Study of changes in physical and chemical properties of corn during drying and storage process using a modified in-store dryer

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Abstract. In-Store Dryer (ISD) is a dryer with a convective system for grain that also serves as a storage. This research was conducted to study the effect of drying and storage—In-Store Dryer (ISD) on maize's physical and chemical properties. Carried out a 200 kg maize capacity test with 60 cm material stack thickness divided into three layers of piles with a thickness of each layer is 20 cm. Drying occurs at the average drying temperature of 38.6°C with an average RH environment of 76.8% and an average RH of dryer space of 52.2%. Drying for 32 hours using ISD can dry the maize with the pre-drying material's initial moisture content of 20.14% to 13.56%, the right water content for storage. The drying process can affect ash, fat, protein, and maize fiber's physical and chemical composition. The chemical composition on the pre-drying are: Ash content 0.72%, Fat content 5.62%, Protein 7.64% and Fiber 2.81%. The maize's chemical components undergo post-drying change to become: Ash content 0.8%, Fat content 5.11%, Protein 7.82%, and Fiber 2.52%. The changing of all components is affected by temperature during the drying process, causing a decrease in water content, affecting other chemical components. The analysis result of maize's nutritional components after drying and storage for 30 days using the In-Store Dryer can maintain maize quality. The analysis result of each component that is the Water Content 11.98%, Ash 1.13%, Fat 5.03%, Protein 8.05%, and 1.8% fiber, and this is by the provisions of SNI 01-4483-1998 for animal feed.

1. Introduction
Corn (Zea mays L) is an agricultural commodity that has many benefits with high economic value. Besides being a food ingredient, corn is also often used as an animal feed ingredient. In the development of corn commodity, apart from increasing the production quantity, the quality aspect is also essential, so that the post-harvest handling technique must be well-conditioned. Syarif and Halid [1] argued that quality control's scope includes quality control efforts during the production process until the product reaches consumers. The post-harvest method of controlling corn quality starts from harvesting, pre-drying, shelling, final drying, packaging, and storage.

The combination of drying and storage systems is one option needed to maintain shelled corn commodities' quality. The In-Store Dryer (ISD) is a tool that has a combination system of the two. The ISD application is used for drying grains. Temperature, airflow, and RH are the critical parameters during the drying process using ISD. ISD's method is to use environmental air blown through a pile of grain to be dried. Although this tool's drying rate is not very high, this Dryer also functions as storage
with the enduring product quality. This method can reduce the use of heaters that require maintenance and higher operating costs. Besides, it can make significant energy savings due to the low demand for thermal energy in operations, which usually requires high enough energy to heat the air [2].

In-Store Dryer (ISD) is a building dryer that can be used as grains (such as corn, rice, coffee, and other grains) storage using the convective system. This Dryer uses natural air as a drying medium, while natural air conditions tend to be inconstant. It will significantly affect the drying process and the dried grains' quality, so the inlet air required temperature and RH conditioning. Nurba et al. suggested the range for air input supply at RH is between 55-70% to get a good drying performance in ISD and can do this by heating the input air [2].

ISD has dimensions; 1.95 m high and 0.80 m diameter. The entire wall is made of galvanized plate coated with a thickness of 0.002 m, reinforced by iron pipes’ framework. The inside of the ISD building is equipped with 13 porous air conduit pipes, which serve as input pipes totaling nine pipes with a diameter of 0.08 m and a height of 0.65 m from the ISD floor, while the output pipes amount to 4 tubes with a diameter of 0.12 m and a height of 0.8 m. ISD floors are shaped like plenum and equipped with material unloading holes. The base is made of galvanized porous esser plates with size following the ISD building size, which is 0.40 m in diameter, while the height of this plenum is 0.25 m. At the bottom of the plenum is a round hole with a 0.4 m diameter that functions to unload the material after the drying and storage process has been completed. At the plenum's lowest point, there is also an Axial Fan and Heat Exchanger to blow the drying air [3]. The ISD building is presented in Figure 1.

![In-Store Dryer with heat exchanger modification](image)

**Figure 1.** In-Store Dryer with heat exchanger modification

### 2. Research Methods

The tools used in this study are In-Store Dryer (ISD), Thermocouple (CA), Hybrid Recorder, Anemometer, Oven Drying, Thermometer, Digital Scales, Measuring Ruler, and Notebook. Simultaneously, the materials used in this study were 200 kg of shelled corn of Pioneer variety with an average moisture content of 20% w.b.

