World Journal of Advanced Engineering Technology and Sciences
eISSN: 2582-8266
Cross Ref DOI: 10.30574/wjaets
Journal homepage: https://wjaets.com/

(RESEARCH ARTICLE)

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Ergo-mechanical evaluation of the post-harvest drying process on a small scale based on participatory principles

I Gede Bawa Susana * and Rudy Sutanto

Department of Mechanical Engineering, Faculty of Engineering, University of Mataram, Jl. Majapahit No. 62 Mataram-Nusa Tenggara Barat 83125, Indonesia.

World Journal of Advanced Engineering Technology and Sciences, 2024, 12(01), 222–227

Publication history: Received on 21 April 2024 revised on 28 May 2024; accepted on 30 May 2024

Article DOI: https://doi.org/10.30574/wjaets.2024.12.1.0215

Abstract

Using direct sunlight for the post-harvest drying process is easy and cheap for most small farmers in rural areas in developing areas. This method has weaknesses, namely the emergence of musculoskeletal complaints, fatigue, and additional workload due to unnatural working postures and exposure to hot sun on workers. Apart from that, the drying temperature is not optimal because it relies only on environmental temperature and is weather-dependent. As an alternative, a dryer can be used by applying ergo-mechanical principles. Ergo-mechanical is used to overcome work problems in the drying process and produce an ergonomic mechanical structure, thereby creating health, safety, and work sustainability. Ergo-mechanical applications are based on workers' participation as users, known as participatory principles. Participatory, as part of applying ergonomics concepts, aims to create harmony between work tools and workers. Ergo-mechanical is applied in designing dryers through ergonomic and mechanical studies to produce dryers that suit their needs and avoid causing new problems for small farmers. To design dryers, ergonomic studies were carried out using anthropometric data of workers as users. Meanwhile, mechanical studies were carried out by applying the principle of heat transfer between two fluids, namely fuel and environmental air.

Keywords: Ergo-mechanical; Drying; Ergonomics; Partisipatory

1. Introduction

Small farmers still dry their post-harvest crops in the sun. This process, viewed from a mechanical perspective, provides temperatures that are not optimal because it depends on the weather. The drying process will take a relatively long time and stop if the weather is cloudy or rainy. The weakness of using the sun impacts the continuity of drying, which cannot be maintained [1]. Ergonomically, sun drying provides additional work for workers or farmers due to work being carried out in the sun. This impacts the emergence of fatigue in workers. Participation from workers or farmers is very much needed for the post-harvest drying process to produce effective, comfortable, safe, healthy, and efficient work, which is known as the participatory principle.

Participatory as part of the application of ergonomics concepts aims to create harmony between work tools and workers to create comfortable and sustainable work. Participatory as part of ergonomics principles has the aim of minimizing health and safety risks, reducing musculoskeletal complaints, fatigue, and realizing more human-centered work, as well as being the most effective way to redesign manual tasks [2, 3, 4]. Worker's or farmers' participation is needed in post-harvest processing, such as in the drying process. Post-harvest management is an important step so that the quality of the material is maintained during the storage period [5]. In most developing countries, post-harvest losses occur in the agricultural sector due to inappropriate drying facilities [6]. Drying is needed to extend the shelf life of post-harvest products. Drying using the direct sun method is commonplace for farmers because it is cheap and easy to process. On

* Corresponding author: I Gede Bawa Susana.

the other hand, this drying is very weather dependent, causing unnatural working postures and additional workload on workers or farmers. The risks that can arise from unnatural working postures in workers are increased fatigue, musculoskeletal complaints, and muscle injuries, which impact health costs and low productivity [7, 8, 9, 10]. Ergo-mechanical applications are an important step in designing work equipment to prevent risks arising from working with unnatural postures. These applications integrate ergonomic and mechanical principles and produce ergonomic designs. Ergonomic mechanical structures are easy to use in various applications [11]. Ergo-mechanical is a system for studying the synergy of ergonomic and mechanical systems, namely the ergonomic synergy between workers and the mechanical system of work tools. This study is carried out on drying machines to increase labor productivity and efficiency [12]. Ergonomic mechanical structures are easy to use in various applications [11]. Ergo-mechanical is a system for studying the synergy of ergonomic and mechanical systems, namely the ergonomic synergy between workers and the mechanical system of work tools. This study was carried out on drying machines to increase labor productivity and efficiency [12]. Ergonomics principles are carried out by measuring the anthropometric data of workers as users, which is then applied in the form of percentile data to the dimensions of work tools. Ergonomic intervention by applying worker anthropometric data in designing or designing work tools can reduce fatigue and musculoskeletal complaints [14, 15]. The results of an ergonomic assessment of a work tool resulting from ergonomic intervention show that work posture becomes natural, reduced musculoskeletal complaints and fatigue, and increased comfort and productivity. Ergonomic interventions currently impact reducing complaints of musculoskeletal disorders (MSDs) widely [16]. Engineering, such as work tool design, is part of the Occupational Safety and Health Administration (OSHA) recommendations regarding ergonomic measures to prevent sources of disease [17]. This recommendation reduces musculoskeletal disorders in workers to avoid the risk of work injury.

