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Techno-feasibility assessment on utilization of rice husk and wood scrap as energy sources of the rotary drier while drying BSF maggot

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ABSTRACT

The Black Soldier Flies (BSF) maggot business is getting increasing attention nowadays, especially the dried BSF maggot. The dried BSF maggot is very suitable for fish feed, thus the dried maggot business has a good prospectus not only in terms of the financial sector but also in terms of the waste management sector. Unfortunately, making dried maggot requires a high cost during the drying process, since additional cost for LPG is needed. It is important to replace LPG fuel with less expensive one, such as biomass fuel which Indonesia has huge potential. The present work aims to investigate the techno-feasibility of rice husk and waste scrap waste as the feedstock of rotary drum driers. The experimental work was conducted by drying 10 kg fresh BSF maggot for 2 hours in the drier using blend feedstock of 6 kg rice husk- 6 kg wood scrap (RH-WS) and feedstock of 12 kg wood scrap (WS). The data taken during the experiment are furnace and drum temperature, and mass of the dried maggot. The data was used to analyze the performance of the drier in terms of drying rate, drying heat, specific fuel consumption (SEC), and the dryer's effectiveness. The results depict that the waste of rice husk and wood scrap are technologically feasible as energy sources for rotary drum dryers while drying BSF maggot. The performance of the drier in terms of drying rate, drying heat, specific fuel consumption, and drier's effectiveness is better when a blend of rice husk and wood scrap is used as a feedstock. Those values when using blend feedstock are 0.92 g/s, 20996.37 kJ, 27940.15 kJ/kg, and 0.67, respectively. It is recommended to use the waste of rice husk and wood scarp in blending form to obtain optimum performance of the rotary drier while drying BSF maggot.

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1. Introduction

Recently, Black Soldier Flies (BSF) cultivation has been getting attention in the waste management sector. Garbage from domestic households, restaurant food waste, and hotel food waste have been utilized as the cultivation medium of the BSF. A BSF maggot has economic value, thus the BSF cultivation not only gives benefit to the waste management system but also gives benefit to a circular economy. The utilization of black soldier flies in the waste management sector is considered one of the promising new technologies by Indonesia's Waste to Energy regulations [1]. The BSF maggot is very suitable for fish meal which was proved by Atlantic salmons did not harm their growth after being fed by BSF maggot [2]. The body weight of the fish improves when fish meal is replaced by BSF larvae [3]. The BSF maggot has a high protein and fat content, so it can be used as a substitute for dairy fish concentrate in the form of fresh maggot as well as dry maggot. Dry maggot has higher selling prices than fresh ones, thus dry maggot gives more profit to the farmers.

In order to speed up drying time, the maggot drying process uses a drying machine. Typically, a rotary type of dryer is used for roasting a BSF larvae. This type of dryer is very suitable for granular foods such as grains [4]. The heat from the furnace is transferred to a rotating drum. This model of dryer is also appropriate for heating, and cooling of granular materials [5-7]. The rotary dryer has the benefit of less specific energy consumption and low maintenance cost [8]. To reduce fuel costs in the drying process, alternative and renewable energy sources should be used as heat sources for the drier. Biomass energy has a good potential as a heat source of the drier since Indonesia has approximately 33 GW of biomass energy resources [9]. This biomass energy mainly comes from the waste from agriculture, forestry, the wood industry, and households. A previous study revealed that the utilization of biomass as an alternative energy source could reduce energy outlay and improve economic constraints [10]. Besides promoting a reduction in the emission of carbon dioxide, the use of biomass energy is also able to prevent a high carbon footprint process [11, 12].

Several works on the utilization of biomass energy-based driers have been reported so far. Rise husk has been used as a heat source in the conventional corn dryer based on the heat exchanger pipe diameter [13, 14]. The rice husk-fired drier provides an opportunity that the drying process to be independent of the weather conditions and gain more hygienic products. A biomass-fired passive-cum-active dryer and a plate heat exchanger were developed and tested [15]. The thermal efficiency of the dryer was estimated from the experimental data which was found to be in the range of 4.35-4.62%. They stated that wide varieties of biomass can be used as fuel in the developed dryer. Other works, hybrid biomass-solar powered driers were also been developed so far [16, 17].

In the present work, the techno-feasibility of rice husk waste and wood scrap is evaluated as an energy source of a rotary drum drier while drying fresh BSF maggot. The performance of the drier in terms of drying rate, drying heat, specific fuel consumption (SEC), and drier's effectiveness was analysed while drying 10 kg BSF maggot for 2 hours with an energy source of rice husk-wood scrap blend (RH-WS) and wood scrap (WS).

