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Design of a Round Tofu Printer Using the Ergo-Product Design Method (Case Study: Mr. Andi's Tofu Factory Palembang)

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Abstract

Background. Tofu is the familiar Indonesian food. It is crucial to produce Tofu effectively and efficiently.

Aim. This research aims to help Mr Andi's tofu factory in Palembang, which has problems with the round tofu wrapping process. Workers are often absent due to specific events, which causes the owner to experience difficulties in producing round tofu. The processing time will be slower than usual, and the owner will have to hire spare tofu wrappers with more expensive wages. This round tofu maker is designed for Mr Andi's tofu factory.

Methods. The research method applies ergonomics in product design (Ergo-Product Design), which applies the AT, SHIP approach, and anthropometry.

Result. The research result is a tool made based on the dimensions of round tofu, size 6.25x6.25x4 cm^3. The cover, base, and pressing cloth size is 50x50x3 cm^3. The core part consists of a wooden part measuring 50x50x10 cm*3* and a small square inner part of aluminum measuring 6.25x6.25 cm*2*. The fabric presses are the same size but added with small nails made of ¾-inch mild steel positioned right in the center of each small square in the core.

Conclusion. The tool manufacturing cost is 560,000 IDR, and the maintenance cost is 10,000 IDR per month. Break event point in 13,728 units or 8,227,778 IDR and payback period in 2 days. Regarding environmental aspects, liquid waste from the tofu filter still exists because it does not change the production process. Worker energy becomes lighter, down 32 kcal/hour.

Implication. The tofu packaging process time is faster, and the amount of production is more significant.

Keywords: Round tofu maker, Ergo-Design Product, anthropometry, BEP, and Energy.

INTRODUCTION

The food industry in Indonesia is currently of particular concern to the public. Indonesia has many staple foods, including high-protein food made from soya beans. Tofu, in addition to the relatively cheap price, also has a reasonably high nutritional content

because the main ingredient is white soya beans, which contain many sources of vegetable protein for the human body. The tofu industry in Indonesia is spread in various regions, one of which is the tofu factory in Palembang city (Cholid & Sudrajat, 2023; Zulhanda et al., 2021; Zairinayati et al., 2020). One of the tofu industries in the Bukit Besar area of Palembang is Mr Andi's Tofu Factory. This tofu factory is one of the small industries that has been producing tofu for 8 years with 9 workers. The process of printing tofu is manually wrapped one by one by workers so it takes a long time and has a large error rate because it produces unequal sizes and often breaks.

The current situation to complete 1 cauldron (wooden drum 100 cm high with a diameter of 50 cm) requires 9 workers who are paid 15,000 IDR/cauldron/person with a completion time of 1 cauldron takes 1 hour. The main problem in this factory is that the workers needed must have special skills. Meanwhile, when tofu wrapper workers are needed to produce tofu, they often resign from work. This makes it sometimes very difficult for Mr Andi as the owner to find permanent workers with special skills and production costs increase because he has to use tofu wrapping workers with more expensive wages because they are considered to be reserve workers.

With this tofu printer, it is expected to print round tofu much faster and does not require a long time and the number of workers needed is not much and does not have to have special skills (Astria Hindratmo & Chendrasari Wahyu Oktavia, 2023; Rusdy & Muda, 2023; Sakuri et al., 2023). So that it can streamline production time and production costs are relatively smaller because only 1 to 2 workers are needed. So that it makes workers more enthusiastic, because workers' wages are greater but the work done is faster and lighter. This assumption is obtained because the process carried out resembles the way of working or the process of printing tofu plots, so the wages received by workers are greater. The work process, posture and physical work environment at Bapak Andi's Tofu Factory Palembang are presented in Figure 1.

Figure 1. Manual Wrapping And Moulding of Round Tofu

LITERATURE REVIEW

Tofu

Tofu is a favored cuisine among the Indonesian populace. It is a food consistently available daily, serving either as a side dish to rice or as a snack, in both its unprocessed state and as a modified ingredient in various tofu-based dishes. Tofu, a processed soybean product, serves as a fundamental food for nutritional enhancement due to its superior quality of vegetable protein, characterized by a comprehensive amino acid profile and an estimated digestibility of 85%-98%. The nutritional value of tofu remains inferior to that of animal-based foods, including eggs, meat, and fish. Tofu is created by exploiting the characteristics of protein, which coagulates upon interaction with acid (vinegar). The clumping of protein by acetic acid will occur rapidly and uniformly throughout the soybean juice, resulting in the entrapment of most of the initially mixed water within it. The release of confined water can be achieved through the use of pressure. Increased pressure facilitates the extraction of more water from protein aggregates. The aggregation of protein is thereafter designated as tofu (Widaningrum, 2015).