Based on the above, in this paper, an ergo-mechanical study was carried out on the drying process using artificial dryers. Application of the dryer to change the worker's posture to a natural one. Tool design uses mechanical and ergonomic principles. Mechanical principle through the method of converting fuel energy into thermal. Fuel can be biomass or solar. Meanwhile, ergonomic principles use anthropometric data on workers as users of work tools. The study's results can be used as guidance in designing drying equipment to increase work comfort.

2. Scope and Methodology

Ergo-mechanical evaluation is used for small farmer activities related to post-harvest in the drying process. To maintain the quality of food during storage, important stages in post-harvest handling are required, such as drying to reduce activity and water content to a minimum level so that it is safe to store [5, 6, 18]. Drying is done in the sun, which is easy and cheap for small farmers in rural areas. This poses risks to workers' health and safety, such as musculoskeletal complaints, fatigue, and additional workload due to workers being exposed to sunlight. As an alternative, the drying process in the sun can be replaced by an ergo-mechanical system. Ergo-mechanical systems are used to overcome work problems related to work tools, ergonomics, and occupational health and safety. Ergo-mechanical is applied in designing dryers through ergonomic and mechanical studies to produce dryers that suit their needs and avoid causing new problems for small farmers. Ergonomic studies used anthropometric data of workers as users to design dryers. Meanwhile, mechanical studies are carried out by applying the principle of heat transfer between two fluids, namely fuel and environmental air. Heat transfer is produced by converting biomass or solar energy into thermal energy for drying. The energy conversion process can be carried out using a heat exchanger. Man-machine interface design defines ergonomics as an integrated human-machine system so that workers and machines or other products can function more effectively and efficiently [19, 20].

3. Results and discussions

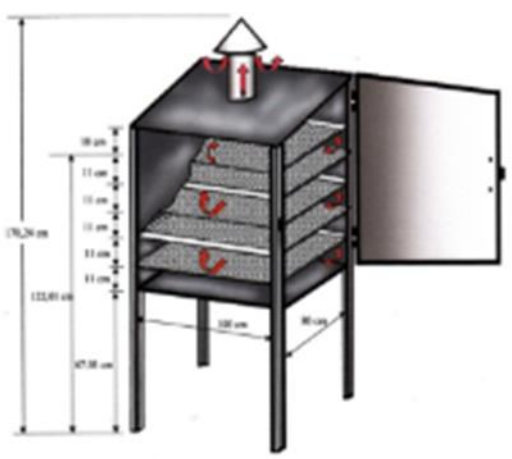
Most small farmers in developing areas dry food ingredients in direct sunlight. This is because energy is cheap and easy to obtain. In addition, modern technology is not affordable due to expensive costs and difficult operations for small farmers. Figure 1 shows the drying process.


a

b

Figure 1 Drying in the sun a) in the yard, b) on the roof

Drying using the method in Figure 1 does not comply with ergonomic and mechanical principles. According to ergonomic principles, workers perform work in unnatural postures such as bending and squatting (Figure 1a), being out of arm's reach (Figure 1b), and being exposed to direct sunlight. The process of manual agricultural work carried out with poor working posture causes musculoskeletal disorders (MSDs) with symptoms such as pain in the wrists, hands, knees, elbows, neck, lower and upper back, shoulders, and ankles [21]. Increased risk of injury to the musculoskeletal area due to work postures that are out of habit and wrong or unnatural [22]. Drying in the sun can be replaced by applying ergo-mechanical principles. In principle, ergo is ergonomics through the design of dryers based on anthropometric data of workers as users. Work tools that match the anthropometric data of workers have a comfortable impact on the production process. Anthropometrics is an ergonomic consideration in human or worker interaction with work tools. Humans have basic forms and sizes, such as height and width, and different weights from one another [23]. Anthropometric data is needed to create compatibility between tools and users, an effective, comfortable, safe, healthy, and efficient working atmosphere [24], and to reduce work disturbances and accidents, namely through appropriate equipment and workplace design with the help of anthropometric databases [25]. The application of anthropometric data impacts comfortable working postures for users or workers. A comfortable working posture is a body posture when done naturally. Natural working posture when working can minimize the occurrence of musculoskeletal injuries [26]. Application of ergonomics principles regarding humans as the center at work to reduce occupational health and safety risks [27, 28]. Work must be adapted to human abilities and limitations, in this case, workers, so that the results achieved can increase. In ergonomics, this is the principle of fitting the task to the man [29]. Figure 2 shows the application of ergonomic principles through worker anthropometric data in drying room design.


