The Application of a Data Acquisition System and Airflow Control System in an Air Dehumidified Drying Machine

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Abstract. There are various possible drying methods used in seed drying. The tray dryer with an air dehumidifying system was used to produce various agricultural seeds. Seed drying by using an optimal air temperature requirement with low relative humidity can accelerate the drying process. To meet the specific drying requirement for agricultural products, air dehumidifying process, measurement data record, and airflow control were conducted in the drying machine. The objective of this research was to apply the data acquisition system and airflow control for seeds drying. The drying machine consisted of an air dehumidifying unit, data acquisition and airflow control unit, and a tray dryer unit. The air dehumidifying system was used to minimize the moisture in the drying air. The data acquisition system was used to monitor temperature and relative humidity distribution along with the drying machine. While the airflow control system was used to confirm that the requirement of air dehumidifying process was reached. A tray dryer used dehumidified air as the air input for the seed drying process. The drying machine was successfully reaching the optimal condition for drying with the temperature and relative humidity distribution were recorded. The optimal condition for the seed drying was reached by using this air dehumidified drying machine.

Keywords: seed drying, dehumidifier drying, Arduino microcontroller

1. Introduction
The drying process is conducted to decrease grain respiration by eliminating its moisture and to prevent the seeds deterioration [1]. The use of dehumidified drying machine for agricultural products especially for seed production is suggested to maintain the quality of the seed [2]. This method was suggested for seeds drying due to the shorter drying time and the ability to preserve seed quality [3]. There were several dehumidification processes in drying technologies for example by using zeolites [4, 5], heat pump system [6], heat pump assisted microwave drying [7] and a solar-assisted dehumidification system [8].

The working principle of dehumidification by using air conditioner system was to flow the moist ambient air to the low-temperature evaporator grille. A condensation process occurred when the ambient temperature has reached the dew point temperature. Then after the condensation process, the dry air can be used for drying operation [2, 9, 10].

The quality of seed product depends on the drying temperature used at the production. An optimal heating temperature is preferred rather than high temperature due to the effect of heat sensitivity to the seed germination. The temperature of 35°C and RH 75 % resulted in the most suitable dehydration regime for pepper seeds [11]. Slow drying procedure was taken in lettuce seed production which is...
20°C for 24 h in a sealed chamber and then transferred into 33% RH and 15°C [12]. The optimal corn seed drying temperature 40–45°C, the 50°C resulted in seed damaged. For pea seed, it was suggested at 40°C[13].

The design and performance test of a dehumidified drying machine for sweet corn seed had been investigated and the seed germination reached 85.7% [2]. The real-time data during drying process need to be monitored, collected, and can be used as the input for a control system to maintain the performance of the dehumidifier drying machine. The Arduino microcontroller for a data acquisition system was widely used in various research applications [14-17]. The use of DHT-22 sensors as for the temperatures and relative humidity data measurement

Therefore, the objective of this research was to apply the data acquisition system and airflow control for seeds drying.

2. Methods
The research was conducted in the Laboratory of Mechatronics, Department of Agricultural Engineering, Faculty of Agricultural Technology, University of Brawijaya.

The dehumidifier employed an evaporator in an air conditioner system [2]. The dehumidifying drying machine was a combination of a dehumidifier and the tray dryer machine and modified from [2] (Figure 1). The drying temperature applied in this experiment was the suggested temperature for sweet corn seeds drying from 38°C to 43°C with an air velocity of the fan was 3.4 m/s [2].

The component used for the data acquisition and control was the Arduino Mega 2560 as the microcontroller, the DHT-22 as the temperature and humidity sensors, an LCD 16X2 for the display, a micro SD module and a micro SD card for the measurement data record, a relay and a 220V electric fan as the airflow actuator, and the Arduino 1.8.8 as the programming software. The flowchart was described in Figure 2.
Figure 2. The data acquisition (DAQ) and airflow control system flowchart

The Arduino Mega 2560 is a microcontroller type which has 54 digital input/output pins, a 16 MHz crystal oscillator, 16 analogue inputs, 4 UARTs (hardware serial ports), a USB connection, an ICSP header, a power jack, and a reset button.

The DHT-22 temperature and relative humidity sensors were attached at six different locations which were at the ambient, at the dehumidifier unit, at before the heat recovery unit, at after the heat recovery unit, at the drying chamber, and the outlet air [18]. The DHT-22 has the measurement temperature range from -40°C to 80°C and the measurement relative humidity range from 0% to 100% which are sufficient for the dehumidifier drying machine operation range [19].

The DHT-22 temperature calibration method was based on comparison to calibrated standard thermometer from 28°C to 60°C [20]. The calibration equations were generated by using a linear regression line for 6 sensors.

The working principle of the airflow controller based on the comparison between the air temperature in the dehumidifier unit (Th) and the calculated dew point temperature from the ambient temperature (Ta). The calculation of the dew point temperature (Td) was calculated with Equation 1 [21]. The control system maintained the airflow of the air to the drying chamber while Th < Td and cut off the airflow to the drying chamber if Th > Td or there was no condensation in the dehumidifier unit.

\[ T_d = T_a - ((100 - RH)/5) \]  

Equation 1

The performance of data acquisition and airflow control system at the dehumidified drying machine can be evaluated by monitoring the temperatures and relative humidity in an experiment and analysing the state by using a psychometric chart.

