# The forming biomass energy rod from the leaf sheath of sugarcane during drying process using microwave energy

*Pornthip* Keangin[1*], and *Aphisara* Charoenlerdchanya [1]

[1]Department of Mechanical Engineering, Faculty of Engineering, Mahidol University
25/25 Phutthamonthon 4 Road, Salaya, Nakhon Pathom 73170, Thailand

**Abstract.** The leaf sheath of sugarcane are agricultural residues. In the past, the agriculturists used to burn leaf sheath of sugarcane which caused pollution. This research aims to develop the management process of leaf sheath of sugarcane and to reduce the burning of sugarcane. In addition, to eliminate the leaf sheath of sugarcane to effectively utilize suitable for agriculture and agro-industry as well as to add value to the leaf sheath of sugarcane. This research has developed biomass energy rod from the leaf sheath of sugarcane using natural rubber as binder during drying process by microwave energy. The ingredients for forming biomass energy rod using the designed machine are sugarcane leaves of 19 %w/w, water of 57 %w/w, tapioca flour of 6 %w/w and natural latex of 19 %w/w. The biomass energy rod has diameter of 5 cm, length of 10 cm, and weighs between 150-153 g is required. The effects of heat source namely microwave drying, hot air drying and microwave-hot air drying is studied. The drying time, net heating value and residual moisture content of biomass energy rod are compared with each drying heat source. The results showed that in case study 2 using microwave energy (8 microwave sources are turned on, 250 W each) in the drying process has the lowest drying time, highest net heating value and has the lowest residual moisture content of biomass energy rod when compared to each drying heat source. The results of this research help to develop innovations in the forming and drying process of biomass energy rod using agricultural products such as leaf sheath of sugarcane.

## 1 Introduction

Currently, agricultural waste such as sugarcane leaf sheath, bagasse, corncob, corn husk, oil palm meal, oil palm bunches, rice straw, and rice husks significantly increase [1]. Moreover, the widespread cultivation of such plants caused the problem of oversupply of agricultural products and the income of farmers decreased, especially sugarcane which is the main economic crop of the country. It is a raw material for sugar production and renewable energy [2]. Thailand is the fifth-largest producer of sugar in the world and the second-largest exporter of sugar. It is also found that sugarcane plantations and sugarcane production in

* Corresponding author: pornthip.kea@mahidol.ac.th

Thailand have been continuously increasing since the production year 2008 to the present. However, farmers tend to burn sugarcane before harvest. Due to the problem of labour shortages to cut sugar cane, the higher cost of cane harvesting, and expensive cane harvester equipment. Burning sugarcane before harvesting makes it easier and faster to harvest sugarcane because there is no need to peel off the cane leaf sheath. This causes problems of small dust particles or PM2.5 and pollution to the environment. In addition, there was also a problem of decreasing rubber prices, which greatly affects the income of farmers. Therefore, there is a necessity for innovation and technology to help manage waste reduction from sugarcane products, especially sugarcane leaf sheaths, and find value-added ways of rubber to increase the value of sugarcane and rubber products. Also helps upgrade the processing of agricultural waste products, reduce pollution from the problem of severe particulate matter or PM2.5 situation, and at the same time improve energy management, by which products from such processing can be produced into biomass energy rods that can be used benefit.