2. Method

A flow diagram of the present work and a photograph of the experimental setup are shown in Fig. 1 and Fig. 2. The work is divided into three parts, i.e. feedstock preparation, experimental work, and data analysis. The rotary drier used in the present work has the main components of a rotary drum, furnace, electric motor, and gear reduction system. The electric motor is used as a prime mover of the drum with a rotational speed of 24 rpm. Heat for drying of a maggot is obtained by burning waste of biomass in the furnace. Fresh maggot is fed through the inlet of a rotating drum. After drying, the dried maggot exits the rotary drum by reversing its rotational direction.

In the present work, the techno-feasibility of the rice husk (RH) and wood scrap (WS) as energy sources of the rotary drier was experimentally studied. The rotary drier was tested with RH-WS blend feedstock and SW feedstock. Each test uses 12 kg feedstock for drying 10 kg fresh maggot for 2 hours. The data taken during the experiment are furnace temperature (T_f), drum temperature (T_d), and mass of the dried maggot. An infrared thermo-gun was used to measure furnace and drum temperatures, thus it enables measuring drum temperature while rotating. Temperatures of a drum and a furnace were taken every 5 minutes. The data was used to analyze the performance of the drier in terms of drying rate, drying heat, specific fuel consumption (SEC), and the dryer's effectiveness. Eq. (1) to Eq. (4) (6) were used to calculate drying rate, drying heat, SEC, and drier's effectiveness, respectively.

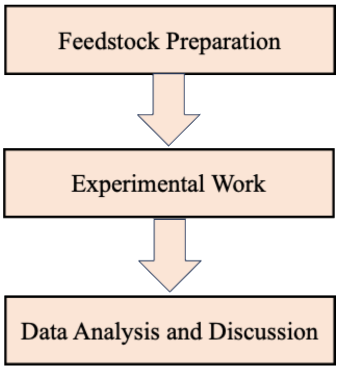

Fig. 1. Flow diagram of the present work

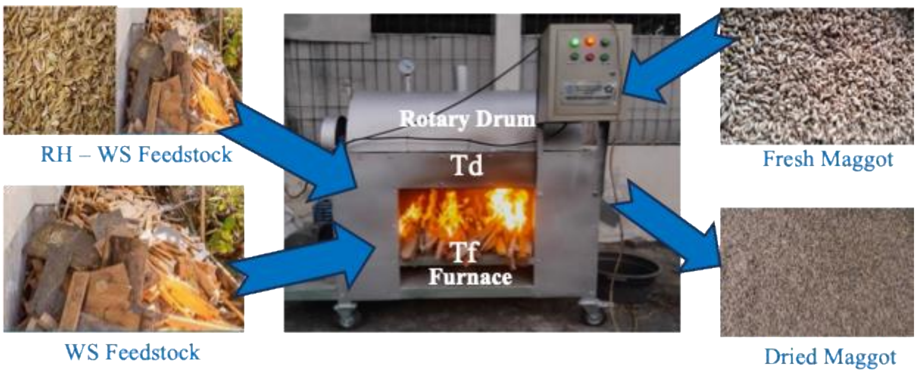

Fig. 2. The experimental setup

$$\dot{r} = \frac{m_2 - m_1}{t} \tag{1}$$

$$Q = m_1 c_p (T_2 - T_1) + m_v h_{fg} \tag{2}$$

$$SEC = \frac{m_b HHV_b}{m_v} \tag{3}$$

$$\varepsilon = \frac{m_2 - m_1}{m_1} \tag{4}$$

where $\dot{r}$ is the roasting rate (g/s), m_1 and m_2 are the mass of maggot before and after roasting, Q is the useful heat for roasting (kJ), c_p is the specific heat of a maggot (3.47 kJ/kg ºC) [18], T_2 is the maximum temperature inside the drum (ºC), T_1 is the initial temperature of the drum (ºC), m_v is the mass loss of the maggot, h_{fg} is the heat of vaporization of water at STP (2260 kJ/kg), SEC is the specific energy consumption (kJ/kg), m_b is the mass of firewood (kg), HHV_b is the higher heating value of the firewood (17.577 MJ/kg) [19] and rice husk (13.39 MJ/kg) [9], and ε is the effectiveness of the roaster.