Round tofu maker

The tofu production method has multiple stages: soaking, washing soybeans, grinding, boiling, filtering, settling, and incorporating vinegar acid. A filtration procedure utilizing tools is essential for producing high-quality tofu and preserving its flavor. A stage in the tofu production process involves manual or traditional screening conducted by the home industry (Ardiawan & Waluyo, 2016). Tanjung et al. (2023) delineate the process of year production as follows:

1. Soaking. The seed cell structure softens upon soaking, resulting in reduced energy requirements for grinding. Furthermore, the liquid cell architecture will facilitate the separation of juice from pulp. The age, fluctuation, and temperature of the immersion water influence the immersion duration. Hot water is absorbed more rapidly. However, if the water exceeds 55°C, the soybeans may be partially cooked, resulting in a reduced yield of soy milk. The artisans typically perform the soaking procedure manually. The plastic and soaking buckets remaining in the sack constitute the soaking kit. Soaking soybeans involves adding sufficient water to a soaking tub (plastic bucket) containing dried soybeans that have been either stacked or encased in bags.
2. Milling. Soybean porridge is made by milling the seeds. The objective of grinding soybeans is to reduce their size, facilitating the extraction of protein from soy milk.

Culinary preparation. Once the soybeans are mashed, the resultant porridge is placed in a cooking vessel with water to achieve dilution. Subsequently, the soybean porridge is prepared. Observations indicate that 10 kg of dried soybeans will yield mature porridge. According to a tofu producer, eight buckets of water are required to produce ready-to-cook soybean porridge from 10 kg of dry soybeans.

3. Filtration. Soy milk, also referred to as soy milk, is generated by straining cooked soybean puree. Soybean dregs are typically filtered by positioning them over a calico cloth (coarse mori) or a chiffon fabric that is intentionally elevated above the reservoir. Subsequently, the most robust clamping boards and weights are employed to compress the soybean dregs, effectively extracting all moisture. The filter residue is repressed with water if required.
4. Acidification. Machine tools have not been employed in the processes of acidification or coagulation. Following the filtration of the cooked soybean porridge, the subsequent phase is coagulation or acidification. Artisans utilize "seeds," an acidic agent, to thicken soy milk.
5. Packaging and Printing. The coagulated soybean pulp is shaped to produce tofu.

Ergo-Design Product

Ergonomics derives from the Greek terms "Ergo," meaning work, and "Nomos," signifying rule or law. Ergonomics has certain limitations; in Indonesia, it is recognized as a science and its application aimed at harmonizing work and the environment with individuals, or vice versa, to attain maximum productivity and efficiency through the optimal utilization of human resources. The aforementioned screening technique has some drawbacks; specifically, it requires considerable labor and energy for personnel to agitate the soybean mixture, which must be filtered under a load of 6 kg and elevated temperatures near the furnace. The duration is considerable; the frequently updated filter cloth must be substituted, and during the filtration process, the hot soybean porridge is immediately put into the filter, exposing workers to the heat from the porridge. The screening activities conducted under the aforementioned conditions resulted in complaints of pain and discomfort in the workers' bodily regions. In relation to these issues, it is essential to create tofu filters grounded in ergonomic principles to mitigate complaints regarding the associated workload (Dermawan et al., 2020).

METHODS

The research method is to apply ergonomics in product design (Ergo-Product Design). Application of the Appropriate Technology (AT), Systemic, Holistic, Interdisciplinary, and Participatory (SHIP) approach and anthropometry (Pratama et al., 2022; Silviana et al., 2022). Observation and interviewing nine workers at Mr. Andi's Tofu Factory to know the problems that exist in the factory. Interviews were conducted to determine the condition of the work environment, production process, introduction of labor, and layout. The problem or object of research is the round tofu wrapping station. The purpose of this research is how to help Mr. Andi in the efficiency of wrapping tofu manually by wrapping it one by one and the wrapping process can still run without having to wait for a certain number of workers with special skills.