Biomass energy rod is an organic substance that is a natural energy storage facility and can be used to produce energy. These organic substances are obtained from plants and animals such as wood chips, waste, and agricultural waste [3]. The use of biomass for energy may be done by burning it to use as the heat source [4]. Therefore, the production of biomass energy rod from agricultural waste such as sugar cane leaf sheath, not only helps to add value to agricultural waste but also helps to conserve energy. A simple drying process of biomass energy rod is to put it under sunlight or leave it to dry. Farmers can do it easily. However, solar energy has limits [5]. These are caused by solar radiation and weather. Therefore, these constraints result in delay and unpredictability in the drying process. Technologies has been introduced into the drying process, including hot air drying, contact drying, infrared drying, and microwave drying. Especially microwave energy, which is used in many fields such as agriculture [6], medicine [7], and is widely used to dry the various materials. In the past, microwave energy was mainly used for drying food, fruit, agricultural products and engineering materials [8-10]. Ouertani et al. [8] studied microwave irradiation's effects on jack pine wood's drying kinetics by using the microwave at 2.45 GHz and power ranging from 300 to 1,000 W. It was found that a higher power of the microwave, a smaller sample (such as lower thickness), and an initial sample temperature can increase the temperature inside the experimental sample. The influences of the microwave process on the drying kinetics, mechanical properties, and surface appearance of rubberwood (hevea brasiliensis) has been explored by Vongpradubchai S. et al. [9]. The experiment focused on energy consumption, drying rate, surface temperature, drying time, static bending properties, and quality of dried rubberwood. The experiment used a combined microwave and convective air drying at frequencies of 2.45 ± 0.05 GHz, microwave power of 4.8 kW, and air-drying temperatures of 30 °C, 50 °C, and 70 °C with a drying velocity of 5.0 m/s. The experimental apparatus was a multi-feed microwave-convection hot air and continuous belt system. In 2022, Shen L. et al. [10] analyzed heating uniformity considering microwave transmission in stacked bulk of granular materials on a turntable in microwave ovens. The research used germinated brown rice (GBR) for the experiment. The study has shown that germinated brown rice stacked on top of each other has uneven surfaces. The placement of materials affected the uniformity of the thermal distribution. Very few studies have studied the microwave drying of biomass energy rod, especially biomass energy rod from the leaf sheath of sugarcane using natural rubber as binder. Due to the complexity of dielectric properties and thermal properties, as well as the complexity of constructing experimental instruments.

Therefore, this research aims to study the drying process of biomass energy rod from the leaf sheath of sugarcane using natural rubber as binder by microwave energy. A continuous microwave belt and hot air drying is used in the study. The ingredients for forming biomass energy using the designed machine are sugarcane leaves of 19 %w/w, water of 57 %w/w, tapioca flour of 6 %w/w and natural latex of 19 %w/w. The biomass energy rod has diameter of 5 cm, length of 10 cm, and weighs between 150-153 g is required. The effects of heat source i.e. microwave drying, hot air drying and microwave- hot air drying is studied. The drying time, net heating value and residual moisture content of biomass energy rod are compared with each drying heat source. The results obtained from the study will help to improve the drying process of biomass energy rod as well as help to increase the value of agricultural waste such as sugarcane leaf sheaths.

## 2 Materials and methods

In this research, a continuous microwave belt and hot air drying is used as an experimental apparatus. The drying area with a length of 250 cm. The apparatus is installed with a microwave source (magnetron) with a power of 1,000 W, eight units (the total power is 8,000 W), four on each side, which are installed not in the same line and match (asymmetry) to reduce the destructive interference of waves and hot air systems, as shown in Figure 1. The microwave power can be adjusted from 0-1,000 W, adjustable every 1 W. Furthermore, there are four heaters with a power of 2000 W installed on the top (the total power is 8,000 W). The heater can be adjusted from 0-2,000 W, adjustable every 1 W. The experimental apparatus can adjust the belt travel speed in the range of 0-10 mm/s and support the weight of the load on the belt up to 6 kg per round. Working time can be set up to 9,999 seconds, adjustable in 1 second. The biomass rod according to the standard size must be produced in diameter of 5 cm and length of 10 cm by biomass rod from sugarcane leaf sheath with natural latex as binder from the forming.

The sugarcane leaf grinding process is the first process in preparing raw materials for forming biomass energy rod. The harvested sugarcane leaves will be dried in the solar and hot air and finely ground before being used are shown in Figure 2. The initial moisture content of the sugarcane leaf used in the biomass energy rod forming is thus assumed to be equal to zero and equal. In the experiment, biomass energy rod from sugar cane sheaths are formed using only one forming formula. The formula is experimentally determined to determine the optimal formulation for both the strength and flexibility of the, biomass energy rod produced. This process takes the harvested sugarcane leaf into a blender to grind or digest the sugarcane leaf into smaller sizes to be suitable for forming biomass ingots and mixed with natural rubber latex and tapioca flour in a ratio leaf of 19 %w/w, the water of 57 %w/w, tapioca flour of 6 %w/w and natural latex of 19 %w/w. Therefore, the initial moisture content of the biomass energy rod is calculated from the water content in the mixture and some water from the natural latex. It is found that the initial moisture content of the biomass energy rod is 66.5 %w/w. In this research, the initial moisture content of the produced biomass energy rod would be the same for all. The effect of initial moisture content on the forming or drying process is not considered. In this experiment, the total ratio of 1,000 g mixed with the objective of forming 7 biomass rods per cycle. The biomass energy rod has diameter of 5 cm, length of 10 cm, and weighs between 150-153 g is required. An example of the biomass energy rod produced is shown in Figure 3. The drying process is dried until residual moisture equals (less than) 15 % (the industrial product standards of Solid Biofuels-Biomass Pellets (Tis no. 2772-2560)) and recorded the time that takes to dry. In addition, collect 150 g of biomass rod samples to the Office of Scientific Instrument and Testing Laboratory, Prince of Songkla University to measure the net heating value and residual moisture content in each drying heat source.

