Journal of Mechanical Engineering and Applied Technology, 1 (3) 2023, 29-35

DESIGN AND PERFORMANCE TEST OF A CABINET TYPE DRYER FOR DRYING BREADFRUIT CHIPS: A CASE STUDY OF THE SUMBER REJEKI PURWOSARI FARMERS GROUP, SEMARANG CITY

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Abstract

This study aims to design and build a cabinet-type breadfruit chips dryer powered by liquefied petroleum gas (LPG) and to assess the dryer's characteristics, particularly by observing the temperature and relative humidity (RH) variables in the drying chamber. This characteristic data is critical for forecasting the dryer's ability during drying. The experimental approach was carried out in three stages: design, assembly, and testing without a drying load under two process conditions, charging and discharging. The testing time is 150 minutes, with the charging procedure taking 70 minutes and the discharging process taking 80 minutes. In general, the distribution of temperature and RH on each shelf in the drying chamber is consistent, both during the charging and discharging processes. In the charging-discharging process, the average temperature of the drying room is 45.39 C with a RH of 40.99%, while the plenum room average temperature is 77.02 C.

Keywords: *breadfruit; charging-discharging; dryer; RH; temperature*

1. Introduction

The processing of post-harvest agricultural products is a classic issue that farmer groups frequently face [1]. Breadfruit is one of the agricultural products that requires post-harvest management. Breadfruit harvest season tends to coincide with the wet season with high yields in the Sumber Rejeki Farming Group. This promotes rot in the breadfruit, which lowers the selling price. Essentially, the drop in post-harvest selling prices of breadfruit can be mitigated by raising the value of processed breadfruit products, such as manufacturing breadfruit flour by exploiting breadfruit's high carbohydrate content [2].

The drying process influences whether processed breadfruit may be converted into breadfruit flour. As a result, it is critical to build a weather-independent drying system, such as a dryer powered by LPG, as reported by [3], [4], a biomass-fueled dryer [5]–[9], and a dryer powered by electricity, as reported by [1], [10], [11]. Aside from that, the designs of drying devices reported by various studies varied from one another. For example, [3]–[5], [8], [11]–[14] reported on the design of cabinet type or rack type dryers, stack type or batch type [9], bed type [7], dehumidification type [1], and the design of a roster type dryer [3].

Aside from the various designs and applications of drying energy sources, the use of dryers for drying agricultural products has also been found to differ. Sudirman et al. [1] used a dryer with a dehumidification system to dry the harvest of herbal plants, whereas Apriandi et al. [5] and Nurmawati [15], dried seaweed using a cabinet type drier. [12] reported drying kapok banana chips in a rack type hybrid drier; meanwhile, Rahmalina et al. [16] employed a dryer to dry chilies using concentrated solar power as a source of drying energy.

Previous study has shown that the features of dryers vary based on the kind, energy source, and purpose for drying specific materials. As a result, the goal of this study is to approach the design of a cabinet-type drier with an LPG energy source for drying breadfruit chips. The dryer's thermal parameters were determined through thermophysical performance testing. The design's final results can be utilized as a reference by breadfruit producers to obtain optimal drying conditions for breadfruit chips.

2. Materials and Methodology

This study was carried out at Semarang State Polytechnic's Energy Conversion Laboratory, Energy Conversion Engineering Study Program, Department of Mechanical Engineering (-7.053253, 110.435327). The flow diagram in Figure 1 was used to guide the design and experimental test approach used to determine the thermal characteristics of the dryer.

Fig. 1. Research flow

2.1. Design

The SolidWork 2023 program is used to design the dryer, which is outlined in the form of a technical drawing. This stage involves functional planning for the dryer's primary components, number of shelves, energy sources, and the dryer air distribution system. Aside from that, structural design is carried out at this step, which involves material selection, dryer size, and the option of using heat absorbing materials as thermal insulators.

2.2. Manufacturing and Assembly

The dryer was built and assembled at the Mechanical Engineering Department Workshop at Semarang State Polytechnic.

