Characteristic of Corn drying (Zea Mays L) using recirculated column dryer

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Abstract. The corn usually are harvested at high moisture content (more 25% w.b.), therefore at those conditions the corn will be very susceptible to damage such as attacked by fungi, bacteria, or physical damage. Drying using mechanical dryer is must conducted on those product to prevent deterioration. In Indonesia there are few recirculated column batch dryer machines with screw conveyor for circulation, however the information of the performance of this dryer is very limited. The objectives of this research is to determine the characteristic of corn drying using those machine. The material is using sheeled corn that have initial moisture 25-30% (w.b.). The corns were dried using the recirculated column batch dryer that have capacity of 2 tons/batch. The drying chamber has diameter of 2,0 m and the height of 3 m. Heat source of this dryer is from liquid petroleum gas that was delivered by high capacity of centrifugal blower. Drying temperature was controlled using automated thermostat that connectd to the gas pipe. Drying experiment was conducted using 45°C, 55°C and 65°C. The measurement of moisture content is used for the determination of the drying rate and the drying efficiency. The quality determination parameters used are bulk density, damage, and cleanliness. The results show that the dryer air temperature affected the drying rate, the efficiency of drying, and the quality of the material. The best drying rate with temperature 65°C average 4,95% / hour, high efficiention at dryer temperature 55°C and 65°C equal to 86,27% and 83,51%, and best material quality with dryer temperature 55°C.

1. Introduction

Indonesia have high productivity of corn. The average corn productivity of all varieties was 6,4 tons/ha [1]. Based on data from the Central Bureau of Statistics [2], each year the production of corn is increasing. In 2015, corn production in Indonesia had reached 19,612,435 tons.

Corn harvesting is done by picking whole skinned corn at a high moisture content of more than 30%. At this situation, corn become more vulnerable to fungi, bacteria, or physical damage. Therefore, it is necessary to do the correct postharvest handling. After harvesting, the corn is peeled and dried until the moisture content reach 20-25%. This is done with purpose that the corn would not be destroyed during the shelling process. The corn is separated from the cob. However, with that value of moisture content, the corn seeds are not safe to store and have to be dried to a moisture content of around 14%. Drying is an important stage in postharvest handling to maintain the quality of corn during the storage period. According to Indonesian National Standard SNI 013920-1995 [3], to maintain the quality of corn seed
From declined by reason of microbial, bacteria, and fungal activities, the corn must be dried until the water content reaches 14%.

From the previous research, the process of postharvest handling at the farmer level is still done manually where drying is conducted by drying under the sun depending on the weather [4]. Such treatment conditions are very susceptible to Aspergillus flavus which produces aflatoxin. This situation is also supported by the climate of our Indonesia where the humidity is relatively high around 70% - 80%. In another research revealed that corn is a commodity that is easily contaminated by aflatoxin [5]. The results from a study in the Philippines stated that there is a high probability of liver cancer rising incidence from aflatoxin contamination of corn. This conclusion can be drawn because of the event rose in areas that use corn as a staple food and aflatoxin was found in the corn.

Farmers in Indonesia mostly using tradition method to dried the corn seed, using sun as the heating source and cement floors or tarp as the mats for corn. This method is cheap but very difficult to predict the result because it is depend on the weather. Sun drying have weakness which are the temperature of cement floors cannot be controlled. High drying temperature might result corn grains easily to break or crack. When the rain suddenly came, the farmer usually bring the corn seed back to the storage house wrapped with the tarp. This treatment can make the corn catches moist and trigger fungi to grow and bacteria to proliferate.

Numerous machines have been developed to dried corn for eliminate these problems also boost the selling price of corn grains due to improved quality. But the existing corn grain drying machines still have many problems. For example, capacity of the machine was too small therefore the product cannot be dried at the same time. The remaining corn will be stacked, wait to be dried. When this happened the contamination of fungi is very high. For drying using bed dryer type, there is provisions for maximum material thickness, therefore to meet the desired capacity by increasing the size of the length and width of the bed without adding to its height, so the machine will need a huge space. In fact, a lot of dryer were not suitable for the farmer needs because it have large capacity and can only be operated by large industries.

Corn grain drying machines in general do not have stirrers, such as bed dryer. Result to periodically manual stirring or add an automatic stirrer. Automatic mixer for bed dryer has been developed, but the construction is still raw and prone to break.

Based on these problems of the previous corn grain drying machine, a recirculated type corn drying machine was made by screw conveyor or recirculated bed dryer. In Indonesia there have been many recirculated batch dryer machines with screw conveyors for circulation, but there is only a few research on this machine. Taken together, the study on the machine was carried out. The purpose of this research is to analyze the characteristic of drying of corn kernels with recirculated batch dryer, and to analyze the quality of corn seeds produced by drying with a recirculated batch dryer machine expressed by moisture content, bulk density, degree of damage, and cleanliness.

2. Materials and Equipment

2.1 Materials

Materials used for this study is shelled corn, the varieties is NK 6328 from Ploso Harjo Village, Toro District, Grobogan Regency, Central Java. As well as DK 88 varieties from Wiromartan Village, Mirit District, Kebumen Regency, Central Java.