The data collected, namely: production process, tool design, technical aspects (tool dimensions), economic aspects (tool manufacturing costs), ergonomic aspects (hand span anthropometry), social and cultural aspects (habits), energy saving aspects (energy standards spent by workers), environmental aspects (waste). Followed by data processing, namely tool dimensions and sizes, Break Event Point (BEP), and Payback Period (PP). Processing of questionnaire results, energy, and calories. After the tofu printer is made with the processed data, its implementation is carried out directly at the round tofu wrapping station. After the implementation, an analysis was carried out between before and after the tool was made to see how the theory was used with practice in the field, with continued improvement. The research phase ends by providing conclusions on the research conducted and suggestions for Mr Andi's Tofu Factory (Arsyad Sumantika et al., 2024; Djunaidi et al., 2024).

DISCUSSION

Production process data and several aspects viz: Technical aspects, economic aspects, ergonomic aspects, socio-cultural aspects, energy saving aspects, and environmental aspects are processed using the Ergo-Product Design method by applying the AT and SHIP approach (Suarbawa et al., 2024; Yuliani et al., 2021). The dimensions and size of the round tofu printer are obtained by determining the length of each side of the round tofu printer, which is adjusted to the size of the wrapped tofu product, which has dimensions of 6.25x6.25x4 cm. So that the length of each side of the round tofu maker produces a size of 50x50x10 cm, with a wood thickness of 3 cm. The size of the dimensions of this round tofu maker after being obtained, then compared with the anthropometric measurements of workers from the span of the hand, hand grip, and the weight of the load that workers can

lift still enters the tolerance so that it is considered that the size of the dimensions of this round tofu maker can be used comfortably by round tofu wrapping workers at the tofu factory of Mr Andi (Silviana et al., 2022; Esqueda et al., 2020). The round tofu wrapper design results are presented in Figures 2 to 5. At the same time, the actual design is presented in Figure 6.

Figure 2. Top View of All Parts of the Tofu Moulding Equipment

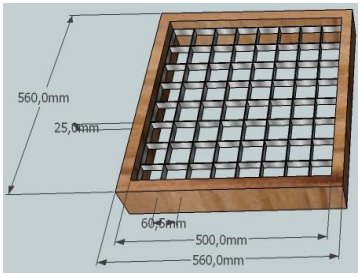


Figure 3.
Design of the Square Core Section of the Round Tofu Press

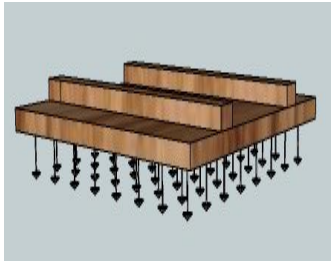


Figure 4.
Design of the Fabric Pressing Part

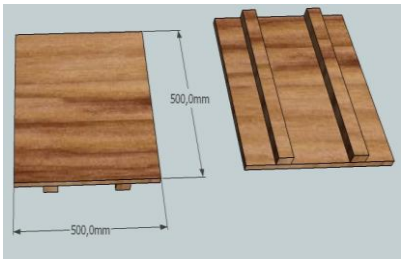
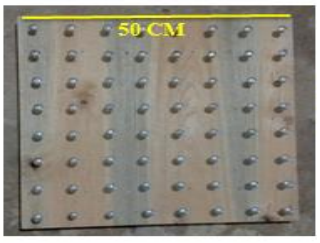


Figure 5.
Design of the Top (Cover) and Bottom (Base) of the Round Tofu Printer

Specificatios:
Weight: 3,5 kg
Long: 50 cm
Wide: 50 cm
Hight: 3 cm

Specificatios:
Weight: 3,5 kg
Long: 50 cm
Wide: 50 cm
Hight: 3 cm

Specificatios:
Weight: 4 kg
Long: 50 cm
Wide: 50 cm
Hight: 3 cm
Samll square: 6,25x6,25 cm



Specificatios:
Weight: 4 kg
Long: 50 cm
Wide: 50 cm
Hight: 3 cm
Nail height: ¼ inch

Figure 6. The Real Design of the Round Tofu Wrapping Tool at Mr Andi's Tofu Factory

Calculation of Break Event Point (BEP) in units of the round tofu printer, rupiah = 8,227,778, - IDR, BEP in units = 13,727.962 units ≈ (13,728 units), and rupiah Payback Period (PP) = 1.166 days ≈ 2 days. Paired t-test was conducted with the help of SPSS software with the hypothesis Ho: Tofu wrapping time before and after using the same tool, and H_1: Tofu wrapping time before and after using different tools t count = 46.070, t table = 1.69726, t count > t table, so Ho is rejected, meaning, there is a difference in round tofu wrapping time before and after. Total BK before = 163 kcal/hour. The results of the calculation of calories expended after the use of the round tofu maker resulted in a total of 131 kcal/hour expended by the average round tofu wrapping worker, using the working time after the use of the round tofu maker, which is 45 minutes/cup.