2.3. Testing

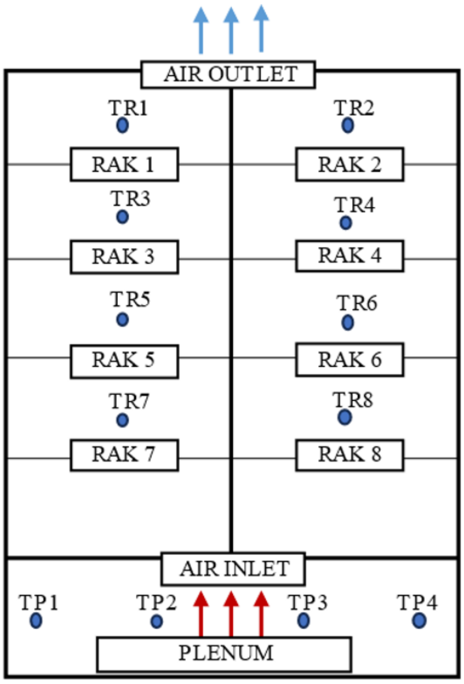


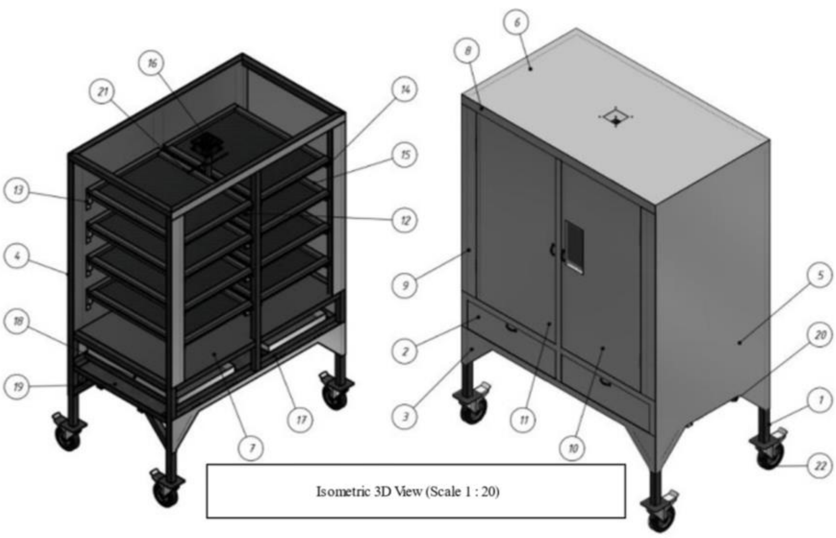
Fig. 2. Illustration of measuring instrument installation

The dryer is tested without a drying load to gather data on the dryer's thermal parameters, which include temperature and air humidity (RH), both in the drying room (TR1-TR8 and RH1-RH8) and in the plenum room (TP1-TP4). The test lasted 150 minutes, with the first 70 minutes assessed in the heating (charging) process and the last 80 minutes evaluated in the cooling phase (without a heating/discharging source). On each shelf, temperature and relative humidity are measured every 5 minutes. Temperature and relative humidity are measured using a type K thermocouple coupled to an Autonics Temperature Indicator T4WM-N3NKCC series and a thermohygrometer. Figure 2 depicts the positioning of measuring instruments.

3. Result and Discussion

3.1. Design and Manufacturing

The drying equipment is designed with precise specifications based on user needs, as shown in Table 1. The cabinet type chosen to enhance drying capacity is ideal for big-capacity drying and is simple to build. In addition, an anthropometric technique is employed to create thorough design specifications that adapt to user situations, resulting in harmony between the user and the work system and equipment to be operated [17].



