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Rotary dryer in a study based on participatory principles for smallholder scale drying

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Abstract

Small farmers who mostly live in rural areas need a cheap and easy technique for the post-harvest production process, especially drying. The participation of farmers is very much needed so that the design of work tools according to their needs and their use can be sustainable. So far, sun drying is very dependent on the weather and causes fatigue to farmers due to sun exposure. To overcome this, a dryer was designed with the application of participatory principles which is part of the ergonomics application. With the participatory principle, a rotary type dryer was developed for grain drying. Energy sources use rice husks, which are widely available so that they are easy to obtain and inexpensive. The rotary-type dryer design utilizes this biomass by energy conversion using a heat exchanger. It is hoped that this type of tool is cheap and easy to operate so that it can be accepted by small farmers. In addition, small farmers do not experience additional workloads due to sun exposure which has an impact on the risk of fatigue, increasing productivity.

Keywords: Rotary Dryer; Participatory; Rice Husk; Heat Exchanger; Fatigue

1. Introduction

Smallholder-scale drying relies heavily on upon the sun because it is easy and inexpensive. Drying is done as an effort to extend the shelf life of post-harvest products. The sun drying process can be carried out throughout the day if there is no cloud or rain. If the weather is erratic, it will hamper the drying process. Apart from being constrained by the weather, sun drying also has an impact on the additional burden of workers, namely sun exposure. This causes increased workload and worker fatigue. An alternative is to replace solar energy with biomass that is tailored to the needs and where smallholders live.

Such is the condition of small farmers in Lombok, most of whom live in rural areas where the dominant agricultural product is paddy. Based on this, it produces waste in the form of rice husks. So far, rice husk waste is only used to warm livestock, and cook by burning rice husk directly, and the rest is burned because it is considered useless. Rice husk has the potential to be used as an energy source to replace the sun. This is based on the calorific value of rice husks of 11-15.3 MJ/kg [1]. The maximum temperature for burning rice husks using a stove and direct combustion is 556.5°C and 560°C, respectively [2, 3]. Based on the participation of small farmers, they need a touch of appropriate technology at an affordable price and easy to operate. The participation of smallholders is very much needed so that a work tool can be used sustainably and does not cause new problems.

The participatory principle is part of the application of the concept of ergonomics in adjusting workers to work tools. The principle of participatory ergonomics is the most effective way to redesign manual tasks to reduce the occurrence of work-related musculoskeletal disorders, reduce risks to safety and health, and create more human-centered work [4,

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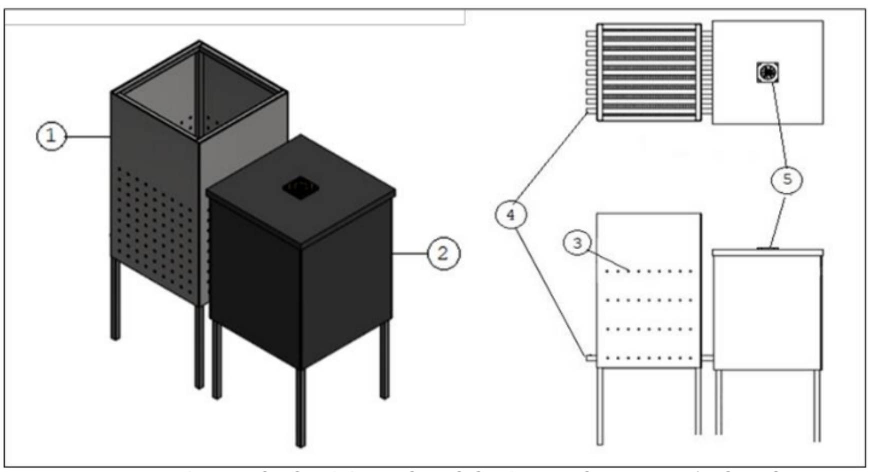
5, 6]. Based on the concept that work is human-centered, to optimize the post-harvest drying process, it is carried out based on input from users, in this case, small farmers.