3. Results and Discussion

The temperature profile of the furnace and the drum for a feedstock of the rice husk-wood scrap blend (RH-WS) and a feedstock of wood scrap (WS) within 2 hours of investigation are displayed in Fig. 3 and Fig. 4. Furnace temperature fluctuated during the test. This was due to uncontrolled combustion of air entering the furnace. The furnace temperature is higher when a blend of rice husk-wood scrap (RH-WS) feedstock is used compared with that using a wood scrap (WS) feedstock. The average furnace temperatures are 342.87 ºC when using the blend and 172.20 ºC when using the wood scrap. The addition of the rice husk to the furnace was able to improve combustion in it, thus more heat was released during combustion. Significant temperature increases start from the beginning of the process up to 50 minutes for the RH-WS feedstock and up to 25 minutes for the WS feedstock. After reaching maximum values, the temperatures tend to decline slightly till the end of the drying.

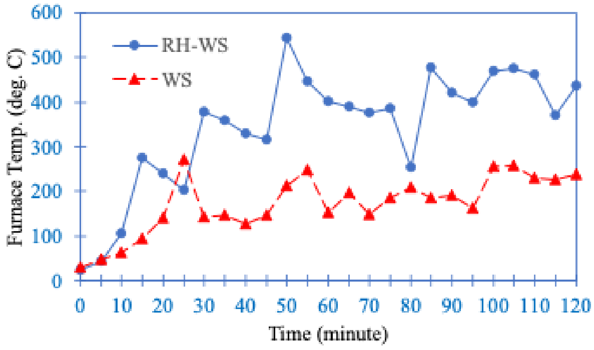

Fig. 3. Temperature profile of the furnace

Meanwhile, the drum temperature reaches drying temperature after 15 minutes for RH-WS feedstock and 25 minutes for WS feedstock. The drum temperature when using blend feedstock is higher than that of wood scrap feedstock. More heat generated by the blend combustion in the furnace leads to a higher heat transfer rate to the drum, thus higher drum temperature when using the blend feedstock. The average drum temperature when using the blend and wood scrap feedstock are 153.64 ºC and 134.56 ºC, respectively.

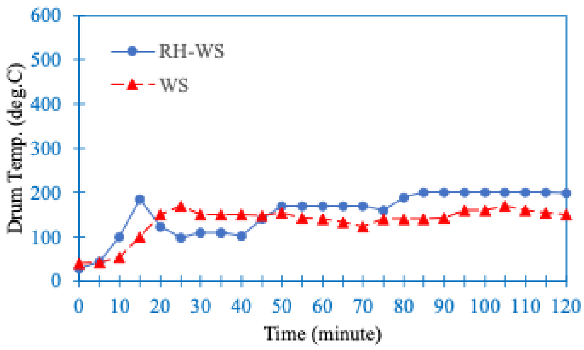

Fig. 4. Temperature profile of the drum

An effect of the feedstock on drying rate, useful heat, SEC, and drier's effectiveness is shown in Fig. 5(a) to Fig. 5(d), accordingly. Higher drum temperature while using the blend feedstock is noted and presented in Fig. 5(a). A higher drying rate happened due to more heat being absorbed by the BSF maggot in the drum. At any given time more water in the BSF maggot evaporates when using the blend feedstock. The drying rates are 0.92 g/s and 0.65 g/s for the blend feedstock and wood scrap feedstock, respectively. The amount of heat from combustion used for the drying is shown in Fig. 5(b). A higher drying rate means that more heat is used for the drying process at any given time. It is found that 20996.37 kJ of heat is utilized for drying when using the blend feedstock and only 15132.22 kJ is useful for drying when using wood scrap feedstock.

Meanwhile, Fig. 5(c) depicts the effect of the feedstock on specific fuel consumption. SEC is defined as the amount of energy required for evaporating 1 kg of water vapour. The lesser the SEC, the better the performance of the dryer. The SEC is found to be 27940.15 kJ/kg when using the blend feedstock and 44877.45 kJ/kg when using the wood scrap feedstock. These values indicate that more energy is consumed to evaporate 1 kg of water when using the wood scrap feedstock compared to using the blend feedstock. In other words, the drier is more effective when using the blend feedstock. As can be seen in Fig. 5(d), the drier's effectiveness when using the blend and the wood scrap feedstocks are found to be 0.67 and 0.47, respectively. Compared with the work by Catrawedarma et al, [20] it is found that the exergy inflow for all initial masses was not significantly different.

