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Comparative Performance of Several Fixed Bed Dryer Arrangement for Seaweed Product Drying

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Abstract

Eucheuma cottonii is a type of seaweed that is widely available on the coast of Indonesia. Seaweed is processed into carrageenan types of Alkali Treated Cottonii to improve quality and sell higher. Carrageenan types Alkali Treated Cottonii contain water very much, so to obtain a high quality of Alkali Treated Cottonii, it would require the drying process by using the right tools, namely fixed bed dryer. The drying process uses such methods to obtain high energy efficiency tools with high quality carrageenan. This study aimed to compare the energy efficiency from a method of single fixed bed dryer, closed loop fixed bed dryer, and a series of fixed bed dryer. These results indicate that the method of series fixed bed dryer is the most effective method for drying carrageenan types ATC with the energy efficiency of 62.1653%; the rate of energy consumption amounted to 0.0100 kWh / min; the ability to evaporate the water of 26.6368 g / kWh.

Keywords: Drying, Alkali Treated Cottonii, Energy Efficiency, Single Fixed Bed Dryer, Closed Loop Fixed Bed Dryer, Series Fixed Bed Dryer.

1 Introduction

Seaweed in scientific language known as algae. Based on pigment contained, Eucheuma cottonii seaweed is a group Rhndopyceae (red algae) were capable of producing carrageenan was widely used in various industries. One of the popular seaweeds, Eucheuma cottonii, contains carrageenan for starch or fiber sources that can be applied for beverages or gelatin[3]. Carrageenan is used to thickeners, stabilizers, and gelling. Carrageenan is also used in the food industry to improve the appearance of the products, such as ice cream and jelly. The pharmaceutical industry uses carrageenan for the manufacture of drugs, syrups, tablets, toothpaste, shampoo, and so forth.

Carrageenan industry that was growing in Indonesia today is semi-finished carrageenan. One of them is the ATC (Alkali Treated Cottonii). ATC industry has had a complex equipment, especially in the drying process. Drying is arguably one of the most popular methods for preserving fruits, vegetables and other foods[1]. ATC drying process is commonly done today is sun drying and the disadvatages of sun drying is dependent on natural weather[4,5,6]. Because of this, the ATC has a water content of about 90% need to be dried with other drying methods[3]. Adsorption dryer with zeolite can be an option for seaweed drying. In this case, the air as drying medium was contacted with zeolite to remove the water content. With low relative humidity, the driving force for drying can be enhanced[3,4,7,9]. And the effects of air temperature and humidity on the drying time of seaweed have been done[8]. Thus, one of the main methods that can be used appropriately in drying is by appliance a fixed bed dryer[2]. This method was chosen because of the nature of the hydrogel ATC. Additionally, fixed bed dryer operated in single, series, and closed-loop. Therefore, Objective of this study was to compare the energy efficiency between single fixed bed dryer, closed loop fixed bed dryer, and series fixed bed dryer.

2 Methods

Fixed bed dryer in this study was equipped with a column as a place to put the ATC was channeled hot air as drying air. Fixed bed dryer using hot air as the media dryers and the material to be dried was contacted directly. The drying process in this study has the following variables:

1. Material used was carrageenan types of ATC (Alkali Treated Cottonii) of seaweed eucheuma cottonii.
2. ATC (Alkali Treated Cottonii) used by 80% of the height of the drying column.
3. Drying air flow rate was 498.0051 ml / s
4. The drying air temperature was 60ºC.
5. The method used is single fixed bed dryer, double fixed bed dryer, and a closed loop fixed bed dryer.