 https://doi.org/10.1051/e3sconf/202337902003

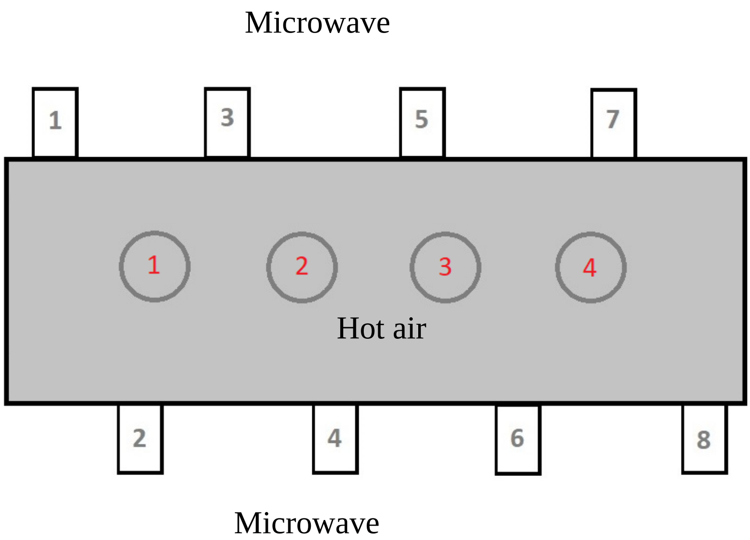


**Fig. 1.** Experimental apparatus in this research and location of eight magnetrons (grey) and four heaters (red).

**Fig. 2.** Sugarcane leaves that have undergone the fine grinding process.

**Fig. 3.** An example of the biomass energy rod produced.

The effects of heat source namely microwave drying, hot air drying and microwave-hot air drying is studied. Table 1 shows the case studies in this research.

**Table 1.** The case studies in this research.

| Case studies | Types of heat source | Heat Source | | Total power |
|---|---|---|---|---|
| | | **Microwave energy** | **Hot air energy** | 2,000 W |
| 1 | Microwave drying | 4 Microwaves, 500 W each | - | 2,000 W |
| 2 | Microwave drying | 8 Microwaves, 250 W each | - | 2,000 W |
| 3 | Hot air drying | - | 4 Hot air, 500 W each | 2,000 W |
| 4 | Microwave-hot air drying | 4 Microwaves, 250 W each | 4 Hot air, 250 W each | 2,000 W |

## 3 Results and discussions

The drying efficiency of each heat sources are studied by comparing the drying time in each experiment. Figure 4 shows the comparison of drying time for each heat sources. The results showed that the drying time of case study 2 (8 microwave sources are turned on, 250 W each) has time duration of 15 min with the shortest time. In addition, it is found that in case study 4 (4 microwave sources of 250 W each and 4 hot air sources of 250 W each) has time duration of 20 min, which is only 5 min more than the case study 2 (time duration of 20 min) followed case study 1 (4 microwave sources are turned on, 500 W each) has time duration of 30 min. Case study 3 (open 4 hot air sources, 500 W each) used the maximum drying time with time duration of 300 min. Based on the results of the experiment, it can be concluded that drying time of case study 2 takes the least amount of time to drying the sample biomass energy rod and time to drying of case study 3 takes the most time to dry the sample biomass energy rod.

