Rattanakosin Journal of Science and Technology: RJST
2025, Volume 7 Issue 3: 259-270
Research Article
Online ISSN: 2673-0553

Hot Air Drying Machine Set with Raspberry Pi

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Abstract

This research is the development of hot air herbal dryer model from the experiment using 3 types of hot air herbal dryers: (i). Factory hot air dryer (ii). Improved hot air dryer and (iii). Reverse hot air dryer. The two herbs, turmeric and lemongrass, were dried to 350 grams, divided into 4 layers, 87.5 grams each, at a drying temperature of 70 degrees Celsius, and for 540 minutes. In the weight test after drying herbs, it was found that the hot air herbal dryer model 3 could dry all layers of herbs thoroughly because the weight measurement of herbs in each layer was the closest. Lemongrass weighed a total of 49 grams and turmeric weighed 55 grams, which were less than the hot air herbal dryer models 1 and 2. The drying of herbs to measure the final moisture after drying took 9 hours, while the herbal dryer model 3 took 7 hours, which was less than the models 1 and 2, which had a difference of 2 hours. After drying, And the moisture content of the herbs that were baked, Type 1 and Type 2, were different from Type 3 in both samples. Turmeric had a moisture content of 16.14% when comparing Type 1 and Type 2 to Type 3, and lemongrass had a moisture content of 13.9% when comparing the same. In conclusion, Type 1 and Type 2, when compared to Type 3, had a baking time difference of 2 hours, and the moisture content when comparing lemongrass, where Type 3 was able to repel moisture better than Type 1 and Type 2.

Keywords: Herbs, Hot air dryer, Raspberry Pi, Relative humidity

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Received 18 12 2024 Revised: 13 02 2025 Accepted: 25 03 2025

1. Introduction

Nowadays, most Thais are starting to pay more attention to herbal plants because they are useful and can be used to prepare medicines to resist diseases. Therefore, herbs have been transformed into health products in the form of drying by sun drying. Most of the products are dried in the sun or driedin various ways, such as drying in the open air using the natural convection of solar energy. Thailand is a country with a hot and humid climate, resulting in many seasons and a long rainy season, with continuous rain for many months. Therefore, there is insufficient sunlight for drying and the product moisture cannot be reduced according to the specified period. Drying takes a longer period of time, resulting in moisture in the product and mold, causing it to rot or deteriorate. Due to chemical reactions, enzymes and microorganisms cause rancid smells and dust contamination, making the product insufficiently clean, affecting the quality of the product, which is not up to standard and inconsistent from the original drying oven. The problem encountered is that the bottom layer always dries before the top layer and cannot stop working when the herbs have the desired moisture, resulting in a waste of energy.

Currently, there is research on herbal drying, so there are many types of herbal drying machines, such as herbal drying machines using heat from heaters or hot air, herbal drying machines using sunlight or solar energy, herbal drying machines using infrared rays, and herbal drying machines using vacuum systems, etc. Most manufacturers use herbal drying machines using heat from heaters or hot air to dry herbs because they can dry herbs more efficiently than drying herbs with sunlight. Drying herbs with sunlight takes a long time and may not dry the herbs as desired.

Therefore, a hot air dryer control system was invented that is controlled by a temperature and relative humidity sensor inside the herb drying room to check the humidity changes. It can read the temperature and relative humidity values and send them to the Raspberry Pi board to process them, ordering the relay to work and cutting off the power when the specified humidity is reached.