Direct sun drying is very dependent on the weather, the emergence of musculoskeletal complaints and fatigue due to unnatural work postures, and exposure to sunlight during the drying process. Unnatural work postures pose a risk of muscle fatigue and injury, an increase in the level of musculoskeletal complaints which have implications for expenditures on health and well-being, as well as additional workloads and low productivity [7, 8, 9, 10]. To overcome things like this the drying process can use a drying chamber with biomass energy. Small farmers mostly live in rural areas and rice husks are abundant. The potential for rice husks in Lombok and West Nusa Tenggara is 269,420.20 tons and 533,150.80 tons, respectively, and 20% of rice husks are produced from rice processing by-products [11, 12]. Based on this, the drying process is carried out using rice husk biomass as an energy source. In Ul Haq et al. it is explained that energy needs and improving the economic status of rural communities in developing countries can be met due to the use of biomass [16]. The conversion of rice husk biomass energy into thermal energy is carried out with the help of a heat exchanger. The hot air produced is used in the drying process. Several studies have applied this method to a variety of foodstuffs and biomass [17, 18, 19]. Heat exchanger functions in the heat transfer process of two fluids with different temperatures and separated by walls [20]. Based on this, a study was conducted on rotary dryers which were compared with vertical rack dryers adjusted to the participation of users, namely small farmers. The type of dryer is adapted to the foodstuffs produced by farmers so that the drying process can be sustainable.

2. Material and methods

This paper examines the application of dryers based on the participatory concept, namely the participation of small farmers in the process of drying post-harvest products. Participation includes the dryers needed by small farmers according to the post-harvest products produced and the available biomass in their vicinity. A biomass dryer is needed as a substitute for direct or indirect solar drying. With the application of participatory principles, it is possible to find suitable drying solutions for small farmers in the drying process. The dryers studied included vertical and rotary shelf type dryers. The energy source uses rice husks with a heat exchanger as a means of transferring hot air. Field observations were carried out on several small farmers who carried out post-harvest drying activities. This is done to obtain the information needed for the design of a sustainable, efficient dryer according to user needs.

3. Results and discussion



Furnace; 2. Drying chamber; 3. Air circulation holes; 4. Heat exchanger pipes; 5. Exhaust fan

Figure 1 Single furnace dryer design with heat exchanger [23]

Preliminary observations show that small farmers need different types of dryers for agricultural products to be dried. For energy sources, it is by the conditions in the smallholder environment, namely rice husk biomass. Rice husks are easy to obtain at low prices and sometimes free because rice husks are considered waste with abundant production. Rice husk provides 99.2% combustion efficiency, flame stabilization, and low emissions [21]. Rice husk as a substitute for firewood so that logging can be reduced [22]. Rice husk is used as a drying energy source through an energy conversion process using a heat exchanger. The hot air resulting from the burning of rice husks has flowed through the heat exchanger pipes into the drying chamber. This method has an impact on the dried product being hygienic and does not mix with the smoke of burning rice husks. Dryer design with heat exchanger and biomass energy source as shown in Figures 1 and 2.