We prepared 200 kg of pioneer type dry maize. We have carried out initial sampling for chemical analysis, including moisture, fat, fiber, protein, and ash content analysis. Then sorting and entering the ingredients into the In-Store Dryer, followed by a 32-hour drying process with a drying duration of 8
hours/day; drying is done at a pile thickness of 60 cm divided into three layers, namely A1, A2, and A3 with a layer thickness of 20 cm.

During the drying process, RH and temperature measurements were taken in the Dryer using a Hybrid Recorder connected to a thermocouple in the ISD every 30 minutes. The samples were taken for water content testing for 4 hours to see water content changes during the drying rate. After drying lasts for 32 hours, and the final moisture content for storage is obtained, drying is stopped, and samples are taken for post-drying chemical analysis. Then proceed with storage in the In-Store Dryer for 30 days. After the storage was complete, resumed the pieces for post-storage chemical analysis in ISD. Furthermore, laboratory testing is carried out for analysis of the nutritional (chemical) composition of maize. After obtaining the laboratory test results, we can compare a chemical analysis result with the Indonesian National Standard (SNI).

3. Results and Discussion

3.1. Drying Temperature Distribution

The temperature distribution for 32 hours of drying at ISD, and the environment is presented in Figure 2. The temperature at ISD ranges from 34.5-42°C with an average of 38.6°C at a standard deviation of 1.84. In contrast, ambient temperature is recorded in the range 29.2-34.2 °C, with an average of 32.1°C at a standard deviation of 1.63. Of the temperature distribution, ISD with a modified heat exchanger can raise an average temperature of 6.6°C from the ambient temperature. The temperature increase in ISD is useful enough for drying corn in the right conditions, so it does not damage the ingredients. According to Winarno, drying with a too high temperature can damage the material's texture and appearance so that the dried material will not last for a long time [4].

![Figure 2. Temperature distribution during the drying process](image)

3.2. Relative Humidity

RH in ISD during the drying process ranges 30-63.7% mean 52.2% a standard deviation of 6.92, the RH in the ambient ranges 62.8-86.1% mean of 76.8% a standard deviation of 5.80. Modification of the heat exchanger on the ISD has reduced the RH by an average of 24.6% of the RH of the ambient, and this decrease is, of course, very supportive of the corn kernels drying process because the smaller the RH, the faster the drying will be. The RH ISD and the ambient during the drying process are shown in Figure 3.
3.3. Moisture Content
At the beginning of the drying process, there was a decrease in each layer's moisture content with a different variation of time and moisture content. Drying lasts for 32 hours at an average drying temperature of 38.6°C, RH 52.2%. The final moisture content for A1 storage is 14.33%; A2 is 13.39%, and A3 is 12.98%, with an average post-drying water content of 13.56%. During the drying process, the trend of decreasing water content fluctuates; this condition is caused by fluctuations in temperature and RH in the ambient air that is blown into the ISD chamber. When low humidity air enters the ISD room, it will absorb the corn kernels' moisture content into the air and flow to the outlet. The opposite condition occurs when air with higher humidity enters the ISD room causing the corn kernels to absorb water again, even though the absorption is not as broad as the water vapor previously released. That happens because the axial fan that supplies the drying air is continuously rotating, even though the air has passed through the heat exchanger, but the time needed to stabilize the air temperature and RH is not enough.
It is necessary to adjust the airflow speed into the ISD space to overcome this condition. The reduction in the moisture content of corn kernels during the drying process is presented in Figure 4.
3.4. Post-Drying Chemical Composition of Corn

The drying process in ISD for 32 hours with average temperature and RH; 38.6°C and 52.2%, have reduced the moisture content to an average of 13.57% from the initial moderate moisture content of 20.21%. Besides that, there is also a change in ash, fat, protein, and fiber composition. The chemical composition of corn after the drying process is shown in Figure 5.

![Figure 5](image_url)

**Figure 5.** The chemical composition of corn after the drying process

The water content in each layer decreased with a different final value according to the sampling layer A1, A2, and A3; 14.33%, 13.39%, and 12.98%. This difference occurs because the drying air input position under the ISD building is close to A3. Although there are differences in the final water content value, all layers have reached the moisture content for the storage process, and the average moisture content value has reached SNI. Water content is one of the main aspects in maintaining the quality and shelf life of materials; the lower the water content in a material, the longer its shelf life.