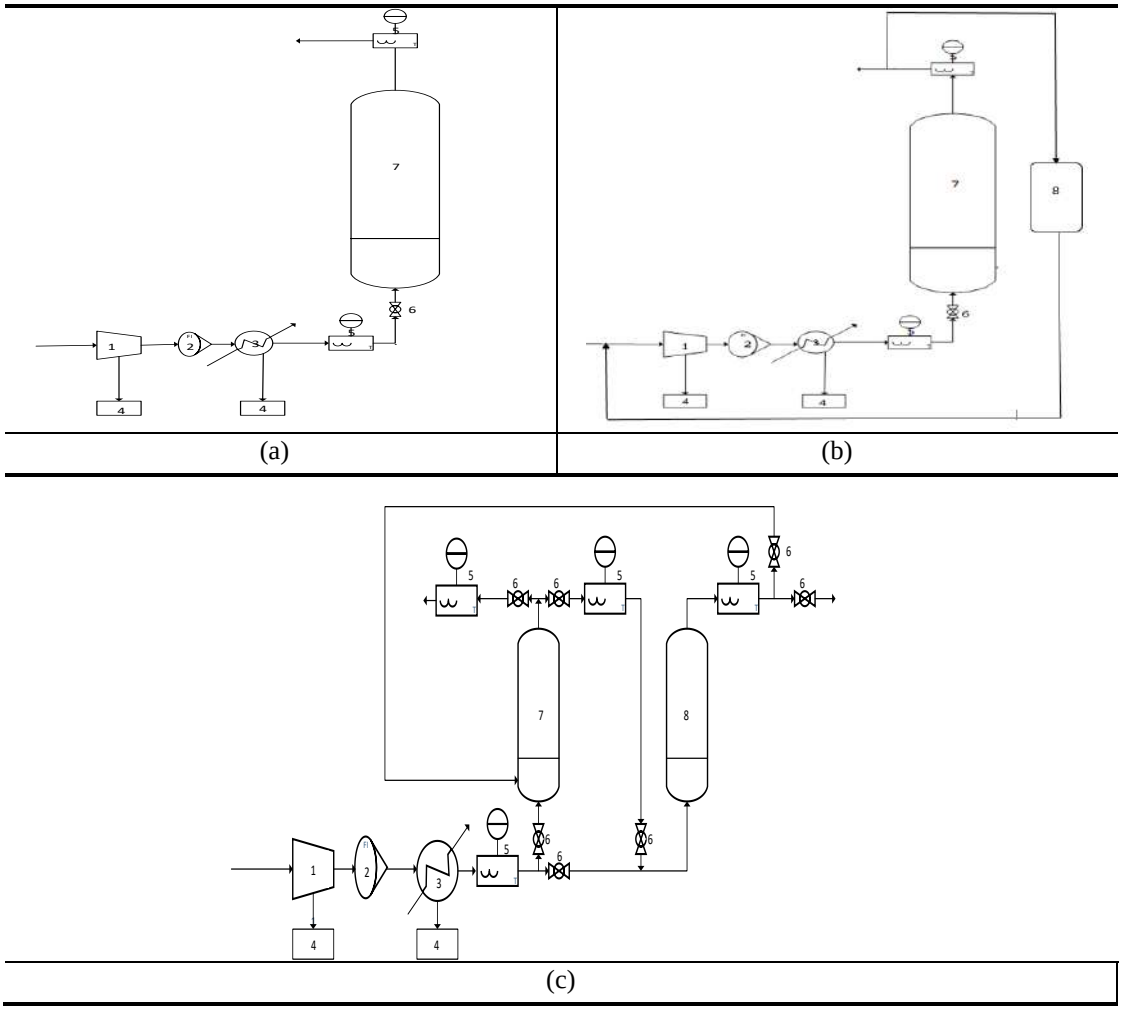

Fig. 1: (a) Schematic tool single fixed bed dryer (b) Schematic tool closed loop fixed bed dryer (c) Schematic tool series fixed bed dryer

There were little difference between a single method, closed loop, and series. The difference between a single and a closed loop that was the method of closed loop air was circulated back into the process after passing through the dehumidifier, while the single method, the air is thrown away. In the series method, the air coming out of the first column is used to dry the ATC in the second column.