2. Research Methods

2.1 Design and development of hot air dryer using rotating tray type hot air

The rotary tray hot air dryer is developed for commercial dry food production. The design objective is to test the whole stainless steel body to place the product into the dryer and to comply with the (GMP) standard. It works by heating with an electric system. The temperature is controlled by a digital control system with a heat circulation system and releasing moisture, causing heat transfer to the raw material to be dried. It evaporates the water from the raw material and flows out. The experimental results show that it can dry the product to the standard. Rotating tray hot air drying is more efficient than the general tray hot air dryer, which currently has 3 acceptable drying formats:

2.1.1 Passive system is a system in which the dryer works using solar energy and the wind flowing through it. For example: 1. Natural dryer: The material is placed outdoors and uses the heat from the sun and the wind in the atmosphere to evaporate moisture from the material. 2. Direct solar dryer: The material is dried in a dryer consisting of transparent materials. The heat used for drying is obtained by absorbing solar energy and using the principle of self-expansion. The hot air inside the dryer causes air circulation to help remove the moist air. 3. Hybrid solar dryer: The material inside receives heat in two ways: directly from the sun and indirectly from the solar collector panel, causing the hot air to flow through the dried material.

2.1.2 Active drying is a drying system that has a device that helps air flow in the desired direction. For example, there will be a fan installed in the system to force the flow of air through the system. The fan will suck air from outside to flow through the solar panel to receive heat from the solar panel. The hot air flowing through the fan and the drying room will have a lower relative

humidity than the humidity of the crop. Therefore, it carries moisture from the crop to the outside, causing the dried crop to be dry.

2.1.3 Hybrid drying is a drying system that uses solar energy and also requires other forms of energy to help when the sunlight is not consistent or when agricultural produce needs to dry faster. For example: It is used in combination with biomass fuel, electric power. The dried material is heated by hot air passing through the solar panel and the air circulation is assisted by a fan or exhaust fan [1].

2.2 Drying rate

During constant drying rate, heat and mass transfer occurs only at the surface of the raw material. A large amount of water vapor is attached to the surface of the raw material. The heat flow through makes the air denser, which reduces heat and mass flow. The temperature of the drying air increases, which reduces the temperature difference between the raw material and the air, allowing it to flow freely, making heat transfer more efficient. However, the humidity of the drying air decreases, which increases heat transfer [2].

2.3 Water activity

Water activity (aW) is the most important parameter of water in terms of food safety. Water activity is the ratio of the water vapor pressure of the food to the vapor pressure of pure water. Under standard conditions, water activity ranges from 0-1.0 of pure water. However, most foods have a water activity in the range of 0.2. For dry foods, the value is 0.99. For moist foods, water activity is usually measured in terms of Equilibrium Relative Humidity (ERH).

2.3.1 Spoilage Water Activity: Water activity is most useful in predicting the growth of bacteria, yeast and mold. In order to have a long shelf life without refrigeration, it is necessary to control the Potential of Hydrogen (pH) or the appropriate water activity level and combination. These two methods can effectively improve the stability of the product and allow predicting the shelf life under safe storage conditions. It can reduce the water activity to the point where pathogens cannot grow. Reduce the water activity to below 0.6, osmophilia yeast cannot grow. Reduce the water activity to 0.93 or below, food-harming bacteria cannot grow. The risk of food poisoning is low acid (pH) more than 4.5, etc. It can be found from equation (1) [3].

$$aW = \frac{p}{p_o} \tag{1}$$

where aW is water activity.

p_o is the vapor pressure of pure water at the same temperature.

p is the vapor pressure of food.

2.4 Relative Humidity

Relative Humidity is a more precise measure of the amount of water vapor in the air. The amount of water vapor in the air is expressed as a percentage (%RH), which is related to the temperature. For example, at 30 degrees Celsius, the volume of air contains up to 4 percent water vapor, while at a temperature of minus 40 degrees Celsius. Air can hold no more than 0.2 percent of water vapor, and relative humidity varies with the temperature of the air, while at a lower temperature, there will be less vapor. Therefore, changing the temperature of the air can change the percentage of relative humidity (%RH). Although the amount of water vapor in the air is constant, it can be found from equation (2)

$$Ms = \frac{M_x}{M_z} x100 \quad (2)$$

Where Ms is relative humidity.
M_x is the amount of water vapor in the air.
M_z is the amount of water vapor that makes the air saturated.