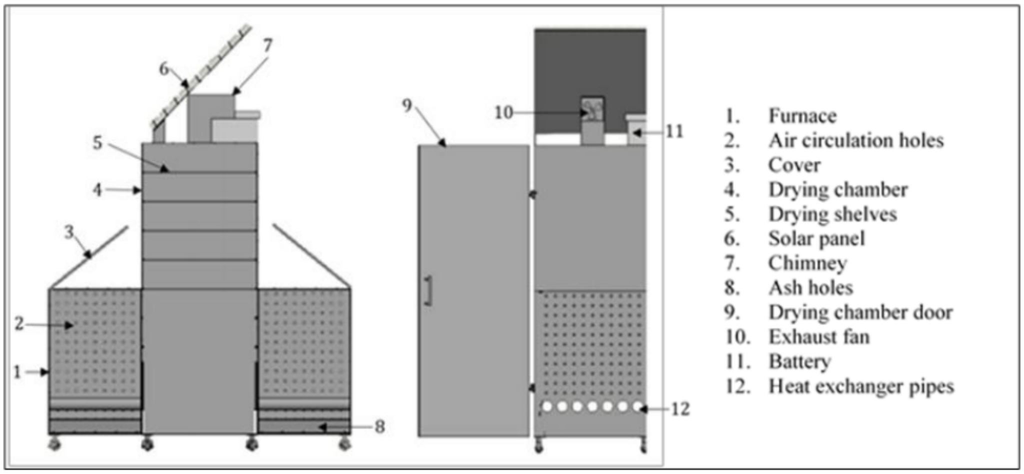


Figure 2 Two-burner dryer design with heat exchanger [24]

Figures 1 and 2 are the result of user participation, in this case, small farmers. The dryer is adapted to the needs of small farmers. Figure 1 is the result of the initial research based on the participation of small farmers to replace sun drying. Sun drying is very dependent on the weather and causes fatigue to workers due to sun exposure. The dryer design in Figure 1 has been tested to dry corn, fruit lunkhead, and red chili [25, 26, 27]. From several tests carried out, it was found that there was a significant increase in temperature and a shorter drying time than sun drying. To further optimize the drying temperature, especially for foodstuffs with fairly high water content, a redesign was carried out in Figure 1. The results are presented in Figure 2.

Figure 2 has carried out a no-load performance test with the results of a higher drying temperature compared to the test results in Figure 1. This is due to the use of two rice husk burning furnaces. In addition, the drying chamber temperature is obtained by convection and conduction. While Figure 1 only uses convection. The desiccant designs of Figures 1 and 2 are suitable for foodstuffs such as lunkhead, chili, turmeric, and other grains. Grains such as corn or coffee require a homogeneous temperature in the drying chamber so that the final dry result is more evenly distributed. This is caused by the difference in temperature on each shelf in the drying chamber. This difference has an impact on uneven drying time. There is still a difference in drying time between the bottom shelf and the top shelf. This difference is acceptable, but based on user participation expect the same drying time, especially for grains like coffee. In addition, coffee farmers also want an automatic drying process that is easy to operate and does not experience fatigue due to sun exposure. Researchers, in this case, apply the participatory concept which is part of the ergonomics application. This is by Hidayat and Purnomo that the application of participatory ergonomics methods can result in improved work systems through dryers that are designed jointly between the parties involved [28] in this case a small farmer. Based on the participation of small farmers who produce coffee, the researchers conducted a study on rotary dryers. The rotary dryer is designed is compact, namely, the combustion furnace is in one unit with the drying chamber. The mechanism is a rotary type dryer with a heat exchanger so that the dried product is not contaminated by gases from burning rice husks. The drying chamber consists of two cylinders, namely a fixed cylinder and a rotating cylinder. The heat exchanger pipes connect the furnace with a fixed cylinder. In the rotary cylinder, the foodstuffs are dried so that drying occurs evenly. The rotating cylinder is driven by a motor with gear transmission. Rotary dryer design as presented in Figure 3.

The tool to be designed is expected to be cheap and easy to operate so that it can be accepted by users. The existence of this tool is expected to increase the selling value of plantation and agricultural products so that the income of farmers will increase. In Ettahi et al. It was explained that rotary dryers have been applied in various industries such as minerals, fuels, and food, and have wide applications involving heat and mass transfer between the gas and solid phases [29]. Rotary dryers are very fault tolerant making them suitable for installation in areas with poor infrastructure [30]. The drying chamber is a cylinder with a circular surface that rotates at a certain speed so that heat transfer occurs uniformly.