3 Result and discussion

3.1 Effect of Drying Method to Decrease Relative Humidity Every Time

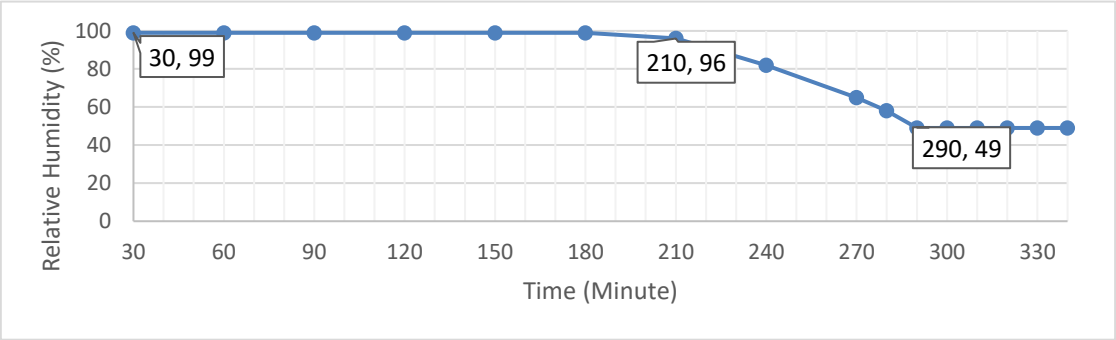

Fig. 2: Relative humidity against time on a single fixed bed dryer

In the Single fixed bed dryer, drying air relative humidity output at the start of the drying was 99% and no change to 180 minutes, because there were many water in ATC can be evaporated by the drying air. Then in 210 minutes, drying air relative humidity output fell to 96%, because the water contained in the surface of the ATC began few in number and difficult to be evaporated by the drying air, so that the water content in the drying air was getting low. Relative humidity of the drying air output continued to fall to 49% in 340 minutes of the drying process. In this method, the air coming out of the drying column still contains fairly low relative humidity and should not be just thrown away and can be used for further drying. Then, we conducted method of series fixed bed dyer.

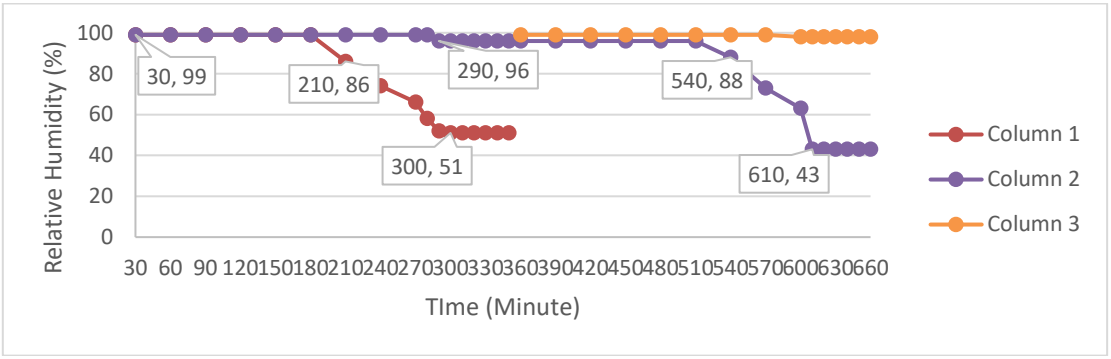

Fig. 3: Relative humidity against time on a series fixed bed dryer

In the method of series fixed bed dryer, drying air was passed in series from the first column to the second column. At the beginning of the process of drying, drying air relative humidity outputs of the first column and the second column was 99%. The process of drying at 30 minutes, only occurs on the first column, whereas, in the second column does not happen the drying process. This was because the relative humidity of the drying air at the output of the first column was worth 99% as a result of the amount of water evaporated from the ATC in the first column, so the ability of the air dryer to evaporate the water from the ATC in the second column was very small. In 210 minutes of drying, drying air relative humidity outputs of first column fell to 86% and the second column remains 99%. That was because water on the surface of the ATC in the first column were few in number and difficult to evaporate, so the drying process started in the second column, because the air drying has the ability to evaporate water from the ATC in the second column, although only slightly. Relative humidity of the drying air in the first column output continued to fall to 51% and was completed in 350 minutes of drying time, while in the second column of the drying air relative humidity at 96% output.

After the drying process in the first column was completed, the drying process was continued with the drying air was passed in series from the second column to the third column. The third column was the first column to be reused after the drying process was complete and filled back with wet ATC. In 360 minutes of drying, drying air relative humidity outputs in the second column was 96% and in the third column was 99%. In these circumstances, the drying process occurs in the second column and the third column, due to the drying air relative humidity outputs second column still has the ability to evaporate water from the surface in the third column. At 540 minutes

of drying time, drying air relative humidity outputs second column dropped to 88% and the third column was 99%. The relative humidity of drying air decreases the output of the second column caused by the water content in the surface of the second column ATC decreased, so the drying air has more ability to evaporate the water surface ATC in the second column. The drying process in the second column was completed in 660 minutes drying time with a relative humidity of the drying air output was 43% and the third column has a relative humidity of 98% with a drying time for 330 minutes.

Seen from Figure 6 that the relative humidity of the drying air discharged after the process contains saturated humidity of around 96-99%. It states that the drying air has been fully utilized, because the air was removed from the process contains saturated moisture and ineffective if used again to dry the ATC.