2.5 Moisture value in the material

Moisture value in the material means the moisture content that indicates the amount of water vapor present in the material compared to the mass of the moist or dry material. There are two types of moisture content in materials: Dry standard is the ratio of weight to dry weight of the material. Wet standard moisture is the ratio of weight of water to total weight of the material as shown in equations (3) – (4)

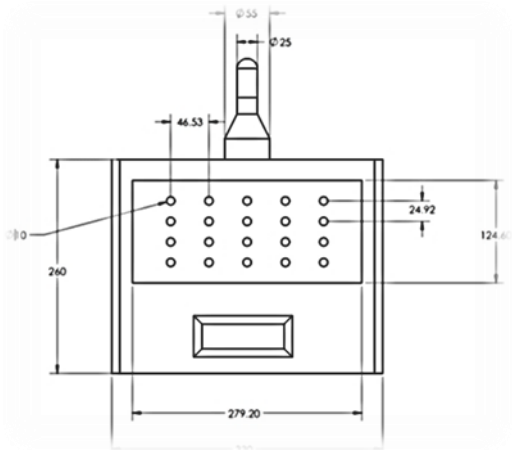
$$m_d = \left(\frac{w-d}{d} \right) \quad (3)$$

$$M_w = \left(\frac{w-m_d}{w} \right) \quad (4)$$

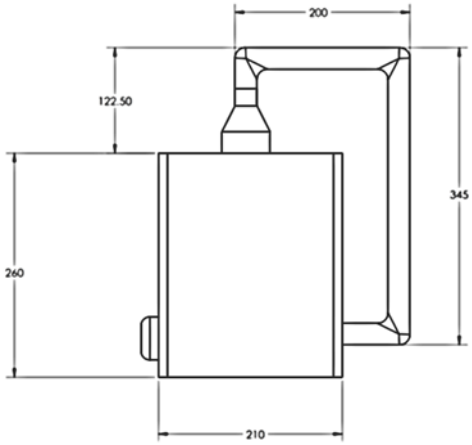
where M_w is the standard wet humidity. (%)
m_d is the standard dry humidity. (%)
w is the mass of material. (kg)
d is the dry mass of the material. (kg)

3. Methodology

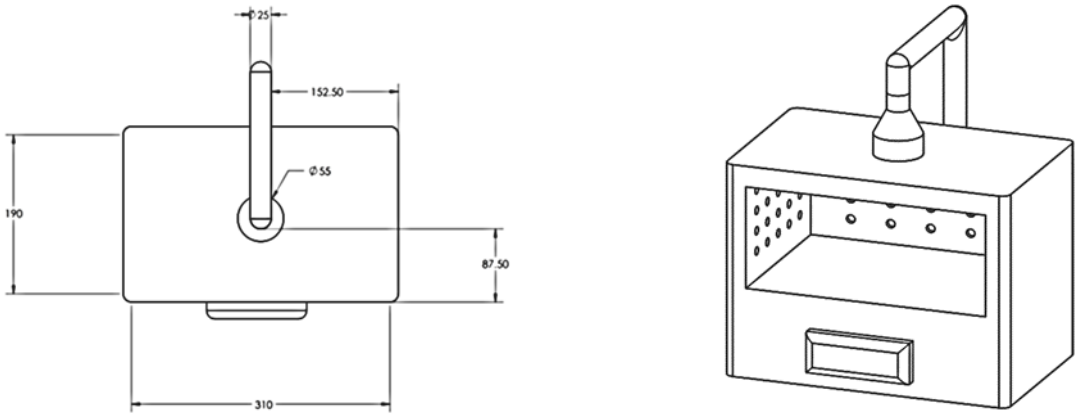
3.1 Structural design of reverse hot air dryer



(a)



(b)



(c) (d)

Figure 1 Design of the structure of the reverse hot air dryer
(a) front view (b) side view (c) top view (d) 3D.

From Figure 1 is the design of the structure of the hot air reverse drying machine. It consists of (a) the front of the hot air reverse drying machine, (b) the side of the hot air reverse drying machine, (c) the top of the dryer, and (d) the three-dimensional shape of the hot air reverse drying machine.