NO	JUMLAH	NAMA BAGIAN	BAHAN
22	4	Roda	Aluminum 6061
21	1	Rangka Tengah	
20	1	Dudukan Kompor	
19	1	Plat Bawah	Steel
18	2	Kotak Penyimpanan	Stainless Steel
17	1	Rak Bawah	
16	2	Kipas	ABS Plastic
15	8	Rak	Stainless Steel
14	16	Penyangga 2	Stainless Steel
13	16	Penyangga 3	Stainless Steel
12	4	Penyangga	Stainless Steel
11	1	Pintu Utama Kiri	
10	1	Pintu Utama Kanan	
9	2	Cover Depan 3	Stainless Steel
8	1	Cover Depan 2	Stainless Steel
7	4	Alumunium Foil	Stainless Steel
6	1	Cover Atas	Stainless Steel
5	2	Cover Samping	Stainless Steel
4	1	Cover Belakang	Stainless Steel
3	1	Cover Depan	Stainless Steel
2	2	Pintu Bawah	
1	1	Rangka	

Fig. 3. Design drawing

The constructed dryer features wheels on the bottom for easy mobility. The dryer has two doors and an exhaust fan for circulation of the drying air. The frame is made of hollow iron that measures 4x4 cm. Meanwhile, for the safety of the goods being dried, the drying rack is made of aluminum, and the dryer walls are constructed of stainless steel to reduce corrosion. The dryer's detailed design is depicted in Figure 3.

Table 1. Design Specifications

Part	Information
Dimensions (PxLxT)	120 cm x 80 cm x 180 cm
Door	2 pieces
Drying rack	8 pieces (4 tiers, 2 rows)
Energy sources	LPG
Drying capacity	40 kg (@ 5kg/rack)
Material	Stainless steel, aluminum, hollow iron