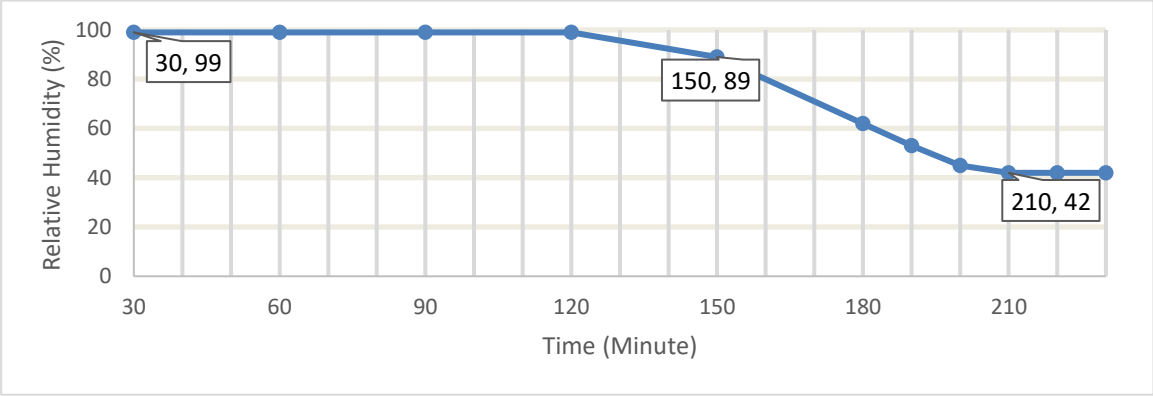

FIG. Fig. 4: Relative humidity against time in closed loop fixed bed dryer

In the picture above, the drying air relative humidity outputs closed loop method of fixed bed dryer was 99% and fell to 96% at 190 minutes. The decline in output drying air relative humidity occur because of water on the surface ATC vaporized into the air dryer becomes less and difficult to evaporate the water bound in the ATC. Relative humidity of the drying air output continued to fall to 49% at 230 minutes drying time at temperatures of 38°C. Method closed loop fixed bed dryer is done with the aim to be able to utilize the energy wasted in the method of single fixed bed dryer ww shown with the temperature, because the drying air is disposed on the method of single fixed bed dryer having a temperature higher than room temperature, so that in the method this, the air output of the drying column inserted back into the process after the dehumidification process. It aims to reduce the heating load carried by the heater.

3.2 Effect of Drying Method to Total Water Evaporated

ATC Drying process carried out at a temperature of 60°C with several methods such as single fixed bed dryer, closed loop fixed bed dryer, and a series of fixed bed dryer. The drying process occurs as a result of mass transfer between the drying air with the water in the ATC. Good mass transfer can be shown by the evaporation of water most of the ATC in a short time.

