Performance test of air input control system for paddy grain drying using in-store dryer

D Nurba*, R Agustina, M Yasar, and A Khurjannah
Department of Agricultural Engineering, Universitas Syiah Kuala, Jalan Tengku Hasan Krueng Kalee No. 3 Darussalam 23111 Banda Aceh, Indonesia

*E-mail: diswandinurba@unsyiah.ac.id

Abstract. The control system is a series of a system that is very important in today’s technology. Wherewith control system can make the human job easy and get a good result. This study used a controlled In-Store Dryer to dry 100 kg of grain with an initial moisture content of 17.77% to reach 14%. The study results using a control system, the average ambient temperature of the three tests ranged from 32°C to 33°C, and the RH ranged from 64.8% to 68.6%. At the same time, the average temperature was 36.7°C to 37.5°C, and the average RH was 49.9% up to 64.7%. The drying airflow speed at the fan input is 6.2 m/s and at the chimney 9.2 m/s. Moisture content during drying differs for each thickness depending on the location, with an average drying rate of 0.92%. During drying, the moisture content varied for each consistency depending on the site, with the drying rate at an average ISD of 0.92% w/hr. total electrical energy consumption of 32.57 kWh and energy in biomass combustion 1,416,600 kJ. The quality during rice drying starts from the initial moisture content of 17.78% to reach the final moisture content of 10.44%.

1. Introduction
Drying reduces the water content of a material to be safely stored for further use. According to [1], drying can be performed using natural methods (drying) or artificial methods of artificial drying. Wide and easily contaminated with outside materials. The level of grain purity will decrease with the increasing number of foreign objects and the amount of water or empty grain in the grain mixture [2]. Drying using an In-Store Dryer (ISD) can be used to overcome this problem. The drying system in the ISD is a drying and storage method that uses environmental air exhaled on the dried material [3]. The axial fan on the ISD is used to carry the ecological airflow in the drying chamber.

Fluctuations in temperature and environmental RH that often change during drying make the air in the drying chamber not constant. When the RH of the environment is excessive, it will bring water vapor back into the drying chamber. To overcome this problem, this study control system in a Digital Temperature and Humidity Sensor - 22 (DHT22) was installed to record the temperature and RH environment. The DHT22 sensor has better accuracy than the Digital Temperature and Humidity Sensor - 11 (DHT11) [4]. The sensor recorded the results, which will control the fan rotation with 3-speed levels, namely fast, medium, and slow, so energy consumption during drying is more efficient because the fan rotation is controlled.
2. Research Methods
The tools and materials used in this research are an In-Store Dryer (ISD), Digital scales (EK-1200 A), Drying oven (SS-204D), control system circuit, Arduino UNO, sensor DHT22, thermocouple (CA), hybrid recorder (HR-2500E), thermometer (wet bulb and dry bulb), anemometer (Kanomax A541), laptop, and camera. The materials used are grain and wood charcoal.

Prepared fresh rice grain (*Oryza sativa* L.), then weighed as much as 100 kg; after weighing, the rice grains were inserted into the ISD to continue the drying process until it reached the moisture content (max 14%). This study, testing the control system's performance and controlling the speed of airflow, temperature, RH, and drying rate with 30 minutes of data retrieval, took place from 09.00-17.00 WIB. Control of airflow, temperature, and RH using sensors installed inside and outside the In-Store Dryer in the form of a DHT22 sensor. The working mechanism of the DHT22 sensor is to record the temperature and RH of the environment, which then controls the speed of airflow entering the drying chamber through a fan speed with 3-speed levels, namely fast, medium, and slow.

ISD is a drying device and storage shape like a silo building, namely a cylinder. The ISD building has a height of 1.95 m, diameter of 0.80 m, and all plates are made of galvanized with a thickness of 0.002 m which is reinforced by a frame and iron pipes. The inside of the ISD is equipped with 13 distribution pipes divided into two types, namely input and output. There are nine input pipes and four output pipes [5]. The schematic of the ISD building can be seen in Figure 1.