2.2. Equipment

2.2.1. Recirculated Batch Dryer type dryer. Recirculated Batch Dryer is a resirculated type screw conveyor, in Figure 1. The main components of this machine consist of drying chamber, plenum room, feeding, discharging, horizontal screw, vertical screw, chamber (air heating room), blower, LPG burner (stove), and control panel.
The shape of the dryer is cylindrical and cone at the bottom (hopper). A cylinder with a height of 1500 mm and a diameter of 1800 mm. The cylinder part used hollow stainless steel with a thickness of 0.8 mm, the diameter of the hole is 2 mm and a distance between holes 2 mm. The hopper is made of plate with stainless steel material which has a thickness of 1.5 mm. The diameter of the top of the hopper is the same as the diameter of the cylinder, while the bottom diameter is 351.5 mm. Hopper with height of 697 mm and slope of 42.5°C have a cylindrical trough which is a meeting between a horizontal screw and a vertical screw at the lower side. The trough wall used a plate with 2.5 mm thickness, while the bottom of the trough uses a plate with a thickness of 5 mm.

![Figure 1. Recirculated batch dryer](image)

Inside of the drying chamber there is a plenum chamber, so it is expected that hot air will spread from the inside of the drying chamber throughout the drying machine. The plenum chamber has a diameter of 1000 mm and a height of 1145 mm. The gap between the plenum wall and the drying chamber wall is 40 cm, later this gap is used as the thickness of the material. With the capacity of ±2 tons, the plenum consist of cylindrical part, a cone at the top and opens at the bottom. Used 1 mm thick perforated stainless steel as the materials, 2 mm hole diameter, and the distance between the holes 2 mm.

In the feeder section, the hopper part used stainless steel plate 2 mm thick, dimensions of length, width, and total height are 939 mm x 539 mm x 211.5 mm. At the bottom part of the hopper is connected to housing screw there is a horizontal screw with 154 mm of diameter screw, pitch 58,7 , and 42 mm shaft diameter. The length of the screw is 1410 mm and total length plus shaft 1820 mm. The vertical screw drive motor used 1 HP power. Feeding capacity of 1.857,79 kg corn / hour.

Vertical screw has function for recirculating materials and for expenditures in the middle of the plenum space. 154 mm screw diameter, pitch 58,7, shaft diameter 42 mm, and screw length 2855 mm. Vertical screw using motors with a power of 2 HP and 5 HP. Lifting capacity with a 2 HP engine is 2216 kg / hour.

The machine is equipped with a chamber for the heating air room. In the chamber section is equipped with LPG burner or stove with LPG gas fuel. Then the chamber is connected with a blower with a power of 5 HP and the air flow rate of 4383.45 m³ / hour, the blower is connected to the plenum chamber.

2.2.2. Supporting Equipment. Supporting equipment used in the research were temperature data logger, grain moisture tester, thermo hygrometer, hot wire airflowmeter.

2.2.3. Research Design. This study was used to determine the effect of temperature and grain location in the drying machine on the quality of dry pipel corn which included moisture content, bulk density, degree of damage, and cleanliness. In addition, in this study an analysis of the kinetic rate of drying and the efficiency of drying were also carried out. The research method used is an experimental method by conducting experiments, data collection, data analysis, and decide a conclusions.
3. Results and Discussion

3.1. Drying rate

Figure 2. shows the moisture reduction during drying. The drying starts at the initial moisture content of 25% wet bases. This machine could not work for the initial moisture content of the bean more than 30%, because at high moisture content (above 30%) the vertical screw will stop when circulating the material and the material could not flow freely into the bottom area. Some grain sticked on the inclined wall. It takes about 4.5 hour to reduce the moisture content into 14% at the air temperature of 65°C.

![Figure 2. Moisture content of the material during drying](image)

The drying rates is about 4%/hour at the air temperature of 65°C. The corn have high tolerant for high temperature during drying, because this product is just for the food and feed. If the corn is used for seed, then the air temperature should not more than 43°C. High drying rate indicates the high performance of the dryer. Indonesian National Standard revealed that the drying rate should 3-5%/hour for corn [6].

3.2. Quality Parameter

Grain damage is the grain that is broken due to the mechanical effect during flow in drying chamber and screw conveyor. The main factor causing grain damage might be from the screw conveyor, in both of horizontal and vertical pipe. During drying the vertical screw continuously lifts the grain from the bottom to the top of drying chamber for few hours. The difference between the whole and broken corn can be seen in figure 3.

The increasing of the percentage of grain damage during drying is showed in figure 4. The damage material could be avoided during drying. The longer grain is recirculated, the damage will be increase. The high moisture content is contribute in increasing the breaking the grain due to the strength of the grain will weak when high moisture content. The percentage of grain damage at drying temperature 45°C, 55°C and 65°C are 21.99, 15.66, and 17.84 respectively. Generally, the grain damage should not more than 5% after drying for the bed dryer. This drying machine did not appropriate for the seed industry. Based on SNI number 4412 in 2011 [6], the maximum damage rate for corn is 35% so this dryer is still appropriate to used for grain drying.

Grain cleanliness is a comparison between pure grain and other materials. The level of grain cleanliness during the drying process can be seen in figure 5. During recirculation, the materials were blown by high speed centrifugal blower. The dust and light material fly on the top dan pass through to the wall pore of drying chamber. This light material will make dirty on the surrounding area, and it need to cyclone to collect the dust. During drying thin layer of the grain skin was removed due to friction...
between grain and metal. The grain cleanliness is about 99% for all running, and the dryer has been effective to remove the dirty material in corn.

![Appearance the whole grain and broken grain.](image)

**Figure 3.** Appearance the whole grain and broken grain.

![Damage grain during drying in recirculated dryer](image)

**Figure 4.** Damage grain during drying in recirculated dryer
4. Conclusion

It can generally be concluded that the recirculated batch dryer can be used for drying the shelled corn. The drying rate was obtained 4%/hour at the drying temperature of 65°C. The dryer temperature affects the drying rate, the greater the temperature of the dryer used, the greater the drying rate. This machine can only dry shelled corn with a moisture content of less than 30%. The damage grain was 15-22%, depend on the drying time.

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