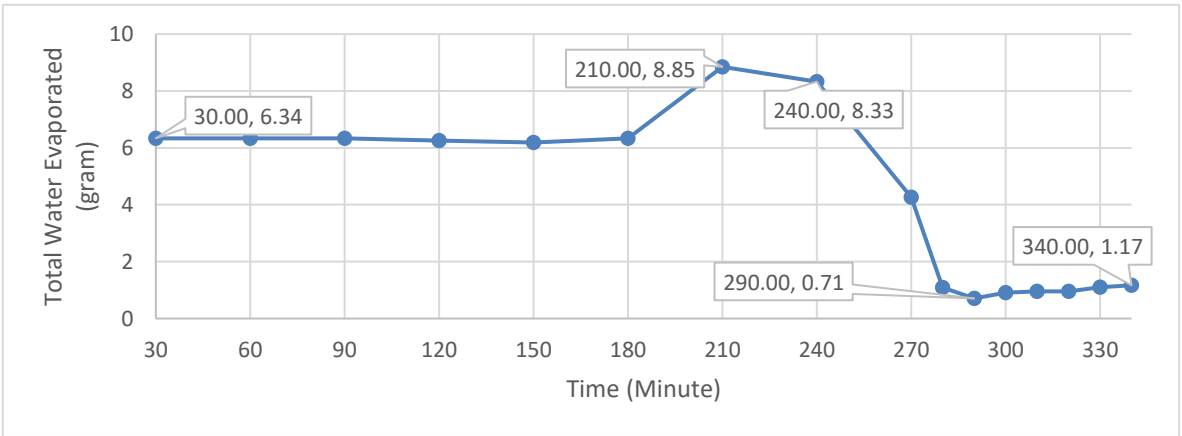

Fig. 5: Water evaporation curve against time in method single fixed bed dryer

In the Single fixed bed dryer, water evaporated within the 30 minutes of the drying process of 6.4 grams and increased to 8.85 grams in 210 minutes due to amount of water moving to the drying air, because of free water on the surface of ATC easy to evaporated by the drying air. Then in 240 minutes, the amount of water evaporated declining due to the amount of water on the surface of the ATC was in decline, it was because of free water on the surface of the ATC have been exhausted and the remaining were bound water contained in ATC and difficult to be evaporated. In the Single fixed bed dryer obtained total evaporated water was 66.1351 grams with drying time was 340 minutes.

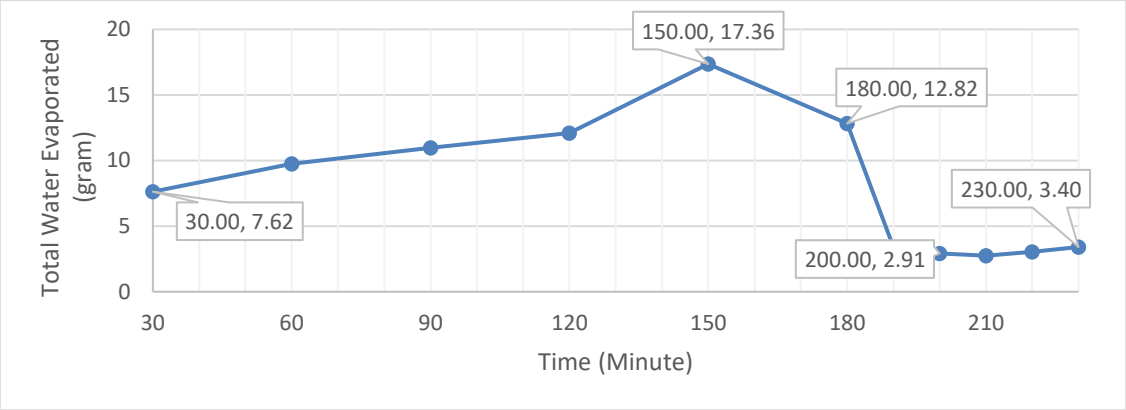

Fig. 6: Water evaporation curve against time in method closed loop fixed bed dryer

In the picture above, it can be seen that using the closed loop fixed bed dryer, water obtained evaporated in 30 minutes drying process that was 7.62 grams and increased to 17.36 grams in 150 minutes. That was because the amount of free water on the surface of ATC easy to be evaporated by the drying air. Then the water is evaporated at 180 minutes to be reduced, due to free water on the surface of the ATC have been exhausted and the remaining are bound water contained in ATC and difficult to be evaporated. In the closed loop method, the total water evaporated totaling 86.0788 grams with drying time for 230 minutes.