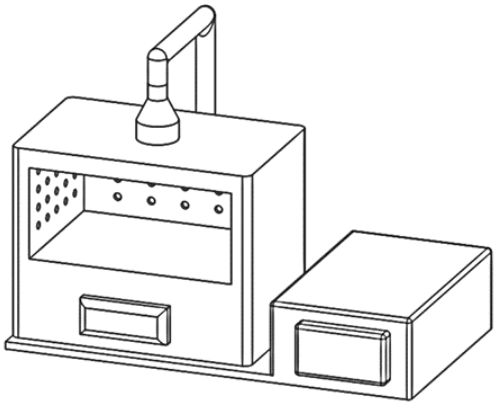


Figure 2 Design of the structure of the complete reverse hot air dryer.

From Figure 2, the design of the complete hot air dryer structure uses a 3D program to design (SolidWorks). The material selection is 1 x 1-inch square steel. It is a drying room structure and has a galvanized sheet as a wall. The door of the dryer uses a clear acrylic sheet. The newly designed drying room is 33 x 21 x 26 cm. There are 4 stainless steel herb shelves. The size of the drying tray is 25.5 x 20.5 cm. Each layer is 2.5 cm apart. There is a return air pipe on top of the dryer. The material is a PVC pipe in the shape of a cone. The air outlet hole at the top of the dryer is 5.5 cm. in radius and the air inlet hole at the bottom of the dryer is 2.5 cm. in radius. Inside the dryer, 4 layers of 6 mm. diameter holes are drilled to allow hot air to blow evenly on every layer. Each layer has 5 holes drilled on the side, each side is about 1 cm apart, and the drying room is tested.

Figure 3 Developed reverse hot air drying machine.

From Figure 3, the developed hot air dryer can set the temperature from 40 to 70 degrees Celsius. There are 4 levels in total. The time can be set up to 24 hours. The developed hot air dryer can display the temperature inside the drying room and the relative humidity on the screen. There is a hot air pipe installed on the machine to the base of the hot air dryer to reuse the hot air that is released. It makes the drying room take longer and the temperature rise faster than the original.

3.2 Sequence of steps in drying herbs

3.2.1 In the test, 1. 350 grams of turmeric were cut lengthwise to a thickness of about 2-3 millimeters. 2. Lemongrass was used only from the base of the strong stem and the leaves at the tip of the stem were cut off. The size used was about 20 cm, cut into lengthwise sections and split the stem in half about 1-2 inches.

3.2.2 The turmeric and lemongrass were weighed to get the correct amount before being put into the herb dryer. It was divided into 4 layers, each layer 87.5 grams, because the developed machine has a limited amount of space for herbs.

3.2.3 The turmeric and lemongrass that have been cut and weighed are then placed on each layer and then put into the dryer.

4. Results and Discussion

4.1 Hot air drying test of turmeric herb

In the test of turmeric herb, the weight was 350 grams and cut lengthwise with a thickness of 2-3 mm. The amount of drying was 350 grams, divided into 87.5 grams each at a temperature of 70 degrees Celsius. The results of the test for the moisture content of the herb are as follows:

Table 1 Turmeric herbal steaming

No.	Quantity (grams)	Original			Develop			Reverse hot air		
		Time (hr.)	Weight (grams)	Residual humidity (%)	Time (hr.)	Weight (grams)	Residual humidity (%)	Time (hr.)	Weight (grams)	Residual humidity (%)
1	350	9	73	21	9	67	12	9	58	7.2
2	350	9	74	19.4	9	65	11.54	9	55	6.8

(a) (b) (c)

Figure 4 Turmeric herbal steaming (a) original (b) develop (c) reverse hot air

From Table 1, it is the drying of turmeric herbs by comparing 3 types of hot air dryers: (a) original hot air dryer, (b) developed dryer and (c) reverse hot air dryer. The original dryer has 78.95 percent moisture after drying according to the dry standard. The developed dryer has 88 percent moisture after drying according to the dry standard. The reverse hot air dryer has 93.2 percent moisture after drying according to the dry standard. In conclusion, Figure (c) is the image that the herbs and color of turmeric herbs have the least moisture after drying with the reverse hot air dryer at the same time and temperature.