The difficulty in forming round tofu, which is usually done by wrapping cloth by workers one by one and takes a long time to complete the perkuali (a wooden drum with a diameter of 50 cm and a height of 1 metre), is 90 minutes, coupled with the habit of tofu wrapping workers who rarely come to work when there are events or personal matters, making it difficult for Mr Andi to complete this round tofu forming (Setiawan, 2023a). Mr. Andi had to find a replacement for the tofu wrappers with backup workers (H Setiawan & M Rinamurti, 2021). The round tofu to be moulded is also considered in terms of completion time if there are few workers and it takes longer to complete it, the result of the round tofu will be harder and of poorer quality than usual because the temperature of the tofu must remain hot. The reserve workers who are sought after to complete this packaged tofu must be paid higher wages than permanent workers at twice the usual cost because it is considered that the owner really needs it, so the cost of paying workers' wages will be higher while profits and production numbers remain (Victoriia, 2020). So the owner feels difficult if he continues to face problems with cases like this, so this research helps the owner by making a round tofu printer that can be used if some workers do not come to work. By paying attention to the product results remain in the same quality. The implementation of the Ergo-Product Design-based tofu printer is presented in Figure 7.

Figure 7. Implementation of the Tofu Printer Tool Based on Ergo-Product Design

Table 1. Implementation of Ergo-Product Design (AT and SHIP Approach)