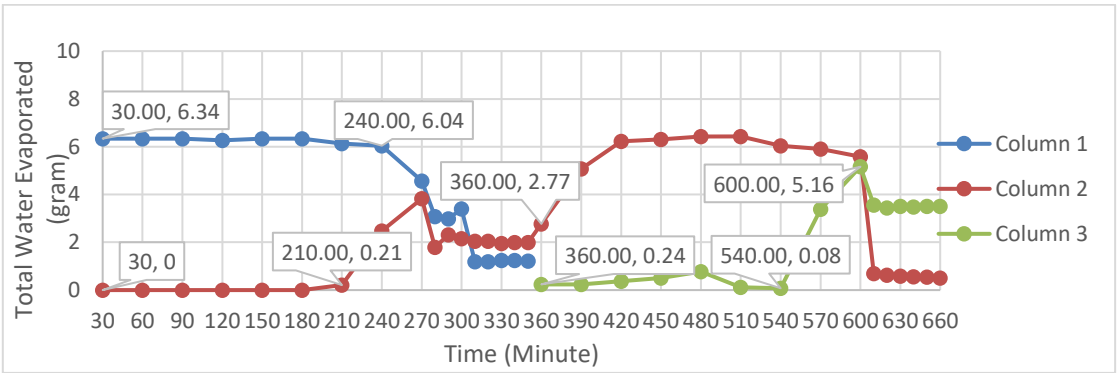

Fig. 7: Water evaporation curve against time in method series fixed bed dryer

For the method of series fixed bed dryer, hot air that flowed in series from the first column to the second column with water that evaporated during the 30 minutes of the drying process in the first column was 6.34 grams and the second column was 0 grams. The drying process does not occur in the second column because the rate of air out of the first column was very low and the moisture content is high, so there was no water in the ATC that move to the drying air. In 210 minutes of drying, the water is evaporated by the first column is reduced to 6 grams, while in the second column of the drying process occurs which is characterized by the evaporation of water as much as 0.2 grams. The cause of the decline of water evaporated in the first column was the water content of ATC the less that can be evaporated because of free water on the surface of the ATC is reduced and the drying process in the second column occurs because the humidity out of the first column is reduced and has the ability to evaporate the water from the ATC in the second column . The drying process in the first column can evaporate the water as much as 63.8951 grams total time of 350 minutes.

After drying in the first column is completed, then the drying process is continued in series in the second column and the third column. At 360 minutes the second column of the drying process, water is evaporated as much as 2.77 grams and the third column of water obtained evaporated as much as 0.24 grams. In the third column of water directly evaporated during the drying process 10 minutes caused by the humidity of air coming out of the second column has been able to evaporate the water in the ATC of the third column, because after the first column was dried, the state of the second column was already half dried and had a low humidity , so that the dry air coming out of the second column had been able to evaporate water from the third column. In 570 minutes of drying, evaporation of water began to decline in the second column as much as 7.42 grams, so that water evaporated from ATC in the third column increased to 3.39 grams. The decrease of water evaporated in the second column because of free water on the surface of the ATC are few in number so that the drying air coming into the third column can evaporate water more than ATC in the third column. By using a series of fixed bed dryer, total evaporative water in the second column was 80.8329 grams for 660 minutes and the total water that can be evaporated from the ATC in the third column was 31.8739 grams by drying for 310 minutes.

TABLE 1: Total evaporation of water and the time needed for each method

Method	T (ºC)	Air Rate (ml/s)	Total Water Evaporated (g/minute)
Single	60	498.0051	0.1945
Closed Loop	60	498.0051	0.3743
	60	498.0051	
Series			0.2676

From the above table, it can be seen that the drying process by using closed loop ATC fixed bed dryer was better than the two other methods that caused the dehumidification process. That was because the air dryer is used in this study was quite humid so require dehumidification process on the drying air, so the inlet air humidity lower and the ability of air to evaporate the water content in the ATC are getting bigger and the faster the drying process is completed. This is evidenced by the total water that evaporated on a closed loop method of fixed bed dryer as much as 0.3743 gram per 1 minute.

3.3 Effect of Drying Method Against Energy Used

The drying process in this research influenced by the needs of the energy used to evaporate water from the ATC. The good drying process can be shown by the evaporation of more water using very little energy.

TABLE 2: Total water evaporated and energy used each method

Method	Total Water Evaporated (g)	Energy Used (kWh)
Closed loop	86.0788	2.35
Single	66.1351	3.31
Series	176.6020	6.63

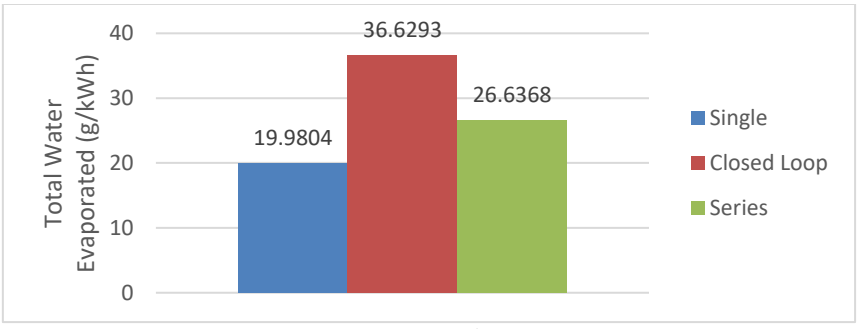

Fig. 8: Graph water evaporation of energy in every method

From the graph above, the drying process which is well demonstrated by the method of closed loop fixed bed dryer, because it was able to evaporate the water more than any other method. This was because the closed loop fixed bed dryer air humidity is lower due to the drying air dehumidification process. Low humidity causes water content in ATC more and faster vaporized. So that the energy used to complete the drying process becomes less

than the two other methods.