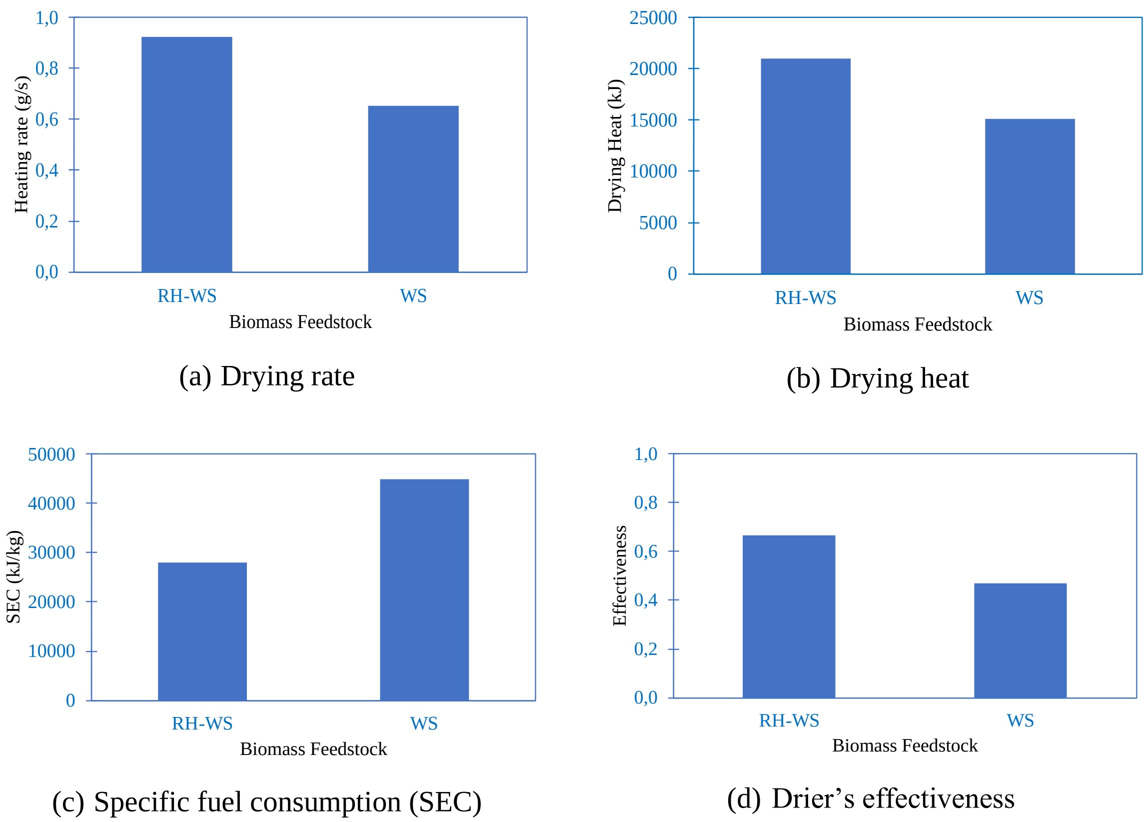

Fig. 5. Performance of the rotary dryer

4. Conclusion

Techno-feasibility of the waste of rice husk and wood scrap as energy sources for rotary drier while drying BSF Maggot was studied experimentally. It can be concluded that:

1. The waste of rice husk and wood scrap is technologically feasible as energy sources for a rotary drum dryer while drying BSF maggot.
2. The performance of the drier in terms of drying rate, drying heat, specific fuel consumption, and drier’s effectiveness is 42.6% higher when a blend of rice husk and wood scrap is used as a feedstock.
3. Heat transfer from the furnace to the drum occurs better while using the blend feedstock, thus more heat is absorbed by the drum for maggot drying. Rice husk can enhance the combustion of the blend in the furnace.
4. Thus, it is recommended to use the rice husk-wood scrap feedstock. Besides giving better performance to the drier, rice husk is also less expensive and abundantly available.

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References

[1] Farahdiba A.U., Warmadewanthi I.D.A.A., Fransiscus Y., Rosyidah E., Hermana J, Yuniarto A., (2023). The present and proposed sustainable food waste treatment technology in Indonesia: A review. Environ Technol Innov, 32: 103256. https://doi.org/10.1016/j.eti.2023.103256

[2] Belghit I. Liland S.N., Petter Gjesdal P., Biancarosa I., Menchetti E., Li Y., Waagbø R., Krogdahl Å, Lock E.J. (2019). Black soldier fly larvae meal can replace fish meal in diets of sea-water phase Atlantic salmon (Salmo salar). Aquaculture, 503: 609–619. https://doi.org/10.1016/j.aquaculture.2018.12.032

[3] Attivi K., Mlaga K.G., Agboka K., Tona K., Kouame Y.A.E., Lin H. (2022). Effect of fish meal replacement by black Soldier Fly (Hermetia illucens) larvae meal on serum biochemical indices, thyroid hormone and zootechnical performance of laying chickens. Journal of Applied Poultry Research, 31(3): 100275. https://doi.org/10.1016/j.japr.2022.100275