4.2 Hot air drying test of lemongrass herb

In the turmeric herb test, the weight is 350 grams, cut into 2-3-inch-long pieces and cut in half along the length of the stem. The amount of drying was 350 grams, divided into 87.5 grams each at 70 degrees Celsius. The results of the herb moisture test are as follows:

Table 2 lemongrass herbal steaming

No.	Quantity (grams)	Original			Develop			Reverse hot air		
		Time (hr.)	Weight (grams)	Residual humidity (%)	Time (hr.)	Weight (grams)	Residual humidity (%)	Time (hr.)	Weight (grams)	Residual humidity (%)
1	350	9	89	25.4	9	70	9.8	9	50	7
2	350	9	90	25.7	9	70	11.3	9	49	6.8

(a) (b) (c)

Figure 5 lemongrass herbal steaming (a) original (b) develop (c) reverse hot air

From Table 2, it is the drying of lemongrass herbs by comparing 3 types of hot air dryers: (a) original hot air dryer, (b) developed dryer and (c) reverse hot air dryer. The original dryer has 74.44 percent moisture after drying according to the dry standard. The developed dryer has 90.2 percent moisture after drying according to the dry standard. The reverse hot air dryer has 93.2 percent

moisture after drying according to the dry standard. In conclusion, Figure (c) is the image that the herbs and color of lemongrass herbs have the least moisture after drying with the reverse hot air dryer at the same time and temperature.

4.3 Comparison of three types of humidity

4.3.1 Comparison of turmeric humidity

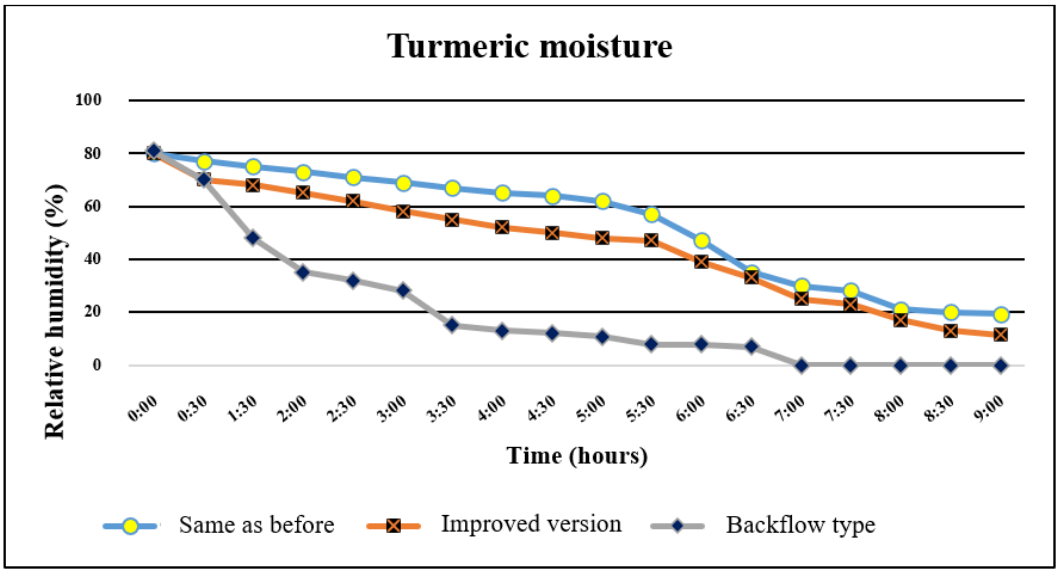


Figure 6 Graph of drying time and humidity of turmeric at 70°C.