Product Design Aspects (AT and Ship Approach)	Implementation Explanation
Appropriate Technology	
1. Technical Aspects	The making of the printer based on the dimensions of the round tofu which is 6.25x6.25x4 cm. This printer is also designed and made by considering how round tofu printing must use cloth as a filter and shaper that produces a neat surface of the tofu. So that in the implementation with a round tofu printer, it is still used. Size considerations in determining the length of each side, adjusted to the size of the wrapped tofu product which has dimensions of 6.25x6.25x4 cm. Consideration of the pressure generated so that the tofu can be formed perfectly. The length of each side of the tool is 50x50x10 cm, with a wood thickness of 3 cm. The size is determined from the span of the worker's hand and the worker's grip. The tool has 4 parts; the base, the core, the cloth pressing part, and finally the cover. The top and bottom covers each have a size of 50x50 cm with a thickness of 3 cm wood weighing 3.5 kg as a suppressor from above and below. The core of the tool is adjusted to the size of the tofu, which is 6.25x6.25 cm made of stainless steel aluminium. The weight of this core part is 4 kg, and its use as a round tofu printing. The fabric pressing part has a size of 50x50 cm as in the base and cover with a thickness of 3 cm wood, right in the middle of this square there are small nails measuring 4 cm positioned straight with a square on the core to be able to press the fabric straight in. The weight of the fabric pressing part is 4 kg. The total weight of the tool is 15 kg (Top cover = 3.5 kg, bottom cover:3.5 kg, core:4 kg, and fabric press:4 kg) (Dominguez-Alfaro et al., 2021)
2. Economical Aspects	The making of this round tofu printer can be said to be very affordable because the materials used are quite easy to obtain. Making tools costs 460,000 IDR per unit of equipment, maintenance costs for tools of 10,000 IDR/month. And the fabric used is more efficient than the previous way of wrapping the cloth and requires pieces of cloth measuring 25x25 cm for one tofu, with a round tofu printer only using a 1x1 m cloth for 64 tofu (Nadia Rawi et al., 2024).
3. Ergonomic Aspects	The design and manufacture of this round tofu maker is still oriented towards the dimensions of the worker's body. Collecting anthropometric data on the length of the hand reach of 6 tofu wrapping workers, the data becomes a consideration for comparing the standard reach, grip and weight that can be tolerated by workers. The size of 50x50 cm is obtained from the average hand span of 60.16 cm. It can be said that the size of 50 cm on the square side of the tool can be tolerated, while the size of the worker's hand grip is 13.3 cm compared to the height of this tool, which is 10 cm, which is still within the criteria of the tolerable limit. In the aspect of weight, this tool is very ergonomic because the total weight of this tool is 15 kg (Setiawan et al., 2023).
4. Socio-Cultural Aspects	The social and cultural aspects (habits) of the workers have been represented in the questionnaires distributed to the workers. One of the workers' habits is that workers often attend parties or personal activities, so they are often absent and other workers feel annoyed because they have to wrap tofu longer with fewer workers than usual. In addition, reserve workers who are hired under these conditions work by asking for double the wage because they are considered very much needed by the owner. The culture or habit of workers when using the tofu press is much faster because they can finish 1 cauldron of tofu in 65 minutes and it is no longer a burden when some workers are absent due to personal events. At first, workers experienced difficulties and felt unaccustomed to using the tool because it changed their habits that had been done for a long time and the printing results were also not very good, many tofu were still often damaged at the beginning, because they had to make a transition to try to get used to using the tool, so they started doing it many times until they got used to it and the results were also better. The round tofu printing process took 90 minutes before using the tool and 45 minutes after using the design tool (Setiawan et al., 2025) (Neag et al., 2020).
5. Energy-Saving Aspects	Energy and calories from round tofu wrapping workers can be calculated. Assuming the type of work performed by workers is a job that works by using 2 arms, standing, and carrying an average load of <5 kg can be said to include category II work and body position 2, with a humid working environment temperature due to a little heat of water vapour. The average work category is 53 kcal/hour while the average and total workload before using the tool is 111 kcal/hour and a total of 163 kcal/hour after using the round tofu printer tool the average and total workload is 78 kcal/hour and a total of 131 kcal/hour. There was a decrease in the number of workloads felt by workers (Ciccarelli et al., 2022).
6. Environmentally Friendly Aspects	Environmental aspects are related to waste, because waste is often one of the impacts on the surrounding environment (Rahayuningsih et al., 2022). The process of making tofu produces waste in the form of liquid, remaining water from the tofu that is filtered and drained properly into the disposal and the remaining fragments of tofu due to errors in packaging to be less (Setiawan, 2023b; Sworo et al., 2022).
SHIP Approach	
1. Systemic	The systemic aspects of the Ergo-Product Design-based round tofu maker include several components that are interrelated and affect worker performance and safety. Some of the resulting systemic aspects are; ergonomic tool design, temperature control, safety system, tool performance, maintenance, worker interaction, raw material quality, and work environment (Suparti et al., 2023).
2. Holistic	Some components of the holistic aspects obtained by the implementation of Ergo-Product Design-based tofu moulding tools are workers‘ physical and mental balance, workers’ quality of life, performance and productivity, health and safety, work environment, social interaction, tofu quality, and environmental impact (Dewi et al., 2024; Chidambaram et al., 2024; Setiawan, 2022).
3. Interdisiplinary	Considered are technology and engineering, ergonomics and anthropometry, health and safety, environment and ecology, social and culture, economics and business, education and training, and regulations and standards. Tools designed to meet workers' needs, improve performance, and minimise errors and accidents and minimise environmental impact (Lamarque et al., 2023).
4. Participatory	Several components enable workers to participate in the design process, development and use of the tool. Some of the participatory aspects to be considered are; worker involvement, worker feedback, participation in testing, education and training, technical support, information disclosure, participation in development, and community involvement (Lin et al., 2022).

This round tofu printer was designed and made by considering aspects of appropriate technology and the SHIP approach (Setiawan et al., 2024; Che Ani et al., 2022). The implementation of the TTG and SHIP approaches as a representation of Total Ergonomics in product design (Ergo-Product Design) is presented in Table 1.

CONCLUSION

(1) The design of an ergonomic round tofu printer based on the AT and SHIP approach consists of the top and cover dimensions of length-width-height of 50x50x10 cm, the core dimensions of 50x50x10 cm plus a small square measuring 6.25 cm made of aluminum as a place to print, in the pressing part of the cloth dimensions of 50x50x10 cm with the entire thickness of 3 cm wood by adding small nails made of mixed steel positioned right in the middle of the aluminum square in the core to press the cloth so that the position is ready to be filled with tofu to be printed. The cost of making a round tofu printing tool is 560,000 IDR. The cost of maintaining this tool is 10,000 IDR, and (2) the work time becomes faster when the round tofu wrapping workers are partially absent from work, and the work completed remains the same amount produced because it has been compared if it is done before using the tool the processing time is 90 minutes, using the cloth wrap method and by using the tool the processing time is 65 minutes, and by using the tool the processing time is 45 minutes.

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