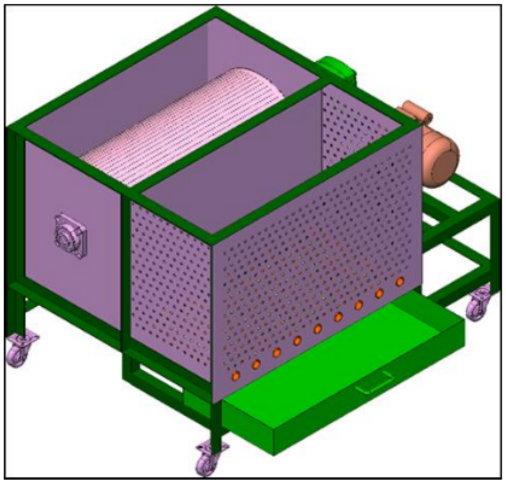


Figure 3 Rotary dryer design with heat exchanger

Rotary dryers are designed based on biomass energy, namely utilizing rice husk waste as an energy source. Hot air with a certain temperature and mass flow rate is produced through the process of converting rice husk energy into thermal. The heat transfer from burning rice husks occurs to the ambient air flowing in the heat exchanger pipes. This hot air is circulated uniformly using an exhaust fan mounted on a non-circular cylinder drying chamber. The driving motor functions to provide a driving force on the transmission device so that the cylinder rotating shaft can rotate at a certain speed according to the engine specifications. With this type of dryer, it is hoped that small farmers can increase the production of foodstuffs, especially grains. In addition, small farmers do not experience additional workloads due to sun exposure which has an impact on the risk of fatigue.

4. Conclusion

Solar drying either directly or indirectly by using solar collectors still poses problems for small farmers. The relatively low temperature due to erratic weather and increasing the risk of fatigue for small farmers when carrying out the drying process. A vertical shelf type dryer with rice husk energy source is an alternative but by small farmers, it is not considered suitable for drying grain. The alternative is a rotary type dryer with a rice husk energy source following what small farmers need to dry foodstuffs in the form of grains. The results of the rotary dryer design show the desire of small farmers for this type of tool. Performance tests are needed to find out whether the rotary type dryer provides optimal results and is under the needs of small farmers.

Compliance with ethical standards

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Disclosure of conflict of interest

The authors declare no conflict of interest.

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Rotary dryer in a study based on participatory principles for smallholder scale drying Ida Bagus Alit and I Gede Bawa Susana * Department of Mechanical Engineering, Faculty of Engineering, University of Mataram, Jl. Majapahit No. 62 Mataram- Nusa Tenggara Barat 83125, Indonesia. Global Journal of Engineering and Technology Advances, 2022, 12(02), 072–077 Publication history: Received on 15 July 2022; revised on 16 August 2022; accepted on 18 August 2022 Article DOI: https://doi.org/10.30574/gjeta.2022.12.2.0139 Abstract Small farmers who mostly live in rural areas need a cheap and easy technique for the post-harvest production process, especially drying. The participation of farmers is very much needed so that the design of work tools according to their needs and their use can be sustainable. So far, sun drying is very dependent on the weather and causes fatigue to farmers due to sun exposure. To overcome this, a dryer was designed with the application of participatory principles which is part of the ergonomics application. With the participatory principle, a rotary type dryer was developed for grain

