PROTOTYPE OF TRAY DRYER UNIT FOR SILICA GEL DRYING BASED ON BAGASSE

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Abstract. Tray dryer is one type of plate-shaped dryer, which is often used to dry materials in the form of solid or paste, therefore the tool is very suitable for drying or converting hydrogel to silica. The working principle of the dryer is to transfer heat around the environment of the material to be dried by means of heat transfer by convection and conduction. Weight reduction due to water loss due to evaporation when drying process is done. In this research, the silica to be dried was made from bagasse using a number of additional ingredients namely hydrochloric acid and sodium hydroxide with various variations. Tool performance is determined based on the amount of thermal efficiency obtained where thermal efficiency is a percentage of the amount of heat flowing during the drying process. In addition, the rate and time of drying will also affect the quality of the product. research steps include; tool design using the functional approach method to find out the functions of the unit of equipment used and structural approach to get the dimensions of the tool. Silica gel produced from the drying process is analyzed using X-Ray Diffraction (XRD) and Fourier Transform Infra Red (FTIR) which aims to characterize the crystal structure and detect functional groups. Based on the analysis results obtained silica gel has a functional group of Si-OH and amorphous crystal structure, so it is categorized as meeting the standards of JIS-0701. Calculation results obtained optimal conditions achieved at the time and speed of drying 360 minutes, 0.019 kg/hour m\(^2\) with a silica gel moisture content of 0.81% and thermal efficiency of 86.4%.

Keywords: Bagasse, Silica Gel, Tray Dryer, FTIR, XRD

1. Introduction

Tray dryer is a plate-shaped dryer equipped with shelves that are used to dry solid material (granular). The purpose of drying is to reduce the water content contained in silica gel. The silica gel drying process is one of the factors that determine the quality of the product produced, conventional silica gel drying results in lower product yield percentages [1]. In the drying process, several parameters greatly affect the quality of silica gel, including time and speed and the heat transfer process that influences. The adiabatic heat transfer process will produce silica gel which has a JIS-0701 standard.

The prototype tool is equipped with an air filter and Thermo control (thermocouple) as a heat control device, so that heat transfer is expected to take place adiabatically. Hot air needed for the drying process has a function as a giver of heat in the material, thus causing the evaporation of water. Another function of hot air is to transport water vapor emitted by the dried material. The drying speed will increase if the airstream is increased. The final water content when it starts to reach equilibrium, it will
make the drying time also increased or in other words faster [2]. Factors that can affect the drying of a foodstuff include; physical and chemical properties of food and the process of transferring from heating media to dried material [3].

The performance of the tool will work optimally and produce silica gel products with a low H₂O content so that a good drying temperature and heat transfer process is needed. 68.5%. The silica content is high enough that it can be used to make silica-based materials [4] in the form of silica gel. Bagasse-based silica gel is made using an adiabatic drying method wherein the product still contains 2% water so the drying process is carried out with a tray dryer. The prototype of this drying device is intended to overcome the breakdown of Si-OH group chains during the drying process so that the ability of silica gel to absorb moisture will be reduced. Because the resulting silica gel can be used as an absorbent which must have a silanol group (Si-OH) and a siloxane group (Si-O-Si), have broad pores and a unique surface [5].

2. Experiment

The method used in this research includes prototype design of the tray dryer, testing and data collection. The tray dryer tool has several components, namely thermocouple, digital hygrometer, heating element (coil), air filter regulator, piston compressor and flowmeter. Tray dryer has a square shape and inside contains shelves. The materials are placed on a rack (tray) made of perforated metal. The use of these holes is to circulate hot air. The heating system in this dryer is done indirectly, that is utilizing environmental air that is inhaled from the compressor, then the air will be passed to the room where there is a heating coil and then the hot air will be exhaled in the tray dryer. The indirect heating system can prevent direct contact which will result in damage to the hydrogel. The heater used is a finned type coil heater which has the most heat of 400 °C.

![Figure 1. Tray Dryer Design](image)

Explanation:
1. Regulator Air Filters
2. Flowmeter
3. Switch on / off
4. Humidity Display
5. Thermocontrol
6. Heater
7. Shelf
8. Chimney
The experiment included 125.42 grams of material put into the tray before the material was weighed, testing the tool with a time variation of 60 to 360 minutes.

Product analysis is carried out based on JIS-0701 Standard using FTIR and XRD tools than data collection in the form of material mass before and after drying, drying time, drying airflow rate in and out, drying air temperature, temperature of material after drying, wet ball and dry ball temperature, with thermal efficiency calculation based on heat transfer method [6].

3. Result and discussion

The test results obtained when determining the performance of the tool with the variables set when testing in the form of time, temperature and water content, so we get the test results for each variable from 60 minutes to 360 minutes and the temperature of 80°C obtained a decrease in water content on average reaches 80%, then based on the drying results of the dryer the tool meets the standards for use in drying silica gel material. The limits that influence the drying time are the first moisture content and dry matter content. The water content of silica gel in dry conditions based on the quality standard of JIS-0701 is ≤ 2.5%.

Drying too fast can damage the material, i.e. the surface of the material dries too quickly, so it is not proportional to the speed of movement of the material's water to the surface. This causes the hardening of the surface of the material (case hardening). Furthermore, water in the material can no longer evaporate because it is blocked [7].

Figure 2. Graph of Effects of Drying Time on Decreased Silica Gel Water Content

Figure 2, shows that the result of a decrease in the water content contained in the hydrogel has experienced a significant reduction due to the first evaporation of water occurring on the surface, then the water content of silica gel has decreased slowly due to the water in the room dryers have begun to flow out of the surface [8].