In the hot air drying of 350 grams of turmeric herbs, it was divided into 4 layers, each layer 87.5 grams at a temperature of 70 degrees Celsius. There were 3 types of comparison: 1. The original hot air dryer 2. The develop hot air dryer 3. The reverse hot air dryer, which took 9 hours to dry the hot air and collect the test results. It is clear that the first and second types take 9 hours to dry, and the third type is a reverse hot air oven, which takes 7 hours to dry. It can be concluded that the reverse hot air drying method takes less time than the first and second types. It takes 2 hours to dry the herbs and the herbs have less residual moisture than the first and second types.

4.3.2 Comparison of lemongrass humidity

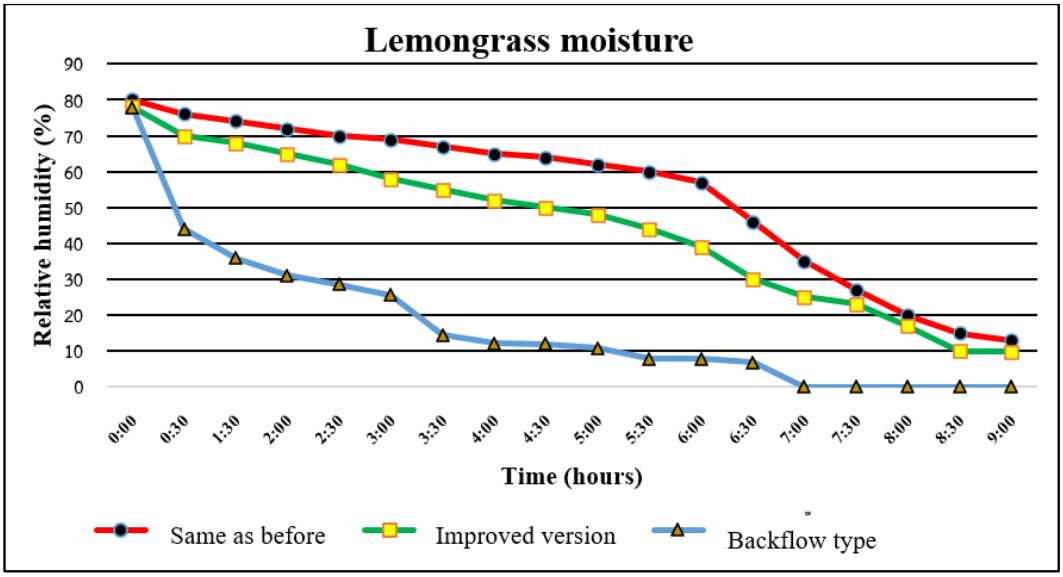


Figure 7 Graph of drying time and humidity of lemongrass at 70 °C.

In the hot air drying of 350 grams of lemongrass herbs, it was divided into 4 layers, each layer 87.5 grams at a temperature of 70 degrees Celsius. There were 3 types of comparison: 1. The original hot air dryer 2. The develop hot air dryer 3. The reverse hot air dryer, which took 9 hours to dry the hot air and collect the test results. It is clear that the first and second types take 9 hours to dry, and the third type is a reverse hot air oven, which takes 7 hours to dry. It can be concluded that the reverse hot air drying method takes less time than the first and second types. It takes 2 hours to dry the herbs and the herbs have less residual moisture than the first and second types.

4.4 Comparison of herb weights

For the weight comparison by using 2 types of hot air dryers to compare the weight of each layer of herbs: 1. Original hot air dryer 2. The developed dryer with reverse hot air. Using 2 types of herbs, lemongrass and turmeric, each sample amount is 350 grams, divided into 87.5 grams each layer, dried at 70 degrees Celsius. The drying test time is 540 minutes and each layer is weighed. It can be summarized as follows:

Table 3 Comparison of weight of herbs in each layer.

Herb drying rack	lemongrass		turmeric	
	Original (grams)	Reverse hot air (gram)	Original (grams)	Reverse hot air (gram)
1	20	12	17	13.7
2	21	12.7	18.8	13.8
3	24.3	12	19	13.9
4	24.7	12.3	19.2	13.6
Total	90	49	74	55

From Table 4.3 is a table of testing and comparing the weight of each layer of herbs. It can be seen that the original hot air dryer makes the drying of the two herbs on the lower layer drier than the upper layer.