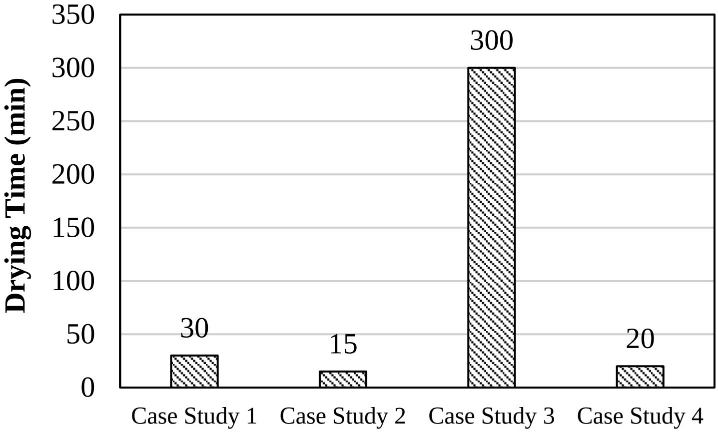


**Fig. 4.** The comparison of drying time for each heat sources.

Consider the relationship between net heating value and residual moisture content value of biomass energy rod for each heat sources. The relationship between net heating value and residual moisture content value of biomass energy rod for each heat sources as shown in Figure 5. In addition, the comparison between net heating value and residual moisture content value of biomass energy rod for each heat sources are shown in Table 2. It is found that the residual moisture content value is inversely proportional to the net heating value of the

 https://doi.org/10.1051/e3sconf/202337902003

biomass energy rod. That is, if there is a high residual moisture content value, the net heating value will be low, but if the residual moisture content value is low, the net heating value will be high. When focusing on the influences of each heat sources, it is found that case study 2 (8 microwave sources are turned on, 250 W each) has the highest net heating value and the lowest residual moisture content value, which corresponds to the least drying time.

However, the net heating value and residual moisture content value do not follow trends as well as the drying time. It is found that case study 1 (4 microwave sources are turned on, 500 W each) has the second highest net heat value, followed by case study 3 (open 4 hot air sources, 500 W each) and case study 4 (4 microwave sources of 250 W each and 4 hot air sources of 250 W each), respectively. Similarly, it is obtained that case study 1 (4 microwave sources are turned on, 500 W each) has the second lowest moisture content, followed by case study 3 (open 4 hot air sources, 500 W each) and case study 4 (4 microwave sources of 250 W each and 4 hot air sources of 250 W each), respectively.

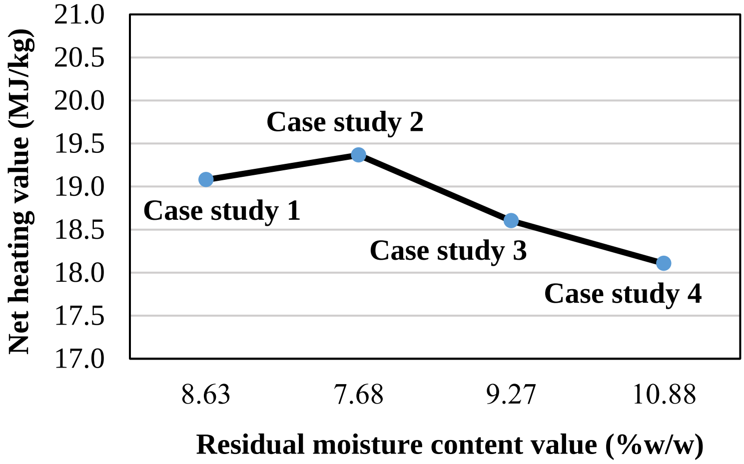


**Fig. 5.** The relationship between net heating value and residual moisture content value of biomass energy rod for each heat sources.

**Table 2.** Comparison between net heating value and residual moisture content value of biomass energy rod for each heat sources.

| Case studies | Types of heat source | Properties | |
|---|---|---|---|
| | | Net heating value (MJ/kg) | Residual moisture content value (%w/w) |
| 1 | Microwave drying | 19.079 | 8.63 |
| 2 | Microwave drying | 19.366 | 7.68 |
| 3 | Hot air drying | 18.602 | 9.27 |
| 4 | Microwave-hot air drying | 18.106 | 10.88 |

This study examined the effectiveness of microwave energy to maintain high product quality and advances in a shortened drying time with volumetric (bulk) heating.

