Performance of Drying Machine with Air Dehumidifying Process for Sweet Corn Seed (Zea mays saccharata)

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Abstract. The number of corn production and consumption in Indonesia has increased every year. One of the activities in achieving the production target is by supplying high-quality corn seeds. The water content of harvested sweet corn was ranging from 60% to 70%. In order to produce a high quality of seeds, drying should perform with a standard drying temperature for seeds which is between 38°C and 43°C. A performance test of a tray drying machine with an air dehumidifying process was conducted. The air dehumidifying process was conducted by an air conditioning system. Drying was carried out until the corn seeds reach 10-11% moisture content with observations every two hours. This drying machine provided lower relative humidity air drying than conventional sun-drying with a 75% relative humidity reduction from the environment. Therefore, drying with optimal temperature can be conducted faster and higher efficiency. The average dehumidified air temperature was 41.1±0.6°C and the average relative humidity was 15.9±0.7% was used for drying air. It took 44 hours 25 minutes to reach 11% of sweet corn’s moisture content while the sun drying process took 89 hours of drying. The seed germination could reach 85.7% by using this method which was a 1% difference from a sun-drying method which was 86.7%.

Keywords: Sweet Corn, Seed Drying, Dehumidifier Drying, Corn Seed Germination

1. Introduction

Sweet Corn has the Latin name Zea mays saccharata becoming known in Indonesia in the 1970s. Sweet corn can be consumed in fresh by boiling or baking and also used as raw material for various processed products. Harvesting sweet corn can be done at the age of 70 days (18-24 days after pollination) up to 110 days [5]. A high daily consumption rate of sweet corn has made the supply of its seeds an important factor in increasing sweet corn production [7]. Whereas the supply of seeds in the market is mostly hybrid corn seeds. The moisture content of freshly harvested sweet corn was ranging from 60-70% need a quick-handling in order to obtain high-quality seeds. The moisture content requirement as a seed is about 10-11% [2].

By using the sun-drying method, it purely depends on environmental conditions and usually takes a longer period to get the seeds dried. Drying can also be done by using a mechanical tray dryer so that drying seeds run faster. A mechanical dryer can get a relatively short drying time because the drying temperature can be adjusted constantly [1]. In addition, a modified mechanical tray dryer with the addition of a dehumidifier was used. This method was recommended for seeds drying due to the faster seeds drying ability and the ability to maintain seed quality [9]. The dehumidifier method was used by reducing the air moisture content so that the drying temperature can be lowered and reach its optimum...
condition and accelerating the drying rate. In the previous research, the application of dehumidifier drying was used for agricultural commodities for example red chili (*Capsium annum*) and ginger [9, 3, 10].

The drying process of the seeds will take place until the equilibrium of seed water content with environmental humidity is achieved [2]. Commonly, sweet corn is dried along with its cob. A dehumidifier is a component that can reduce the moisture contained in the air so that the air humidity level becomes low through a process called dehumidification. The use of a dehumidifier was combined with a drying machine where the dehumidifier utilized the refrigeration cycle of the air conditioner. The air conditioner components included evaporators, compressors, condensers, expansion valves, and refrigerant liquids. The working principle of dehumidification was to pass ambient air to the evaporator which had a temperature cooler than room temperature so that the process of condensation of water vapor in the air by the evaporator when the temperature below the dew point temperature. The moisture content in the air will stick to the evaporator due to the dew condensation process. The low humidity air made the difference in material vapor pressure thereby increasing the drying rate. This was also followed by a decrease in air temperature because heat was absorbed by the evaporator so that it provided drying at low temperatures [8]. Therefore, this research aim is to test the performance of the tray dryer with the dehumidification process for sweet corn drying for seeds.

2. Methods

The research was conducted in the Laboratory of Food Processing and Agricultural Product Engineering, Department of Agriculture Engineering, Faculty of Agricultural Technology, University of Brawijaya. The main material was fresh harvested sweet corn. The tray dryer with a dehumidifier was used including 790W air conditioners, anemometers, dimers, a temperature regulator, thermohygrometers, fans, stopwatch, digital weighing scale, drying tray, and opaque paper. The temperatures were measured by a K type thermocouples and recorded in a GRAPHTEC midi logger GL820 data logger.