4.5 Comparison of the weight of each layer of the dryer and the two types of herbs.

4.5.1 Comparison of weight of each layer of lemongrass herb

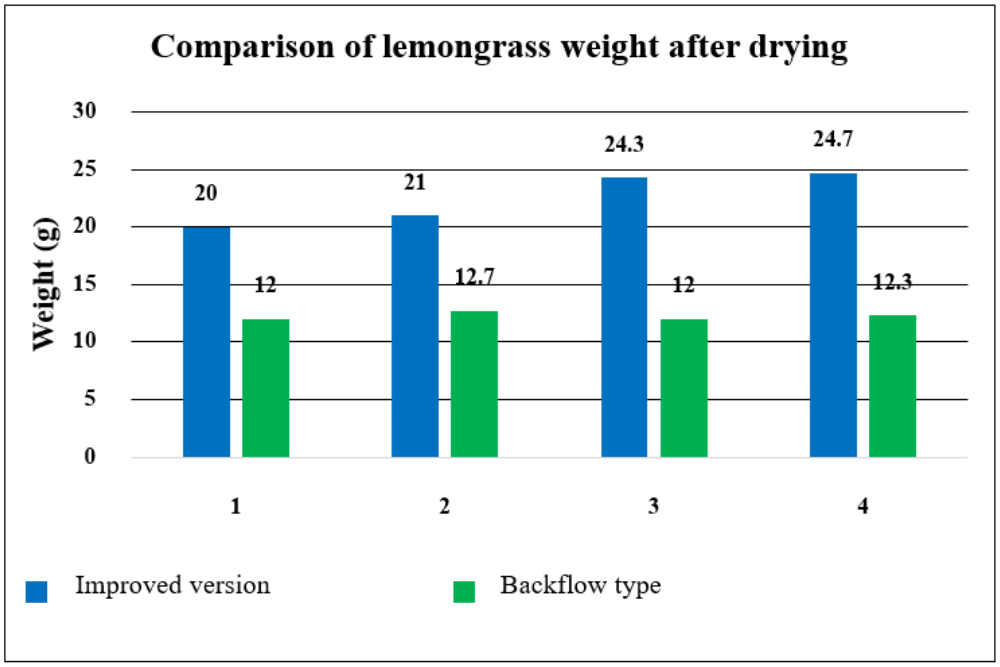


Figure 8 Graph comparing the weight of each layer of lemongrass.

From Figure 8 is a graph comparing the weight after drying each layer of lemongrass, quantity 350 grams, divided into 87.5 grams per layer, temperature 70 degrees Celsius, drying time 540 minutes. Using the original hot air dryer and the reverse hot air dryer.

1st floor, original hot air dryer, lemongrass weight remaining 20 grams, reverse hot air dryer weight remaining 12 grams.

2nd floor, original hot air dryer, lemongrass weight remaining 21 grams, reverse hot air dryer weight remaining 12.7 grams.

3rd floor, original hot air dryer, lemongrass weight remaining 24.3 grams, reverse hot air dryer weight remaining 12 grams.

4th floor, original hot air dryer, lemongrass weight remaining 24.7 grams, reverse hot air dryer weight remaining 12.3 grams.

It can be seen that the conventional hot air dryer has different weights in each layer. The reverse hot air dryer has similar weights in each layer.