In addition, when comparing net heating value and residual moisture content value with the industrial product standards of Solid Biofuels-Biomass Pellets (Tis no. 2772-2560), both property values are found to have passed values as determined by the benchmark in all experimental with reference to the standard value residual moisture content is not more than 15% and net heating value is more than 14.5 MJ/kg.

## 4 Conclusion

This research aims to study the drying process the biomass energy rod from the leaf sheath of sugarcane using natural rubber as binder by microwave energy. The ingredients for forming biomass energy rod using the designed machine are sugarcane leaves of 19 %w/w, water of 57 %w/w, tapioca flour of 6 %w/w and natural latex of 19 %w/w. The biomass energy rod has diameter of 5 cm, length of 10 cm, and weighs between 150-153 g are produced by a developed machine. The effects of heat source namely microwave drying, hot air drying and microwave-hot air drying on the drying time, net heating value and residual moisture content of biomass energy rod is considered. The results obtained from the experiment revealed that in the case of using microwave energy in the drying process has the lowest drying time, highest net heating value and has the lowest residual moisture content of biomass energy rod when compare to using hot air drying clearly. The results have led to support for the application of microwave energy in drying biomass energy rod and materials. In addition, when comparing net heating value and residual moisture content value with the industrial product standards of Solid Biofuels-Biomass Pellets (Tis no. 2772-2560), both property values are found to have passed values as determined by the benchmark in all experimental. The results obtained in this research can be fundamental to develop ideas for technologies of the forming and drying process of biomass energy rod using agricultural products.

## Acknowledgement

The authors would like to gratefully acknowledge the National Research Council of Thailand (NRCT) and Mahidol University for supporting this research.

## References

1. Patricia, N., Omo-Okoro Adegbenro, P., DasoJonathan, O., and Okonkwo, A. A Review of The Application of Agricultural Wastes as Precursor Materials for The Adsorption of Per-and Polyfluoroalkyl Substances: A Focus on Current Approaches and Methodologies, Environmental Technology & Innovation, 9: p. 100-114 (2018)
2. Santos, F., Eichler, P., Machado, G., Mattia, J.D., and Souza, G.D. Chapter 2 - By-Products of The Sugarcane Industry, Sugarcane Biorefinery, Technology and Perspectives, p.21-48 (2020)
3. Shilev, S., Naydenov, M., Vancheva, V., and Aladjadjiyan, A. Composting of Food and Agricultural Wastes, Utilization of By-Products and Treatment of Waste in the Food Industry, p. 283-301 (2007)
4. Li, H., Chen, Q., Zhang, X., Finney, K.N., Sharifi, V.N., and Swithenbank, J. Evaluation of A Biomass Drying Process Using Waste Heat from Process Industries: A Case Study, Applied Thermal Engineering, p. 71-80 (2012)
5. Moradi, I. Quality Control of Global Solar Radiation Using Sunshine Duration Hours, Energy, 34(1): p. 1-6 (2009)

https://doi.org/10.1051/e3sconf/202337902003

6. Fodah, A.E.M., Ghosal, M.K., and Behera, D. Microwave-Assisted Pyrolysis of Agricultural Residues: Current Scenario, Challenges, And Future Direction, International Journal of Environmental Science and Technology, 19: p. 2195-2220 (2022)
7. Keangin, P., and Rattanadecho, P. Analysis of Heat Transport on Local Thermal Non-Equilibrium in Porous Liver During Microwave Ablation, International Journal of Heat and Mass Transfer, 67: p. 46-60 (2013)
8. Ouertani, S., Koubaa, A., Azzous, S., Bahar, R., Hassini, L., and Belghith, A. Microwave Drying Kinetics of Jack Pine Wood: Determination of Phytosanitary Efficacy, Energy Consumption, and Mechanical Properties, 76: p.1101-1111 (2018)
9. Vongpradubchai, S., Makul N., and Rattanadecho P. Influence of The Microwave-Accelerated Process on The Drying Kinetics, Mechanical Properties, and Surface Appearance of Rubberwood (Heavea Brasiliensis). European Journal of Wood and Wood Products, 80(2): p. 395-407 (2022)
10. Shen, L., et al. Analysis of Heating Uniformity Considering Microwave Transmission in Stacked Bulk of Granular Materials on a Turntable in Microwave Ovens. Journal of Food Engineering, 319: p. 110903 (2022)