a

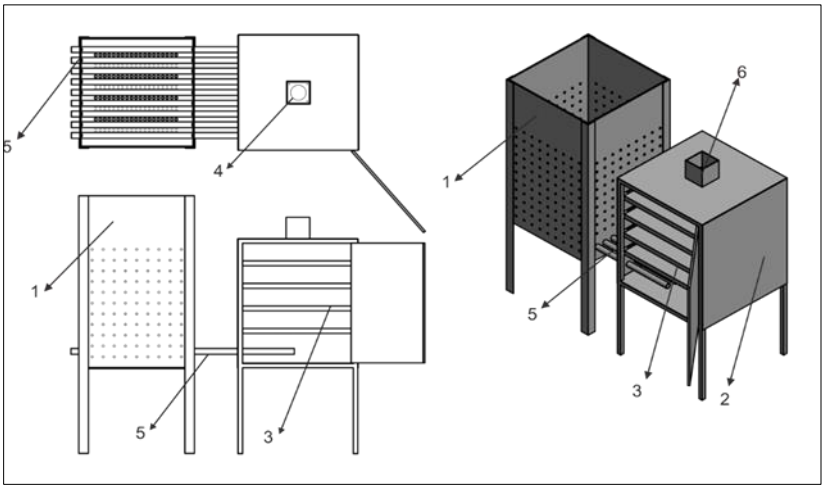
b

Figure 2 Drying chamber design based on ergonomics principles through worker anthropometric data [7]

The drying chamber in Figure 2a was designed based on ergonomic principles using anthropometric data of workers as users. This results in a natural working posture like Figure 2b, namely standing, compared to Figure 1a with a squatting working posture. In addition, workers are not exposed to direct sunlight because the drying process can be carried out in a shady place if using a biomass energy source. The drying chamber is designed based on workers' anthropometric data to produce an ergonomic tool design. This has an impact on preventing workers from sources of disease such as musculoskeletal complaints and fatigue which can cause work injuries. Exposure to risk factors for musculoskeletal disorders increases the risk of work injury. The Occupational Safety and Health Administration (OSHA) recommends

that ergonomic measures to prevent sources of disease include engineering, such as the design of workstations and work tools [30]. For this reason, it is very necessary to apply mechanical principles in designing work tools in addition to ergonomic principles.

The mechanical principle is applied through energy conversion to increase the ambient temperature through a heat exchanger. A heat exchanger is used to transfer heat from an energy source such as biomass or the sun to the environmental air so that hot air is produced for drying. Application of a heat exchanger for heat transfer in two fluids separated by a wall at different temperatures and without fluid mixing [31, 32]. Application of mechanical principles, as shown in Figure 3.



Furnace, 2. Drying box, 3. Drying shelves, 4. Exhaust fan, 5. Heat exchanger pipe, 6. Chimney

Figure 3 Dryer design based on mechanical principles [33, 34]

Designs like those in Figure 3 can use biomass energy sources such as rice husks, coconut husks, corn cobs, and other organic materials by burning them in a furnace. The heat resulting from burning biomass is transferred to the ambient air through the heat exchanger pipe walls. The hot air produced is used for the drying process in a closed drying chamber. This dryer is used in the shade because it does not require sun for drying. This means workers are not exposed to the sun's heat, preventing fatigue and additional workload. Apart from that, workers' working posture becomes natural because they no longer do work by squatting or bending. Applying ergo-mechanical principles is very important for workers so that work can be carried out effectively, comfortably, safely, healthily, efficiently, and sustainably. Work tools resulting from ergo-mechanical applications, namely the integration of ergonomic and mechanical principles, will produce ergonomic work tools that comply with technical specifications. Apart from that, the work tools are in accordance with what workers or farmers need as users. Compatibility between work tools and workers will provide a feeling of comfort when working and impact increasing productivity. Ergonomic assessments are important to increase productivity and reduce risks in physical work [14]. Ergonomic interventions currently have an impact on reducing complaints of musculoskeletal disorders (MSDs) widely [16]. Ergo-mechanical is used to overcome work problems related to the fields of work tools, ergonomics, and occupational health and safety [35]. Ergonomic mechanical structures are easy to use in various applications [11].

4. Conclusion

Based on studies conducted on several kinds of literature and research results, the drying process requires drying equipment that suits the needs of workers. The dryer is designed based on the participation of workers as users. Cost and technology limitations can be replaced with appropriate dryers that are affordable both in cost and technology. In addition, the drying equipment is adjusted to the worker's anthropometric data and drying temperature requirements. The application of ergonomics and mechanical (ergo-mechanical) principles is very important in designing dryers based on workers' participation as users. Ergo-mechanical applications impact the creation of ergonomic work postures, namely natural work postures because they are designed based on worker anthropometric data. In addition, the resulting drying temperature is more optimal than the environmental temperature. Mechanical applications play a vital role in producing the optimal temperature. This can be done by converting energy from a fuel source into thermal energy for drying. The ergo-mechanical system used in designing dryers integrates ergonomic and mechanical

principles. For the drying process, the application of ergo-mechanical principles produces a dryer that is easy to use by utilizing waste energy sources. Using dryers ergonomically means workers are not exposed to direct sunlight, so there is no additional workload. This creates work with a natural posture and avoids exposure to sunlight, thereby preventing the emergence of musculoskeletal complaints, fatigue, and additional workload.

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.

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