![Figure 1 ISD building with axial blower](image)

In this study, an axial fan is used; the fan rotates at three speeds according to the control system output, fast, medium, and slow. The fan rotation speed will be controlled using a control system; the fan rotates depending on the ambient temperature and RH, which is read on the DHT22 sensor. Fan speed aims to regulate the flow of air entering the drying chamber. If the ambient temperature is 34°C-40°C and the environmental RH <55.25%, the fan rotates quickly to circulate the airflow. If the ambient temperature is 32°C-34°C, and the ambient RH is 55.23-65.53%, the fan rotation is medium. Suppose the ambient temperature is 31°C-32°C and the environmental RH is 65.53-77.25%. In that case, the fan rotates slowly if the ambient temperature is 31°C-32°C and the environmental RH is ≥ 77.25, then the fan is OFF, which aims to prevent the entry of water vapor into the ISD.

3. Results and Discussion

3.1. Control System On ISD
The control system is a series of scenarios that are very important in today's technology; the existence of a control system can facilitate a human job because it can command, control, and regulate the state of a system to get better satisfying results[6]. The application of control systems in agriculture has been
widely carried out, especially for controlling food drying. One study showed that a heater's automatic control provides a more stable air temperature in a solar dryer [7].

In this study, a control system was used during drying in the In-Store Dryer. The use of automatic control systems on machines is now an essential part [8]. The DHT22 sensor is used to measure the temperature and RH of the environment that enters the drying chamber to control the fan's rotation on the dryer. The front view of the control system can be seen in Figure 2.

3.2. Sensor Calibration

Calibration is a process to see the accuracy of a tool by comparing it with the value read on a standard measuring instrument. Calibration in this study was carried out on the DHT22 type sensor; calibration was carried out by heating the air on the DHT22 sensor adjacent to a standard thermometer. After the calibration results are out, the results are recorded and converted into graphs. The graph can be seen in Figure 3.

From the graph, it can be seen that the relationship between the standard temperature value and the temperature measurement of the DHT22 sensor is linear with the value of $y = 0.980x + 0.154$, where $x$ is the temperature output value from the standard thermometer, which is the temperature output value from the DHT22 sensor. The result of the degree of linear correlation of the graph is $R^2 = 0.997$. This value has shown that the relationship between the sensor output value and the standard thermometer output value at the time of temperature measurement is linear and has a solid correlation coefficient value.
3.3. Drying Temperature Distribution

The drying chamber temperature measurement was carried out at eight sensor ballpoints inside the ISD using a thermocouple cable connected to a hybrid recorder. Then the height of the ambient temperature will be controlled using a series of control systems to control the temperature and RH that enters the drying chamber.

![Figure 4](image)

**Figure 4.** The decreased moisture content of corn kernels during the drying process

Figure 4 shows the comparison between the ambient temperature and the temperature in the ISD room. The graph shows that the ambient temperature ranges from 31°C to 35°C, suitable for the drying process. The higher the ambient temperature, the lower the humidity, thus causing the drying process to be faster [9]. In contrast, the temperature inside the ISD during drying ranges from 33.3°C to 40.1°C. From the graph, it can be seen that the ISD temperature is greater than the ambient temperature. Indicating that using a control system during drying has worked well to maintain the temperature in the drying chamber so that the temperature recorded on the ISD is suitable for drying up to 40.1°C. A good grain drying process is carried out at a slowly rising surface temperature from an ambient temperature of 30°C to 45°C. The heating temperature, which increases to 45°C, can remove the water contained in the material [10].

3.4. Drying Air Humidity

Air humidity is very influential on the drying process because air humidity indicates the water content in the air. High air content will affect the drying process so that drying will last longer and vice versa; if the air humidity is low, it will speed up the drying process.