4.5.2 Comparison of weight of each layer of turmeric herb

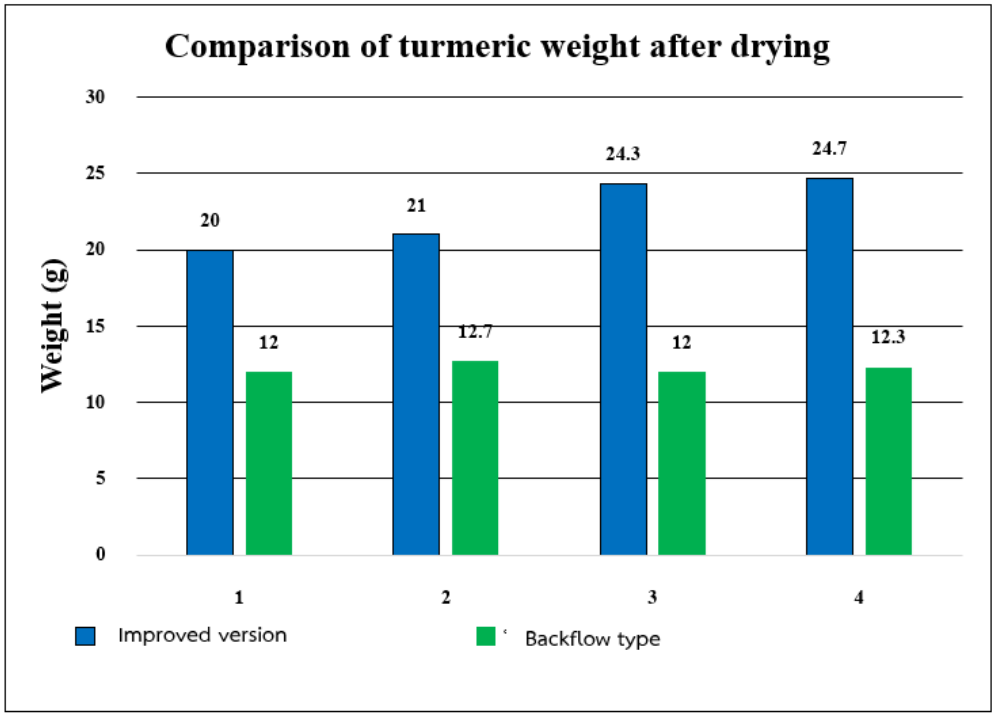


Figure 9 Graph comparing the weight of each layer of turmeric.

From Figure 9 is a graph comparing the weight after drying each layer of turmeric, quantity 350 grams, divided into 87.5 grams per layer, temperature 70 degrees Celsius, drying time 540 minutes. Using the original hot air dryer and the reverse hot air dryer.

1st floor, original hot air dryer, lemongrass weight remaining 17 grams, reverse hot air dryer weight remaining 13.7 grams.

2nd floor, original hot air dryer, lemongrass weight remaining 18.8 grams, reverse hot air dryer weight remaining 13.8 grams.

3rd floor, original hot air dryer, lemongrass weight remaining 19 grams, reverse hot air dryer weight remaining 13.9 grams.

4th floor, original hot air dryer, lemongrass weight remaining 19.2 grams, reverse hot air dryer weight remaining 13.6 grams.

It can be seen that the conventional hot air dryer has different weights in each layer. The reverse hot air dryer has similar weights in each layer.

5. Conclusion

From the experiment of drying lemongrass and turmeric with 3 types of hot air dryers: 1. The original dryer 2. The developed dryer 3. The developed dryer with reverse air. The original hot air dryer cannot measure humidity and has a problem that the machine will dissipate heat from the bottom to the top, causing the herbs on top to have a fairly high humidity, which makes the herbs dry unevenly. The developed type blows hot air from the side to heat all layers equally and uses a humidity monitoring system to help monitor the humidity. The conclusion is that drying herbs with the same drying time of 9 hours uses 350 grams of both herbs. It can be seen that the final humidity of the herbs of the developed machine will achieve the desired humidity within about 7 hours, saving up to 2 hours. It can dry the herbs to have less humidity than the original type, which is 73 percent more efficient in drying lemongrass than the original dryer and 65.4 percent more efficient in drying turmeric than the original dryer.

6. Acknowledgements

We would like to thank Bangkokthonburi University for supporting the research venue. We would also like to thank all lecturers from the Electrical Engineering Program, Faculty of Engineering, for their support in conducting this research.

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