[4] Susana I.G.B, Alit I.B., Okariawan I.D.K. (2023). Rice husk energy rotary dryer experiment for improved solar drying thermal performance on cherry coffee. Case Stud. Therm. Eng. 41: 102616. https://doi.org/10.1016/j.csite.2022.102616

[5] Xie Q., Chen Z., Mao Y., Chen G., Shen W. (2018). Case studies of heat conduction in rotary drums with L-shaped lifters via DEM. Case Stud. Therm. Eng., 11: 145–152. https://doi.org/10.1016/j.csite.2018.02.001

[6] Trojosky M. (2019). Rotary drums for efficient drying and cooling. Dry. Technol., 37(5): 632–651, https://doi.org/10.1080/07373937.2018.1552597.

[7] Ettahi K., Chaanaoui M., Sebastien V., Abderafi S., Bounahmidi T. (2022). Modeling and design of a solar rotary dryer bench test for phosphate sludge. Modelling and Simulation in Engineering. 5574242, https://doi.org/10.1155/2022/5574242.

[8] Giudice A.D., Acampora A., Santangelo E., Pari L., Bergonzoli S., Guerriero E., Petracchini F., Torre M., Paolini V., Gallucci F. (2019). Wood chip drying through the using of a mobile rotary dryer. Energies, 12 (9): 1590, https://doi.org/10.3390/en12091590.

[9] Susastriawan AAP, Purwanto Y, Warisman A. (2021). Development of An Air-Stage Downdraft Gasifier and Performance Evaluation on Feedstock of Rice Husk. J. Adv. Res. Fluid Mech. Therm. Sci., 84 (1): 20–32. https://doi.org/10.37934/arfmts.84.1.2032

[10] Wincy WB and Edwin M. (2020). Techno-economic assessment on the implementation of biomass gasifier in conventional parboiling rice mills. Int. J. Energy Res., 44 (3): 1709–1723. https://doi.org/10.1002/er.4991.

[11] Pirasteh G, Saidur R, Rahman SMA, Rahim NA. (2014). A review on development of solar drying applications. Renew. Sustain. Energy Rev., 31: 133–148. https://doi.org/10.1016/j.rser.2013.11.052.

[12] Motevali A and Koloor RT. (2020). A comparison between pollutants and greenhouse gas emissions from operation of different dryers based on energy consumption of power plants. J. Clean. Prod., 154: 445–461. https://doi.org/10.1016/j.jclepro.2017.03.219.

[13] Alit I.B., Susana I.G.B., Mara I.M. (2020). Utilization of rice husk biomass in the conventional corn dryer based on the heat exchanger pipes diameter. Case Studies in Thermal Engineering, 22:100764. https://doi.org/10.1016/j.csite.2020.100764

[14] Alit I.B., Susana I.G.B., Mara I.M. (2021). Thermal characteristics of the dryer with rice husk double furnace-heat exchanger for smallholder scale drying. Case Studies in Thermal Engineering, 28:101565. https://doi.org/10.1016/j.csite.2021.101565

[15] Rabha D.K. (2021). Performance investigation of a passive-cum-active dryer with a biomass-fired heater integrated with a plate heat exchanger. Renewable Energy, 169: 598-607. https://doi.org/10.1016/j.renene.2020.12.126

[16] Hamdani, Rizal T.A., Muhammad Z. (2018). Fabrication and testing of hybrid solar-biomass dryer for drying fish. Case Studies in Thermal Engineering 12: 489–496. https://doi.org/10.1016/j.csite.2018.06.008

[17] Bhattacharya S.C., Ruangrungchaikul T., Pham H.L. (2000). Design And Performance Of A Hybrid Solar/Biomass Energy Powered Dryer For Fruits And Vegetables. Worm Renewable Energy Congress VI.

[18] Shinozaki J. (1957). The Specific Heat of Insects. *Jour. Fac. Sci. Hokkaido Univ. Ser. VI, Zool.* 13.

[19] Susastriawan A.A.P, Saptoadi H, Purnomo (2019). Comparison of the gasification performance in the downdraft fixed-bed gasifier fed by different feedstocks: rice husk, sawdust, and their mixture, Sustainable Energy Technologies and Assessments, 34: 27-34 https://doi.org/10.1016/j.seta.2019.04.008

[20] Catrawedarma I. G. N. B., Afandi A., Prastujati A.U., Haq E.S. (2024). Exergy evaluation while drying fish waste in the forced convection rotary dryer. AIP Conf. Proc. 3145, 020018. https://doi.org/10.1063/5.0214140