3. Results and Discussion

The modified dehumidified drying machine is shown in Figure 3. There were five main units which were the electronic control box unit, the dehumidifier unit, the condenser unit, the heat recovery unit, and the drying chamber unit. The data acquisition and airflow control hardware were stored inside the electronic control box unit. The schematic diagram is shown in Figure 4.
1. Control box; 2. Dehumidifying unit; 3. Condenser; 4. Heat recovery unit; 5. Drying chamber

**Figure 3.** The modified dehumidified drying machine

The air temperature and relative humidity in six places were observed by using DHT-22 sensors which were at the ambient (1), at the dehumidifier unit (2), before the heat recovery unit (3), after the heat recovery unit (4), in the drying chamber (5), and the air outlet (6). The DHT-22 sensors calibration was conducted and resulted in six equations for every DHT-22 sensor consecutively as shown in Table 1. Then, the equations were written in the program to allow the output data calibrated.

**Table 1.** The calibration equations for DHT 22 sensors

| No | Location                        | Equation         | R²   |
|----|---------------------------------|------------------|------|
| 1  | ambient                         | \( y = 1.0224x + 2.2766 \) | 0.9278 |
| 2  | dehumidifier unit               | \( y = 0.9623x + 2.8394 \) | 0.9617 |
| 3  | before the heat recovery unit    | \( y = 1.0638x + 1.8218 \) | 0.9057 |
| 4  | after the heat recovery unit     | \( y = 1.2200x - 2.9116 \) | 0.9327 |
| 5  | drying chamber                  | \( y = 1.1319x - 1.5521 \) | 0.9366 |
| 6  | air outlet                       | \( y = 1.0116x - 0.8365 \) | 0.9788 |
The observations were conducted for approximately 3 hours. The average measurement data taken from the data acquisition system was served in Table 2. The temperature and the relative humidity measurement data was consecutively served in Figure 5 and Figure 6. The ambient temperature was decreasing when it flew into the dehumidifier unit and when it below the dew point temperature, the condensation of water vapour has occurred which is indicated by the maximum value of relative humidity in the dehumidifier unit (Figure 6).

During the experiment, the airflow controller calculated the dew point temperature from the real-time ambient temperature. Initially, the fan was off because the air temperature at the dehumidifier unit has not reached the calculated dew point temperature. When it reached or below the calculated dew point temperature, then the fan was on. The time needed for reaching the condition was 20 minutes after the system started.

| Location                        | Temperature (ºC) | Relative humidity (%) |
|---------------------------------|------------------|-----------------------|
| Ambient                         | 29.3 ±1.4        | 73.9±4.9              |
| dehumidifier unit               | 13.5 ±1.1        | 99.3±4.9              |
| before the heat recovery unit   | 13.9 ±0.8        | 99.6±2.3              |
| after the heat recovery unit    | 19.5 ±0.8        | 77.4±3.0              |
| drying chamber                  | 41.7 ±2.1        | 32.3±1.6              |
| air outlet                      | 47.7 ±2.1        | 29.0±1.3              |

The heat recovery unit was designed to restore the dry air temperature after the dehumidification process. The heat dissipated from the condenser was returned through a heat exchanger to the dehumidified air. The dehumidified air temperature can increase by an average of 6 ºC after passing through the heat recovery unit.

The setpoint temperature for the drying chamber was ranging from 38ºC to 43ºC. An automatic heater was utilized to increase the air temperature to reach the setting point. The relative humidity level was decreased from 73.9% to 32.3% at the drying chamber. The low-level humidity content in the air offered higher mass transfer gradient for more efficient drying.

![Figure 5. The measured temperature in the modified dehumidifier drying machine](image-url)
The drying air properties were described in a psychrometric chart which was shown in Figure 7. There were four points evaluated in the psychrometric chart which were at the ambient (A), the dehumidifier chamber (B), the heat recovery unit (C), and in the drying chamber (D). From point B to C, the heat recovery unit played an important role in restore heat energy from the condenser. The automatic heater was utilized to reach the setpoint temperature for seed drying had only need to heat from point C to D. If no heat recovery unit installed, the automatic heater was utilized from point B to D. The energy contained in the air can be observed through the enthalpy value. It is observed that the enthalpy at the point D has a higher value compared to point A.

The amount of energy utilized to increase the dry air temperature from the dehumidifier unit was higher than the amount of energy utilized to increase the dry air temperature after passing through the
heat recovery unit. Therefore, by using the heat recovery unit, less energy was utilized to reach the setpoint temperature [22, 23].

4. Conclusions

The data acquisition system applied for the dehumidified drying system based on Arduino Mega with DHT-22 sensors in 6 position which were at the ambient, dehumidifying unit, before heat recovery unit, after heat recovery unit, drying chamber, and drying chamber outlet. The airflow control unit holds the airflow to the drying chamber until the water condensation occurs at the dehumidifier unit. The data acquisition and airflow control system application in the dehumidified drying machine can provide the optimal condition for seed drying.

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