drying. Energy sources use rice husks, which are widely available so that they are easy to obtain and inexpensive. The rotary- type dryer design utilizes this biomass by energy conversion using a heat exchanger. It is hoped that this type of tool is cheap and easy to operate so that it can be accepted by small farmers. In addition, small farmers do not experience additional workloads due to sun exposure which has an impact on the risk of fatigue, increasing productivity. Keywords: Rotary Dryer; Participatory; Rice Husk; Heat Exchanger; Fatigue 1. Introduction Smallholder-scale drying relies heavily on upon the sun because it is easy and inexpensive. Drying is done as an effort to extend the shelf life of post-harvest products. The sun drying process can be carried out throughout the day if there is no cloud or rain. If the weather is erratic, it will hamper the drying process. Apart from being constrained by the weather, sun drying also has an impact on the additional burden of workers, namely sun exposure. This causes increased workload and worker fatigue. An alternative is to replace solar energy with biomass that is tailored to the needs and where smallholders live. Such is the condition of small farmers in Lombok, most of whom live in rural areas where the dominant agricultural product is paddy. Based on this, it produces waste in the form of rice husks. So far, rice husk waste is only used to warm livestock, and cook by burning rice husk directly, and the rest is burned because it is considered useless. Rice husk has the potential to be used as an energy source to replace the sun. This is based on the calorific value of rice husks of 11- 15.3 MJ/kg [1]. The maximum temperature for burning rice husks using a stove and direct combustion is 556.5oC and 560oC, respectively [2, 3]. Based on the participation of small farmers, they need a touch of appropriate technology at an affordable price and easy to operate. The participation of smallholders is very much needed so that a work tool can be used sustainably and does not cause new problems. The participatory principle is part of the application of the concept of ergonomics in adjusting workers to work tools. The principle of participatory ergonomics is the most effective way to redesign manual tasks to reduce the occurrence of work-related musculoskeletal disorders, reduce risks to safety and health, and create more human-centered work [4, * Corresponding author: I Gede Bawa Susana Department of Mechanical Engineering, Faculty of Engineering, University of Mataram, Jl. Majapahit No. 62 Mataram-Nusa Tenggara Barat 83125, Indonesia. Copyright © 2022 Author(s) retain the copyright of this article. This article is published under the terms of the Creative Commons Attribution Liscense 4.0. 5, 6]. Based on the concept that work is human-centered, to optimize the post-harvest drying process, it is carried out based on input from users, in this case, small farmers. Direct sun drying is very dependent on the weather, the emergence of musculoskeletal complaints and fatigue due to unnatural work postures, and exposure to sunlight during the drying process. Unnatural work postures pose a risk of muscle fatigue and injury, an increase in the level of musculoskeletal complaints which have implications for expenditures on health and well-being, as well as additional workloads and low productivity [7, 8, 9, 10]. To overcome things like this the drying process can use a drying chamber with biomass energy. Small farmers mostly live in rural areas and rice husks are abundant. The potential for rice husks in Lombok and West Nusa Tenggara is 269,420.20 tons and 533,150.80 tons, respectively, and 20% of rice husks are produced from rice processing by-products [11, 12]. 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Material and methods This paper examines the application of dryers based on the participatory concept, namely the participation of small farmers in the process of drying post-harvest products. Participation includes the dryers needed by small farmers according to the post-harvest products produced and the available biomass in their vicinity. A biomass dryer is needed as a substitute for direct or indirect solar drying. With the application of participatory principles, it is possible to find suitable drying solutions for small farmers in the drying process. The dryers studied included vertical and rotary shelf type dryers. The energy source uses rice husks with a heat exchanger as a means of transferring hot air. Field observations were carried out on several small farmers who carried out post-harvest drying activities. This is done to obtain the information needed for the design of a sustainable, efficient dryer according to user needs. 3. Results and discussion Furnace; 2. Drying chamber; 3. Air circulation holes; 4. Heat exchanger pipes; 5. Exhaust fan Figure 1 Single furnace dryer design with heat exchanger [23] Preliminary observations show that small farmers need different types of dryers for agricultural products to be dried. For energy sources, it is by the conditions in the smallholder environment, namely rice husk biomass. Rice husks are easy to obtain at low prices and sometimes free because rice husks are considered waste with abundant production. Rice husk provides 99.2% combustion efficiency, flame stabilization, and low emissions [21]. Rice husk as a substitute for firewood so that logging can be reduced [22]. Rice husk is used as a drying energy source through an energy conversion process using a heat exchanger. The hot air resulting from the burning of rice husks has flowed through the heat exchanger pipes into the drying chamber. 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The results are presented in Figure 2. Figure 2 has carried out a no-load performance test with the results of a higher drying temperature compared to the test results in Figure 1. This is due to the use of two rice husk burning furnaces. In addition, the drying chamber temperature is obtained by convection and conduction. While Figure 1 only uses convection. The desiccant designs of Figures 1 and 2 are suitable for foodstuffs such as lunkhead, chili, turmeric, and other grains. Grains such as corn or coffee require a homogeneous temperature in the drying chamber so that the final dry result is more evenly distributed. This is caused by the difference in temperature on each shelf in the drying chamber. This difference has an impact on uneven drying time. There is still a difference in drying time between the bottom shelf and the top shelf. This difference is acceptable, but based on user participation expect the same drying time, especially for grains like coffee. In addition, coffee farmers also want an automatic drying process that is easy to operate and does not experience fatigue due to sun exposure. Researchers, in this case, apply the participatory concept which is part of the ergonomics application. This is by Hidayat and