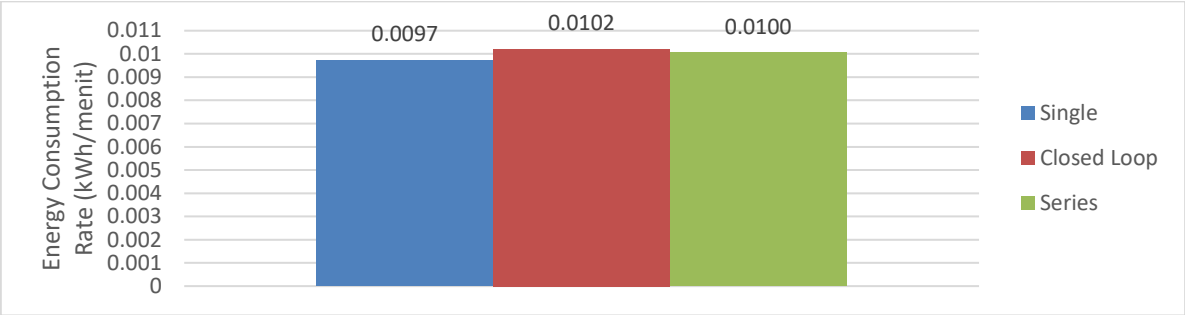

Fig 9: Rate of energy consumption every drying method

Of the three methods, method of closed-loop fixed bed dryer was a method that generate the rate of energy consumption was greater than in the two other methods, because the method of closed loop fixed bed dryer was able to evaporate the water more, in the amount of 34.2286 g / kWh compared with the other method more thus requiring greater energy and also there was just a little difference between the three methods.

3.4 Effect of Drying Method Against Water Content Products

TABLE 3: The water content of the product of each method

Method	Product Water Content (%)
Single	10.1328
Closed loop	7.6987
Series	9.4634

The drying process in this research accomplished with three methods of closed loop fixed bed dryer, single fixed bed dryer, and a series of fixed bed dryer. Products with different water content produced by each method. The good drying process can be shown by the evaporation of more water, which is indicated by the results of a product with a low water content.

From the above table, it can be seen that the products with water content of 10.1328% produced by by the method of single fixed bed dryer, a product with a water content of 7.6987% produced by by the method of closed-loop fixed bed dryer, and a product with a water content of 9.4634% produced by methods series fixed bed dryer. Of the three methods, method of closed-loop fixed bed dryer was a method, which produce products with low water content. That was because the air dryer is used in this study was quite humid, so the process of dehumidification on this method caused the moisture of drying air was getting lower and resulted in the ability of the air dryer to evaporate the water content in the ATC was getting bigger, therefore, products with low water content is equal 7.6987% generated.

3.5 Energy Efficiency of Each Method

At the end of the drying process, the analysis of the efficiency of the drying process is done. The results of the analysis of energy efficiency for the drying of carrageenan are presented in Table 4.

TABLE 4: The energy efficiency of each method

Methods	Number of evaporate water (g)	Energy use (kWH)	Efficiency (%)
Single	66.1350	3.31	18.8691
Closed Loop	80.4371	2.35	26.2101
Series	188.6166	6.63	62.1653

Table 4 shows that the greatest energy efficiency contained in fixed bed dryer series method that was equal to 62.1653%. Although the method of series of fixed bed dryer uses more energy than other methods, but the energy was also vaporize more water. That was because the method of series of fixed bed dryer contained energy utilization, which was the hot air coming out of the first column was used to dry the next column so that the heat energy from the air can be fully utilized and wasted energy was relatively less than in the two other methods.

4 Conclusion

Based on the results of this study, can be concluded that: The energy efficiency of the method of single fixed bed dryer at 18.8691%; the rate of energy consumption amounted to 0.0097 kWh / min; the ability to evaporate the water of 19.9804 g / kWh, energy efficiency of the method of closed loop fixed bed dryer at 26.2101%; the rate of energy consumption amounted to 0.0102 kWh / min; the ability to evaporate the water of 36.6293 g / kWh, and energy efficiency was found in the most excellent method of series fixed bed dryer with energy efficiency of 62.1653%; the rate of energy consumption amounted to 0.0100 kWh / min; the ability to evaporate the water of 26.6368 g / kWh

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