3.2. No-Load Testing

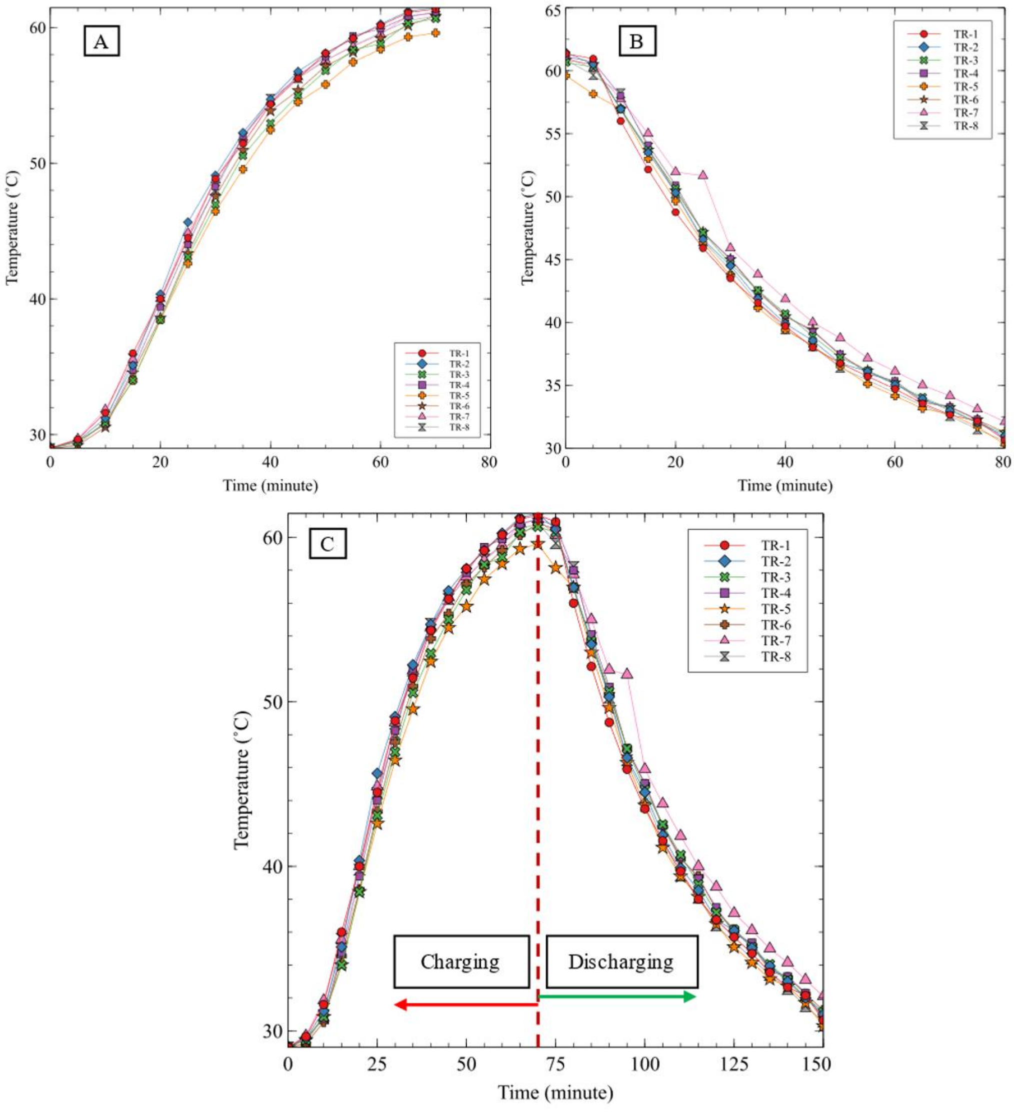


Fig. 4. Temperature distribution of each drying rack: A) charging process; B) discharging process; and C) combined charging-discharging process

The thermophysical parameters of the dryer, both without and with a drying load, are defined as the dryer's characteristics. Temperature and relative humidity are the two most essential variables in the drying process [4]. This characteristic data indirectly reflects the dryer's drying ability, allowing us to forecast the duration of drying time for a product being dried. Figure 4 depicts the temperature distribution on each drying room shelf. Data is collected using two process approaches: charging (when the stove is turned on) and discharging (when the stove is turned off). It was discovered that the temperature on each shelf grew over time during the charging process and reduced over time during the discharging process. The addition of heat energy from the LPG stove during the charging process has an effect on this. This is the same condition described by [4], who characterized the dryer by adding heat storage material in the form of iron grams in the plenum area. Aside from that, Figure 4 shows that the temperature distribution on each shelf in the drying chamber is relatively close to each other. This indicates that the drying room has temperature homogeneity, implying that the dryer's performance is excellent.