Purnomo that the application of participatory ergonomics methods can result in improved work systems through dryers that are designed jointly between the parties involved [28] in this case a small farmer. Based on the participation of small farmers who produce coffee, the researchers conducted a study on rotary dryers. The rotary dryer is designed is compact, namely, the combustion furnace is in one unit with the drying chamber. The mechanism is a rotary type dryer with a heat exchanger so that the dried product is not contaminated by gases from burning rice husks. The drying chamber consists of two cylinders, namely a fixed cylinder and a rotating cylinder. The heat exchanger pipes connect the furnace with a fixed cylinder. In the rotary cylinder, the foodstuffs are dried so that drying occurs evenly. The rotating cylinder is driven by a motor with gear transmission. Rotary dryer design as presented in Figure 3. The tool to be designed is expected to be cheap and easy to operate so that it can be accepted by users. The existence of this tool is expected to increase the selling value of plantation and agricultural products so that the income of farmers will increase. In Ettahi et al. It was explained that rotary dryers have been applied in various industries such as minerals, fuels, and food, and have wide applications involving heat and mass transfer between the gas and solid phases [29]. Rotary dryers are very fault tolerant making them suitable for installation in areas with poor infrastructure [30]. The drying chamber is a cylinder with a circular surface that rotates at a certain speed so that heat transfer occurs uniformly. Figure 3 Rotary dryer design with heat exchanger Rotary dryers are designed based on biomass energy, namely utilizing rice husk waste as an energy source. Hot air with a certain temperature and mass flow rate is produced through the process of converting rice husk energy into thermal. The heat transfer from burning rice husks occurs to the ambient air flowing in the heat exchanger pipes. This hot air is circulated uniformly using an exhaust fan mounted on a non-circular cylinder drying chamber. The driving motor functions to provide a driving force on the transmission device so that the cylinder rotating shaft can rotate at a certain speed according to the engine specifications. With this type of dryer, it is hoped that small farmers can increase the production of foodstuffs, especially grains. In addition, small farmers do not experience additional workloads due to sun exposure which has an impact on the risk of fatigue. 4. Conclusion Solar drying either directly or indirectly by using solar collectors still poses problems for small farmers. The relatively low temperature due to erratic weather and increasing the risk of fatigue for small farmers when carrying out the drying process. A vertical shelf type dryer with rice husk energy source is an alternative but by small farmers, it is not considered suitable for drying grain. The alternative is a rotary type dryer with a rice husk energy source following what small farmers need to dry foodstuffs in the form of grains. The results of the rotary dryer design show the desire of small farmers for this type of tool. Performance tests are needed to find out whether the rotary type dryer provides optimal results and is under the needs of small farmers. Compliance with ethical standards Acknowledgments The author also wishes to thank the Department of Mechanical Engineering, University of Mataram for facilitating the implementation of this research. Disclosure of conflict of interest The authors declare no conflict of interest. References [1] Awulu JO, Omale PA, Ameh JA. Comparative analysis of calorific values of selected agricultural wastes. Nigerian Journal of Technology. 2018, 37(4): 1141-1146. [2] Tangka JK, Ngah JK, Tidze VC, Sako ET. A rice husk fired biomass stove for cooking, water and space heating. International Journal of Trend in Research and Development. 2018, 5(6): 83-89. [3] Yan S, Yin D, He F, Cai J, Schliermann T, Behrendt F. Characteristics of smoldering on moist rice husk for silica production. Sustainability. 2022, 14(1): 317. [4] Burgess-Limerick R. Participatory ergonomics: Evidence and implementation lessons. Applied Ergonomics. 2018, 68: 289-293. [5] [6] [7] Wilson JR, Sharples S. Evaluation of Human Work. 4th ed. Boca Raton:

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