![Figure 5](image)

**Figure 5.** comparison of ISD RH and ambient RH
It can be seen in Figure 5, the recording on the data control system of the highest environmental RH obtained during drying is 82%. In this case, the fan is off, while the lowest environmental RH is 53%, and the fan is rotating in a fast state. The highest ISD RH during drying is 75.3%, and the lowest RH is 42.1%; airflow with low RH is very suitable for the drying process. If the RH is low, the water vapor in the material will be more and more absorbed by the air; therefore, the drying rate takes place quickly, and drying also takes place in a fast state [3].

3.5. Dryer Airflow
The velocity of airflow in the drying process serves as a distribution of hot air, which is used to evaporate the water content in the dried grains, and at the same time to remove water vapor so that no condensation occurs when drying is in progress. Figure 6 shows the airflow velocity during the drying process.

![Figure 6. Airflow at ISD inlet and outlet](image)

Figure 6. Shows the airflow velocity during drying; the airflow velocity in 3 replications did not significantly differ. The fastest airflow in the chimney, 9.2 m/s, occurs at 11.30 WIB on test 3. In comparison, the quickest airflow at the fan input of 6.2 m/s occurs at 11.30 in replicate 3. the more significant the drying airflow, the faster the drying time due to the more hot air and water vapor carried by air [11].

3.6. Paddy grain water content
In the drying process, it is known that decreasing the water content will determine the absolute limit of a drying process. Because the water content is a factor that affects the yield and durability of the material, the lower the water content in a material, the longer the storage process time, and so should also be[12]. Figure 7. shows the change in content during drying that the average initial moisture content of the grain is 17.3%, and the moderate final moisture content of the grain is 10.6%. The moisture content of grain during drying is permanently reduced; the difference between the initial and final moisture content during drying is 6.9%. Changes in water content during drying occur due to changes in ambient temperature and drying room temperature. So that it can cause the water vapor pressure in the material to be higher than air-water vapor; therefore, there is a transfer of water vapor from the material to the air and towards the environment.
3.7. Drying Rate

The drying rate decreases the material’s water content, which aims to reduce the water content contained in the grain. The faster the decrease in the water content of the grain, the quicker the drying rate of the grain [13]. Figure 8. shows that the drying rate of grain ranges from 0.33% wb/hour to 1.33% wb/hr. The highest average drying rate occurred in the third Test, around 1% wb/hour, because there is a lot of water content on the material’s surface, classified as free water. While increasing time and the dryness of the remaining material is bound to water contained in the cells of the material, the decrease in water content in the material is getting minor and finally constant [14].

3.8. Energy Consumption

Based on the graph in test 1, the highest electrical energy consumption occurred at 13.30 WIB, which reached 0.72 kWh; while drying, the fan rotated quickly; therefore, the energy consumption required was higher, and the average consumption of electrical energy in the first Test is 0.63 KWh. While in the second Test, the highest energy consumption occurred at 14.30 WIB, which was around 0.75 Kwh, and the highest energy consumption in the third Test occurred at 14.30 WIB when the fan was spinning fast. The electrical energy consumption was about 0.74 Kwh with an average the average energy consumption in the third Test is 0.65 Kwh.
The consumption of biomass energy during drying serves to heat the Heat Exchanger during the drying process. Consumption of biomass energy in the drying of rice grains took place three times of testing with one time of testing starting from 09.00-17.00 WIT. In the first Test, the biomass energy consumption used was 0.50 MJ, and in the second, it was 0.47 MJ, while in the third Test, it was 0.45 MJ/Kg, and the heat used during drying was 1.42 MJ. 1 kg of charcoal produces 23,610 KJ of heat.

4. Conclusions and Suggestions
4.1. Conclusions
The performance of the ISD control system has been able to provide suitable environmental temperature and RH input during drying and has been running according to the control algorithm. The average ISD room temperature during drying was 36.8°C, in the range of 35.4-38.7°C. RH was recorded in the field of 42.8–64.8%, with an average of 54.9%. Drying lasted for 8 hours and reduced the water content from 17.8% to 11.2%. To dry 50 kg of paddy grain consumes an average of 0.64 kWh of electrical energy and 0.47 MJ of biomass energy.