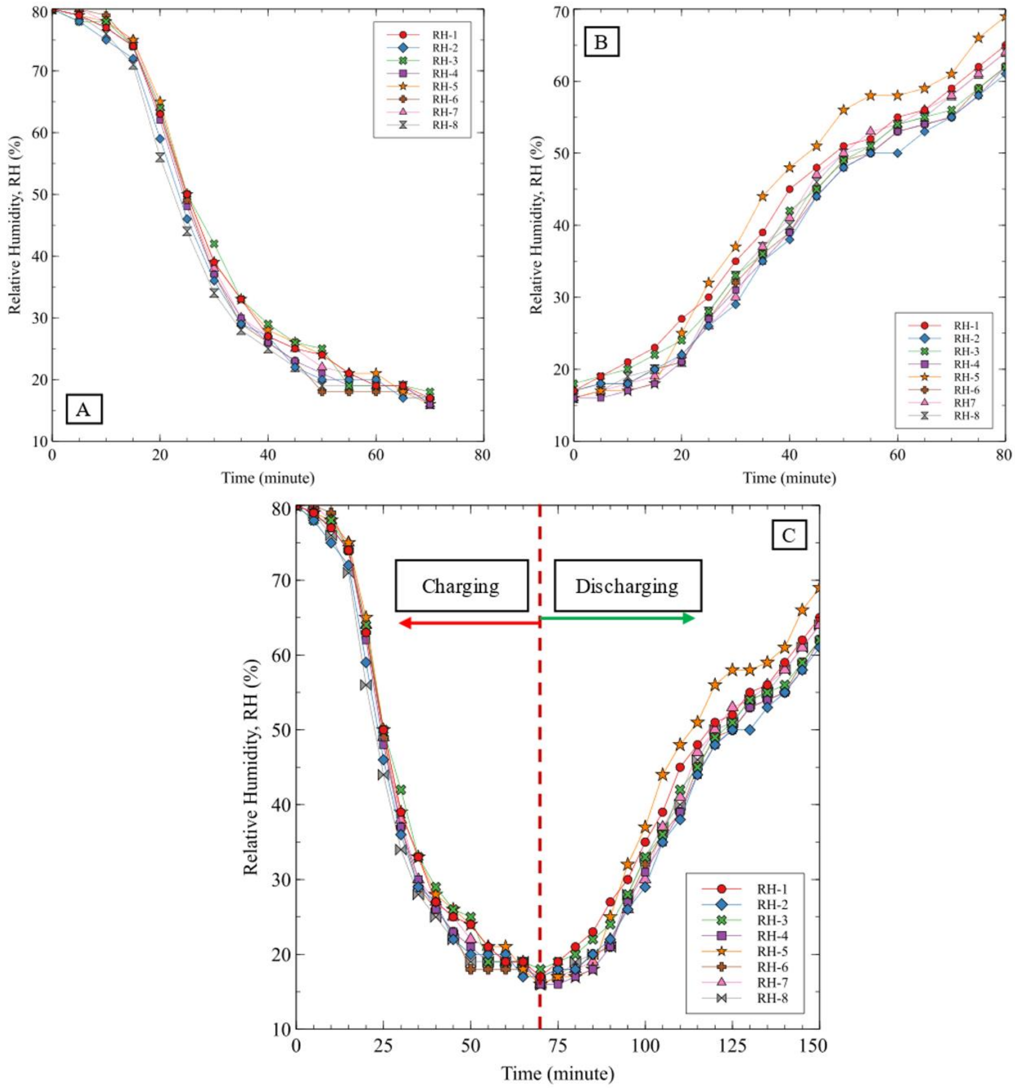


Fig. 5. RH distribution of each drying rack: A) charging process; B) discharging process; and C) combined charging-discharging process

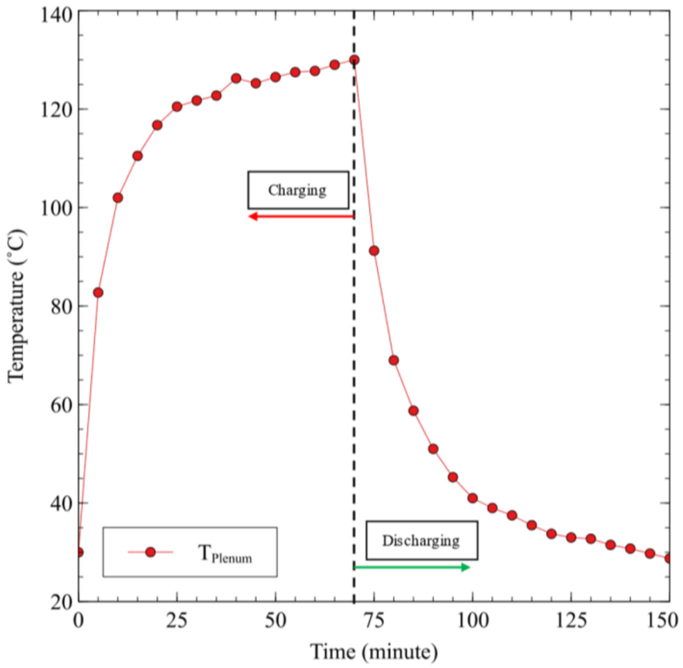


Fig. 6. Average temperature distribution in the Plenum chamber

Figure 5 indicates that when the temperature in the drying chamber rises, the proportion of water vapor content in the drying airdrops. As shown in Figure 6, the air that enters the drying chamber first passes through the plenum chamber, which has a high temperature, especially during the charging process. The plenum chamber homogenizes the air that will flow into the drying chamber, causing the water vapor concentration in the ambient air to decrease as the temperature rises. Figure 5 also clearly shows that the trend of decreasing RH distribution on each shelf in the drying chamber is comparable, with percentages that are not too dissimilar.

4. Conclusion

Data on the characteristics of the dryer, represented by the variables temperature and RH, show uniformity and almost the same distribution pattern for each drying rack in the drying room. The average temperature of the drying room during the charging process was 47.63 ˚C with an intermediate RH of 42.34%. Meanwhile, in the discharging process, the average temperature of the drying room was 43.14 ˚C with an average RH of 39.63%.

Acknowledgment

The author would like to thank the Semarang State Polytechnic Research and Community Service Center (P3M) for funding this research activity through the Penelitian Terapan Pratama (PTP-2023) and Pengabdian Masyarakat Pratama (PMP-2023) schemes.

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