Decrease in water content at the time of drying 0-360 minutes a decrease in water content by 47%. At 360 minutes drying time produces a moisture content of 0.814% from the first water content of 95.6% and the results meet the JIS-0701 standard that is ≤ 2.5%. The longer the drying process occurs, the greater the decrease in water content that occurs when drying is done in the tray dryer.

The drying rate depends on the difference between the moisture content of the material and the moisture content of the balance. In this study, the drying rate continues to increase until the water content decreases. In inverse proportion to the existing drying rate concept where it should be, the drying rate will decrease along with the decrease in water content that occurs during the drying process [9].
In Figure 3, a graph shows the relationship between drying time and drying rate. The drying rate at 60 to 360 minutes continues to increase i.e. 0.01446 kg/hour m² to 0.01941 kg/hour m². In the 300th minute, the drying rate increased because this was because in the 240th minute the tray containing the raw material was removed to be weighed so that the temperature of the material decreased and the drying rate rose to reach equilibrium. The drying rate will increase if the airspeed is increased. The last water content when it starts to reach equilibrium, it will make the drying time also increased or in other words faster [10].

In the 300th and 360th minutes the drying rate is constant, in this case it shows that the drying time conditions of 300 and 360 minutes are not affected by the content, so that if the drying rate is continued it will allow the drying rate to decrease, with decreasing wetness content, a constant rate period will end at a certain wet content and in next drying it will decrease and will reach equilibrium [11].

Convection heat transfer occurs because the fluid (hot air) comes in direct contact with the dried material (hydrogel). At the beginning of the drying time, the value of the convection heat transfer rate is greater than the value of the heat transfer rate at the drying time of 60 minutes. This can occur because at the beginning of the drying process there is direct contact between the hydrogel and the hot air dryer media. The water contained on the surface of the hydrogel will evaporate more and there will be a decrease in the water content in the hydrogel.

![Figure 3. Effect of Drying Time on Drying Rate](image1)

The convection heat transfer rate increases at a drying time of 120 minutes, this is because the temperature of the hydrogel is changing so that the heat transfer also changes. Whereas at the time of drying to 180 minutes and 240 minutes the rate of convection heat transfer tends to be constant. At this time the rate of heat transfer begins to tend to reach an ideal value. Although at the time of drying to 300 minutes the value of the heat transfer rate has decreased slightly. This happens because at the end of the drying process the heat transfer rate tends to be constant so that the heat transfer into the material decreases.

![Figure 4. Determination of Convection Heat Transfer Rate Graph for Drying Time](image2)
At the time of drying to 360 minutes the value of the heat transfer rate increases again, an increase in the convection heat transfer rate can occur due to an increase in the value of the convection heat transfer coefficient.

The decrease or increase in the value of the heat transfer rate is influenced by changes in the Reynolds number, with changes in the Reynolds number the flow movement will be more irregular or faster [12]. Heat conduction in this drying process occurs when heat from the walls of the plates propagates into the dried silica gel. Heat transfer takes place on the surface of the material slowly until there is even distribution of heat. At the beginning of drying the conduction heat transfer rate value is greater than the drying time of 60 minutes and 120 minutes. The size of the conduction transfer rate at 0 minute drying time is due to the first drying of each layer of the hydrogel surface where there is a high increase in heat transfer rate because at this stage there is direct contact between the hydrogel and the hot air media from the surrounding plate drying walls.

The decrease occurred at the drying time to 60 and 120 minutes. This decrease in heat transfer rate occurs because the heat in contact with the dried material has begun to flow into the surface layers of the hydrogel. At the drying time of 180, 240, 300, and 360 minutes the conduction heat transfer rate tend to increase and is constant. The speed of the air and the viscosity affect the movement of air particles so that the contact between the air and the hydrogel will be uniform. The value of thermal conductivity and specific heat have influenced the amount of heat absorbed by the air, so the rate of heat transfer tends to be constant.

Thermal efficiency shows the results of tool performance which is calculated based on the size of the convection and conduction heat transfer rates. Thermal efficiency affects the drying time used.

Figure 6, the highest thermal efficiency was at a drying time of 60 minutes, which was 86.4404%. This is due to the large hot air coming from the conversion of electricity to the air heated by the heater. This is by the statement of Joko et al, (2009) showing that the large hot air that affects the amount of
thermal efficiency because in the presence of energy from enough hot air can evaporate the water that is in the material.

The lowest thermal efficiency is at 360 minutes drying time of 61.9886% because if the longer the drying process to dry the raw material, the heat energy used will be higher and cause efficiency is not so great [13]. This is caused by the use of heat energy supplied to cut the water content in the hydrogel, which is supplied from the heat energy of the heater (heater) which is arranged inside the drying chamber, which has a power of 300 watts.

Based on the drying time, the ideal thermal efficiency in the drying process of this material is estimated at 180 minutes with a temperature of 800℃, which is equal to 84.9939%. The factors that influence the speed of drying include temperature and length of drying time, the moisture content of the material or product to be dried, the amount of material included in the dryer, the temperature of the drying air at the beginning and end of the process [14].

4. Conclusion
Based on the data analysis of the results of testing that has been done it can be concluded that:
1. The process of drying silica gel using a tray dryer using hot air as a drying medium, obtained silica gel made from sugarcane bagasse with the results of FTIR and XRD analysis in the form of amorphous silica gel and has a functional group in the form of Si and OH, according to JIS-0701 standard.
2. The most conditions are achieved at 360 minutes drying time, drying rate 0.01941 kg/hour m², moisture content 0.814%, conduction heat transfer rate 0.327 kJ, convection heat transfer rate 0.082 kJ, and thermal efficiency 86.4%.

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