4.2. Suggestion
To get a more comprehensive performance, we need further testing, with total capacity ISD space.

Acknowledgments
Thanks to the Universitas Syiah Kuala for funding through the "Penelitian Lektor" program in 2021.

References
[1] Gunasekaran K, Shanmugam V, Suresh P. Modeling and Analytical Experimental Study of Hybrid Solar Dryer Integrated with Biomass Dryer for Drying Coleus Forskohlii Stems n.d.
[2] Harini RR. Tingkat Efisiensi Perubahan Usahatani Padi Di Kecamatan Seyegan Kabupaten Sleman. Majalah Geografi Indonesia 2016;17:81–94. https://doi.org/10.22146/MGI.13258.
[3] Nurba D, Wulandani D, Purwanto YA, Paramawati R, Nelwan LO. Analisis Sebaran Kadar Air Jagung Selama Proses Pengeringan dalam In-Store Dryer (ISD). Rona Teknik Pertanian 2016;9:11–24. https://doi.org/10.17969/RTP.V9I1.4381.
[4] Saptadi AH. Perbandingan Akurasi Pengukuran Suhu dan Kelembaban Antara Sensor DHT11 dan DHT22 Studi Komparatif pada Platform ATMEL AVR dan Arduino. Jurnal Informatika,Telekomunikasi Dan Elektronika 2015;6. https://doi.org/10.20895/INFOTEL.V6I2.73.
[5] Nurba D, Raida A, Khathir R. LAJU PENGERINGAN JAGUNG DALAM IN-STORE DRYER TERMODIFIKASI DENGAN HEAT EXCHANGER DAN TUNGKU BIOMASSA. Prosiding Seminar Nasional PERTETA 2018.

[6] Wati D. Sistem kendali cerdas: Fuzzy Logic Controller (FLC), Jaringan Syaraf Tiruan (JST), Algoritma Genetik (AG) dan Algoritma Particle Swarm Optimization (PSO) / Dwi Ana Ratna Wati | OPAC Perpustakaan Nasional RI. Graha Ilmu 2011. https://opac.perpusnas.go.id/DetailOpac.aspx?id=538570 (accessed October 15, 2021).

[7] Nelwan L.O, Abdullah K, Suhardiyanto H, Alhamid M. Performansi Pengeringan Kakao dengan Alat Pengering Tipe Efek Rumah Kaca. Seminar PERTETA, Bandung: PERTETA; 1997.

[8] Bolton W. Sistem Instrumentasi dan Sistem Kontrol. Jakarta: Erlangga; 1993.

[9] Widjanarko A, Ridwan R, Djaeni M, Ratnawati R. Penggunaan Zeolite Sintetis dalam Pengeringan Gabah dengan Proses Fluidisasi Indirect Contact. JURNAL TEKNOLOGI KIMIA DAN INDUSTRI 2012;1:157–64.

[10] Risharyanto. Pengaruh Reflektor Terhadap Karakteristik Pengeringan dan Kualitas Produk pada Model Pengering Gabah Sistem Radiasi Infra Merah. 2005.

[11] Hidayati N, P. UD, Ratnawati S, Suherman S. Penerapan Teknologi Fluidized Bed Dryer dengan Penambahan Zeolit 3A Untuk Meningkatkan Efisiensi Pengeringan Gabah. JURNAL TEKNOLOGI KIMIA DAN INDUSTRI 2013;2:65–71.

[12] Supardi, I, Sukamto. Mikrobiologi dalam Pengolahan dan Keamanan Pangan. Bandung: Alumni; 1999.

[13] Nurba D. Analisis distribusi suhu, aliran udara, Rh dan kadar air dalam In-store dryer (ISD) untuk biji jagung 2008.

[14] Wijaya A. Uji Unjuk Kerja Mesin Pengering Tipe Efek Rumah Kaca (ERK) Berenergi Surya dan Biomassa untuk Pengeringan Biji Pala (Myristica Sp.) di UD. Sari Awi, Cihara Pondok, Caringin, Bogor. 2007.