The ash content in layers A1, A2, A3 are 0.76%, 0.90%, 0.80%, with an average of 0.82%. This value is still stable after drying, although there is an increase from the average value initially 0.72% but still within the SNI Standard. According to Susanto and Saneto, an increase in ash content during the drying process is caused by increased temperature. That reduces the moisture content due to evaporation, leaving a residue in the material [5].

After the drying process, the maize fat content in the layers A1, A2, and A3 became 5.44%, 4.26%, and 5.64%, with an average of 5.11%. The average value has decreased from the initial fat value of 5.63%. According to Purnomo, in the fat oxidation process, water content has an important role. Still, the increase in temperature during the drying process causes the water content to drop, so that the high temperature causes a decrease in the fat content in the material [6].

Post-drying maize protein content also changed from the initial protein content for layers A1, A2, and A3 of; 8.06%, 89%, and 7.52%, with average value of 7.82%. The amount of post-drying corn protein has met the SNI minimum standard of 7.5%. The fibers in this drying process did not change significantly, with the post-drying values for layers A1, A2, and A3 of 2.53%, 2.56%, and 2.48%. With an average of 2.52%, still within the standard of a maximum of 3% in the SNI standard. According to Winarno, temperature and drying time does not affect crude fiber, and this is because crude fiber is difficult to decompose even at high temperatures [7].
3.5. Post-Storage Chemical Composition of Corn

The process of storing corn for 30 days in the In-Store Dryer resulted in changes in several parameters. After the storage process is complete, the water content has decreased by 1.59% from the water content before storage. The value of water content is an average of 12.10%, and at each sampling layer, A1, A2, and A3 at 12.81%, 11.03%, and 12.10%. These data indicate that the moisture content still falls toward equilibrium with the storage space in a good storage system with low temperature and humidity. As an adiabatic storage system, ISD has maintained corn moisture content not to be affected by fluctuations in the surrounding air.

The second parameter is the ash content; the layers A1, A2, and A3 are recorded at 1.16%, 0.96%, and 1.28%, with an average of 1.13%. The change in ash content in each layer after storage also meets the SNI standard for feed quality, a maximum of 2%. The third parameter is fat; the value of fat in post-storage maize in layers A1, A2, and A3 is 5.45%, 4.24%, and 5.41% with an average value of 5.03, still in SNI standards with a minimum value limit of 3%. The fourth parameter is protein, in layers A1, A2, and A3, respectively 8.05%, 8.01%, and 8.09%, with an average of 8.05% also still exceeding the minimum limit of 7.5% in the SNI standard. Furthermore, the crude fiber content in post-storage corn kernels for layers A1, A2, and A3 were 1.76%, 1.67, and 1.97%, with an average value of 1.8%, which was also within limits given SNI standards, namely a maximum of 3%. The chemical composition of post-storage corn is presented in Figure 6.

![Chemical Composition of Corn](image)

Figure 6. The chemical composition of post-storage corn

4. Conclusions and Suggestions

4.1. Conclusions

Based on the discussion that has been done, can draw the following conclusions:

1. The Axial Fan with Heat Exchanger in the In-Store Dryer can distribute the temperature into the drying room of 34.5-42.0 C with an average drying temperature of 38.6 C and an intermediate RH of 52.2%
2. Corn kernels drying using an In-Store Dryer can dry the corn to the final moisture content for storage with an average value of 13.57% for 32 hours of drying duration.
3. The fluctuation in corn moisture content during the In-Store Dryer's drying process was due to the thickness of the pile and the layer of the material and the layers' position. In A3, the material experienced a rapid decrease in water content during the drying process, with a moisture content value of 12.86% on the third day.
4. The results of the chemical content analysis of corn after drying and storage obtained mean values for; water content of 11.98%, ash 1.13%, 5.03% fat, 8.05% protein, and 1.80% fiber. The decline and increase in chemical composition caused by the drying and storage process at ISD still meet the SNI Standard requirements for raw materials for animal feed.

4.2. Suggestion
It is necessary to adjust the air input so that the volume of air entering the ISD can receive sufficient heating from the heat exchanger. The air temperature and humidity entering the ISD room are more stable for a better drying process.

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Acknowledgments
Thanks to the Research and Community Directorate Services (DRPM) from the Ministry of Research and Technology of Higher Education for funding through the "Penelitian Produk Terapan" program.