handling methods. Corn grains subjected to the proposed postharvest handling method had a water content of 12.4%, while the water content of traditionally handled corn was 16.3% (wet basis), and the two methods were significantly different ($p < 0.05$). The proposed postharvest handling method gave a better result than the traditional one.

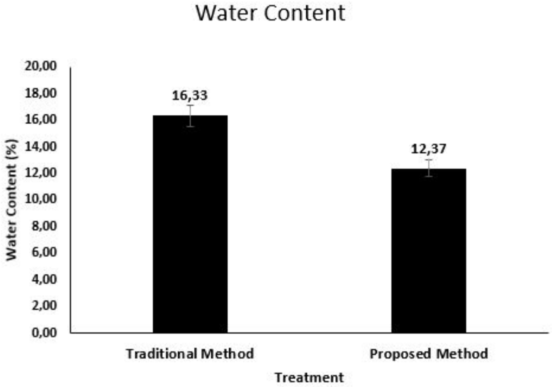

Figure 1. The water contents of corn grains after treated with two different postharvest handling methods.

Damaged grains

The percentage of the damaged corn grains resulted from the two different postharvest handling methods can be seen in Figure 2. The traditional method had a significantly higher percentage of damaged grain ($p < 0.05$) than the proposed postharvest handling method.

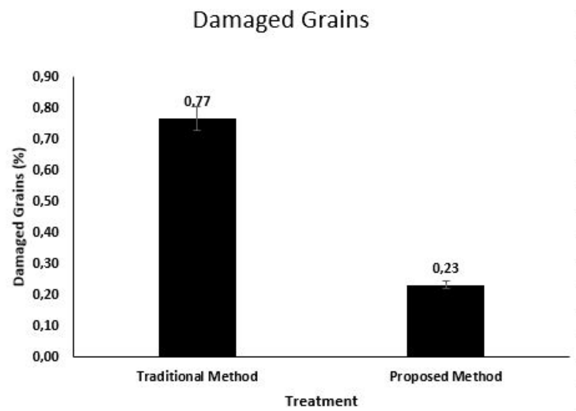

Figure 2. The percentages of damaged corn grains after treated with two different postharvest handling methods.

Broken grains

According to the International Standard (ISO 3920-2013), broken corn grains have a size smaller than 0.6 parts of unbroken / normal corn grains. Figure 3 depicts the percentage of the broken grains resulted from the two different postharvest handling methods. The traditional one produced 3.17% of broken grain, significantly higher ($p < 0.05$) than that achieved by the proposed postharvest handling.

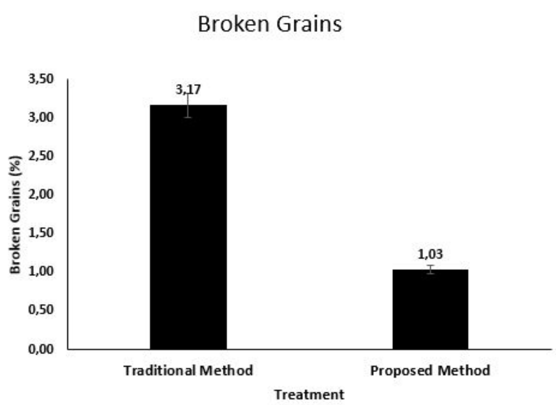

Figure 3. The percentages of broken grains after treated with two different postharvest handling methods.

Aflatoxin content

Figure 4 shows the different aflatoxin levels of the corn grains resulted from the two different postharvest handling methods. In the traditional method, a high level of aflatoxin was detected (68.65 ppb). The maximum limit (ML) of aflatoxin allowed in foods is different from countries to countries, and from food to food. European Union countries set up the ML of aflatoxin at 5 µg/kg in corn. The United States sets 20 µg/kg as the limit in corns. For Asian countries, about 15 µg/kg are allowed to be present in corns. FAO and WHO set 10 - 15 µg/kg as the limit in corns. The proposed postharvest handling resulted in only 1.17 µg/kg of aflatoxin for one sample, while it could not be detected in the two other samples.

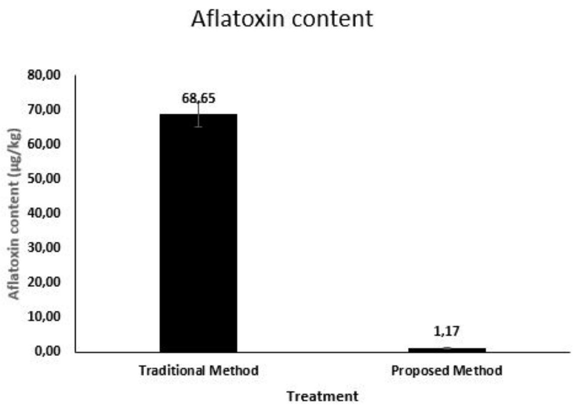

Figure 4. The aflatoxin contents of corn grains after treated with two different postharvest handling methods.