The drying temperature used in this research was the standard temperature for sweet corn seeds drying ranging from 38°C to 43°C. The drying is carried out with an airflow velocity of 3.4 m/s which was the maximum fan speed. Drying is carried out until the corn reaches 10-11% moisture content with observations every two hours. The design and components of the dryer can be seen in Figure 1.

![Figure 1. The tray drying machine with an air dehumidifying process](image_url)

The main components of the dehumidifier system were namely the air inlet and filter, a fan, an evaporator, and a condenser. The air inlet was located in front of the evaporator. Its function is as a channel for the air entry from the environment. An evaporator reduces the environment air until below
the dew point temperature so that the moisture in the air can be condensate in the form of water. The water condensate flows into the bottom of the chamber. While the fan keeps the dry air flows into the heater and drying chamber. The condenser dissipates heat from the cooling system to the environment.

The heater is used to increase the dry air temperature for optimal drying. It was equipped with a temperature regulator and set into 38°C to 43°C [6]. The heated dry air then flows into the drying chamber. Inside the drying chamber, two trays were occupied for the material to be dried. The water vapor from the material in the drying chamber was discharged. Each tray contains 4-5 cobs of sweet corn. It was prepared with a tray capacity then weighed.

The performance of the dryer can be evaluated by the drying temperatures and humidity, the moisture content of the material, the drying rate, percentage of germination, and calculation of efficiency and energy consumption.

3. Results and Discussion

As a result, the drying by using the sun-drying, oven, and tray drying with air dehumidification were compared (Figure 2). Observations were conducted until the material reaches 10-11% of water content. The graph shows that mechanical drying using both dehumidifier drying and an oven drying resulted in constant air temperature and humidity during the drying period, whereas the sun-drying resulted in a fluctuation value during the drying period.

![Figure 2. Temperature and relative humidity of various drying methods](image)

The humidifier drying provides a constant temperature with an average of 41.1±0.6°C and ovens provide an average of 40.4±0.9°C with the average ambient temperature of 25.8±0.7°C. Whereas the sun drying reaches an average of 34.0±9.0°C. While the relative humidity level can reach 15.9±0.7% which was lower value and less fluctuate compared to ovens which are 30.1±3.4% with the average of ambient relative humidity 64.27±0.7% and the sun-drying reach the average relative humidity of 49.9±24.8%. The lower relative humidity value in drying results in a higher drying rate compared to oven drying and the sun-drying. The higher the drying rate the faster the drying time for tray dryer with air dehumidification.

The high rate of drying with a dehumidifier is due to the large moisture difference in the drying air with moisture in the material. Where the greater the difference, the greater the transfer of water vapor from the material to the drying air to achieve a moisture balance.

The dehumidifier dryer could reduce 75% relative humidity from the ambient. Whereas oven drying can only reduce 50% from the ambient. It shows that the addition of a dehumidifier in the tray
The dehumidifier dryer was useful for humidity reduction so that the drying process of the sweet corn seed conducted in a shorter time.

The initial water content of all drying methods is about 50% (Figure 3). The drying rate at the dehumidifier dryer 0.87%/hour results in the fastest drying time compared to the oven (0.55%/hour) and the sun-drying method (0.46%/hour). It only takes 44 hours 25 minutes to reach 11% sweet corn water content. Whereas the oven drying takes 72 hours 54 minutes and the drying of the sun takes 89 hours to reduce the moisture content of the material to 10-11%.

![Figure 3. The water content of various drying methods](image)

The dehumidifier dryer has the best time efficiency compared to other drying methods. It shows that the addition of a dehumidifier can provide drying at low temperatures at a higher drying rate. So that the processing of seeds can be quickly handled and safe for seeds. It was similar to the use of a desiccant drying system in a low-temperature range [4].

The calculation of energy consumption was obtained by adding up the power of each component times the drying time needed. Components used include air conditioning, fans, and heaters. The total power of all components is 2,636 kW then multiplied by 46.5 hours to find out the power used during drying takes place. And the power obtained is 122,574 kWh.

The energy for sweet corn seed drying was used to heat corn seed, heat water inside the corn seed, and finally to evaporate water inside the corn seed. To calculate the energy for heating corn using the following formula: \( Q_{\text{Corn}} = m \times c_p \times \Delta T \). Where \( m \) is the weight of wet corn before drying, with \( c_p \) or hot sweet corn type of 1851.5 kCal/kg\(^0\)C [11] and \( \Delta T \) is the difference in material temperature and drying air temperature. Obtained the results of corn heating energy of 34768.72 kCal.

The energy to heat water in corn uses the formula: \( Q_w = W_i \times C_{\text{water}} \times \Delta T \). Where \( W_i \) is the initial weight of corn water and \( C_{\text{water}} \) or the specific heat of water is 1 kCal/kg\(^0\)C or 4,200 J/ Kg\(^0\)C [11] and \( \Delta T \) is the average temperature of drying air minus the temperature of the material. And obtained energy of 12,400 kcal.

To calculate the energy of evaporation of corn water using the formula: \( Q_l = W_r \times h_{fg} \). Where \( W_r \) is to calculate the weight of water transferred during drying. The \( h_{fg} \) is the latent heat of water of 2,260 kJ/kg to obtain a yield of 393.16 kCal. With the formula, \( Q_{\text{evaporation}} = Q_{\text{Corn}} + Q_w + Q_l \) and the results obtained were 35,174.28 kCal. If it is compared to the total energy produced by the dehumidifier, fan, and heater to determine the efficiency of the dryer.
Calculation of energy efficiency of the dehumidifier dryer using the formula:

$$\eta = \frac{Q_{\text{evaporation}}}{Q_{\text{heater}} + Q_{\text{compressor}} + Q_{\text{fan}}} \times 100\%.$$ 

The calculations resulted an efficiency of 23%. The result was relatively low due to the addition of a dehumidifier unit in the drying machine which increases energy consumption. In addition, the amount of dried corn seed was also on an experimental scale of 0.853 kg.

The germination test was carried out to find out the possibility of the corn seed damage during dehumidifier drying. Corn germination testing uses plastic rolled paper test method. From the test an average of 85.67% for dehumidifier drying, 85.33% for oven drying and 86.67% for sun-drying. Sun-drying resulted in better seed germination compared to dehumidifier drying and oven. However the insignificant difference also showed that dehumidifier drying did not cause damage to the dried sweet corn seeds.

The dry weight of the sprouts was used to determine the activity of seeds in the growth and development phases of the seed (Table 1). The higher the normal dry weight of the sprouts, the higher the food reserves in the seeds. The results show that there was a difference in the dry weight of sprouts with an average difference of 0.2 grams. The difference was insignificant but it showed drying with the sun produces better sweet corn seeds.

| No | Sweet corn seeds | Dry weights   |
|----|------------------|---------------|
| 1  | The dehumidifier drying | 5.4 ± 0.1 gram |
| 2  | The sun-drying    | 5.6 ± 0.1 gram |
| 3  | The oven drying   | 4.8 ± 0.1 gram |

Drying was carried out on dehumidifier drying using two trays. Drying used a setpoint temperature of 40°C. The dehumidifier dryer can dry sweet corn with an initial moisture content of 50% to 11% moisture content in 44 hours 25 minutes for tray two and 46 hours 25 minutes in tray one with a final mass of material 248 grams for tray two and 230 grams for tray one. A comparison of the energy efficiency of various drying methods can be seen in Table 2.

| Drying methods  | Time (Hours) | Energy efficiency |
|-----------------|--------------|-------------------|
| Dehumidifier drying | 44.5          | 12.6 %            |
| Oven            | 72.5         | 7 %               |
| Sun-drying      | 89           | 0.002649 %        |

Dehumidifier drying had the highest energy efficiency among other methods. It also used a minimal amount of energy which was 105,394,714 kCal. Whereas the energy used of oven drying was 124,678.25 kCal and the energy used of sun-drying was 1,356,480 kCal.

4. Conclusions

The performance of the dehumidifier dryer for sweet corn seed was successfully conducted with the average of dry air temperature of 41.1±0.6°C and the average relative humidity was 15.9±0.7%. This temperature was in accordance with the safe and optimal condition for drying sweet corn seeds.

By using the dehumidifier dryer, the seed germination percentage was 85.67% and oven drying was 85.33% and the sun-drying was 86.67%. While the seed dry weight with the dehumidifier dryer with an average of 5.46g, oven drying 4.8g and the sun-drying of 5.6 gr. It showed that sun-drying performed better results, but with insignificant differences with the dehumidifier dryer which did not result in damage to the dried sweet corn seeds.
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