Quality achievement

The corn grain needs to meet the quality standards for both human and animal feeding. Table 2 shows the quality achievements for corn grains treated with the two postharvest handling methods as compared to Indonesia and International standards. Implementing proposed postharvest handling method can improve the quality of corn grains to meet international requirements.

Discussion

Water content

For corn, a high water content indicates a low-quality grain, as high moisture levels facilitate the growth of mycotoxin-producing fungi. According to the Indonesian National Standard (No. 01-3920-1995) requirements, the maximum permitted moisture content of corn is 14% (wet basis). In the present work, the traditionally handled corn did not meet this requirement, while the corn subjected to the proposed postharvest handling method was below the threshold. Farmers generally dry their corn in the open for three days, which is not sufficient to meet the requirements. On the other hand, using the mechanical dryers, or flatbed dryer, can reduce the moisture content of 100 kg of corn grain from 19.2 to 12.4% in 2 h. This indicates that corn subjected to the proposed postharvest handling method would be more resistant to microbial growth during storage due to very low moisture content. Corn moisture content affects its shelf life and quality; and above 14% moisture content will facilitate mould growth. Fungal contamination can result in the production of various mycotoxins such as aflatoxins (Widaningrum *et al.,* 2010).

Damaged grains

One important parameter in ensuring the quality of corn is the number of damaged grains. It is mainly caused by insect or mould infestation. Damaged grains cannot be used for food or animal feed (Gawande and Patil, 2018). Mould invasion is one consequence of damaged grains, resulting in a brown discoloration (Paulsen *et al.,* 2019). Insect infestation can be prevented by growing insect-resistant host plant, using hermetic bag for storage, or better cultivation management and fertilisation (Baoua *et al.,* 2014; Likhayo *et al.,* 2018; Aghaye *et al.,* 2019; Souri and Hatamian, 2019).

In the traditional method, the corn is left on the field for a couple of days after harvesting. This will provide the opportunity for insects to contaminate the corn. The proposed handling method packs the corn after harvesting, and transports the packages out of the farm, thus decreasing the possibility for insect contamination.

Broken grains

In the shelling machine, there is physical contact between the grains and cylinder when the grains are threshed from the cob. The corn grain undergoes stress crack in the shelling machine (Alhassan and Kumah, 2018). The moisture content

Table 2. Corn grain quality after treated with two different postharvest handling methods as compared to the Indonesia and International Standards.

No	Parameter	Traditional postharvest-handling	Proposed postharvest-handling	Indonesia National Standard	Codex Alimentarius (2015)
1	Water content (%)	16.33	12.37	14	15.5*
2	Damaged grains (%)	0.77	0.23	2	7*
3	Broken grains (%)	3.17	1.03	1	6*
4	Aflatoxin (µg/kg)	68.65	1.17	5	10 - 15**

Note: * = Codex Stan 154-1985; ** = in grains, Codex Stan 193-1995, revised 2015.

also affects the grain during shelling (Pavasiya *et al.,* 2018). The higher moisture content of the shelled corn decreases the shelling capacity, thus resulting in higher numbers of broken grains and dirt. The grains are difficult to release from the cob at a higher moisture level and their surface is easier to be scratched or broken.

Aflatoxin content

Aflatoxins are secondary metabolites produced by *Aspergillus flavus* and *A. parasiticus*. Aflatoxins are the most common contaminants found in staple food crops in many developing countries, and seriously threatening their food security. The exposure to a high level of aflatoxins can result in cancers such as hepatocellular carcinoma (Umoh *et al.,* 2011). Aflatoxin contamination of food is unusually severe after a long-term storage of crops at high humidity (Guchi, 2015). The presence of aflatoxins in corn grain as a result of *A. flavus* infection could begin from the field. Hence, the first step to prevent fungal contamination can be done while the crop is still in the field (Mahuku *et al.,* 2019). Aflatoxin contamination in corn can also occur during handling and storage (Kachapulala *et al.,* 2017). The threshold of aflatoxin in grain that has been set up by FAO and WHO is 10-15 μg/kg.

Conclusion

In conclusion, the traditional postharvest handling method results in higher water content, percentage of damaged and broken grains, and aflatoxin concentration as compared to the proposed postharvest handling method. The corn grain quality meets the Indonesian National Standard and International Standard requirement after handled with the proposed postharvest method. Future studies are needed to investigate the storage stability of corn grains under different moisture conditions.

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