Biochar Making Machines Design for Increasing Food Security

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Biochar Making Machines Design for Increasing Food Security

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Abstract

The development of sustainable agriculture is one of the steps to achieve national food security. The created agricultural system is demanded to be able to continue for the present and the future in managing resources for the sake of agriculture in meeting human needs. Over time, agricultural land in Indonesia has also decreased due to the consequences of increasing population growth. It is predicted that the depreciation of agricultural land can hamper sustainable agricultural development. Indonesia is included in the wet tropics, where many soils have undergone a further weathering process. This soil has low nutrient content, cation exchange capacity, pH, and organic matter, while for anion exchange capacity, the exchangeable aluminum, oxide, and clay content are high. High levels of aluminum in the soil can be toxic to plants. Toxic properties in the soil, which are caused by aluminum, which can be exchanged on acid soils, can be overcome by using pyrolysis charcoal, from now on better known as biochar. The purpose of this research is to design a biochar making machine to increase food security. Based on the needs, technology, and several other aspects, this research gets to design a prototype of a biochar making machine.

Keywords: design, prototype, biochar, agriculture, ergonomic

I. INTRODUCTION

The development of sustainable agriculture is one of the steps to achieve national food security. The agricultural system that is created is demanded to be able to continue for the present and future in managing resources for the sake of agriculture in meeting human needs while maintaining and improving environmental quality and conservation of natural resources. Sustainable agricultural development focuses more on conditions that will occur in the next few years, such as food shortages due to unfavorable political economy situations, extraordinary population explosions, and pandemics that occur in several countries.

Over time, agricultural land in Indonesia has also decreased due to the consequences of increasing population growth. It is predicted that the depreciation of agricultural land can hamper sustainable agricultural development. It is hoped that the use of marginal land will be a solution to the ongoing depreciation of land. Marginal land can be defined as fragile land, easily damaged by its sustainability if the management is not correct, and has the following main characteristics: (1) low fertility, (2) high

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erosion, (3) frequent drought or flood, (4) high level of high soil acidity, and (5) high toxicity under certain conditions (Sujana and Pura, 2015). Large marginal lands in Indonesia are Podsolic Red Yellow dry land and tidal marshlands. This land is very large, reaching around 51 million hectares, which are spread across Kalimantan, Sumatra, Sulawesi, Irian Jaya, and Java (Supraptoharjo, 1961; Rifin, Supriadi and Sutriadi, 1990). The total area of swamps in Indonesia covers 33.4 million hectares, of which around 9.5 million hectares are potential for agriculture and livestock (Rachim, Situmorang, and Hartono, 2000).

Indonesia is included in the wet tropics, where many soils have undergone a further weathering process. This soil has the properties of low nutrient content, cation exchange capacity, pH, and organic matter, while for anion exchange capacity, aluminum, oxide, and clay content are classified as high. (Sujana and Pura, 2015). High levels of aluminum in the soil can be toxic to plants. Toxic properties in the soil, which are caused by aluminum, which can be exchanged on acid soils, can be overcome by using pyrolysis charcoal, from now on better known as biochar (Lehmann and Joseph, 2009).

Biochar is a carbon-rich solid material converted from organic waste (agricultural biomass) through incomplete combustion or limited oxygen supply (pyrolysis) (Nurida, Rachman and Sutono, 2015). Simply put, biochar is a carbon-rich product that is obtained when biomass, such as wood, manure, or leaves, is heated with little or no available air in a closed container. Biochar is also known as biological charcoal with black carbon content derived from biomass, the process of biochar through combustion at temperatures <700°C under limited oxygen conditions produces organic matter with a carbon concentration of 70-80% (Lehmann and Joseph, 2012). This process often represents one of the oldest industrial technologies developed by humanity (Harris, 1999). The addition of biochar to agricultural soils serves to (1) increase nutrient availability, (2) increase nutrient retention, and (3) increase water retention (Glaser, Lehmann and Zech, 2002), (4) creates a good habitat for symbiotic microorganisms (Ogawa 1994), (5) increase the production of food crops, and (6) reducing the rate of CO_2 emissions, contributing to carbon stocks (± 52,8%) (Nurida, Dariah, and Rachman, 2013).

Raw materials that can be used for making biochar are biomass waste that is not used, such as rice husks, corn cobs, cocoa or chocolate pods, candlenut shells, coffee skins, wood saw waste, eucalyptus oil leaves, wood branches such as residual waste, animal feed, coconut shells, and the like (Widiastuti and Lantang, 2017). Various techniques for processing biomass waste into biochar are available, ranging from those using traditional to modern stoves, but they have not yet applied the ergonomic aspects in their design. Agriculture is a more dangerous industry than any other (Patel, 2017). Heavy physical work, inadequate work methods, work techniques, and equipment can cause fatigue, work accidents, and decreased productivity. Most of the agricultural tools or machines used are based on the body dimensions of western workers because the equipment is imported from there, so it is not suitable for the population in Indonesia because Western nations have higher body dimensions when compared to Indonesians (Patel, 2017). Therefore, this study aims to design ergonomic biochar making machine to minimize fatigue and work accidents by using Indonesian anthropometry.

II. LITERATURE REVIEW

The term ergonomics comes from Latin, namely "Ergon" and "Nomos", which can be defined as the study of human aspects of the work environment in terms of anatomy, physiology, psychology, engineering, management, and design or design. In ergonomics, it is necessary to study humans, work facilities, and their environment that interacts with each other with the main objective of adjusting the work atmosphere with the people. The design of machines, equipment, and ergonomic work environments has been applied in various fields.

Ergonomics intervention has been carried out for three years in the truck assembly factory sector to reduce Musculoskeletal Disorder (MSDs) (Zare et al., 2020). In this study, an evaluation of the effectiveness of ergonomic interventions, including technical and organizational interventions, was conducted. Five ergonomic solutions engineering solutions and organizational interventions have been implemented after a comprehensive ergonomic analysis is carried out. The organizational intervention consists primarily of the transfer and redistribution of tasks, as well as redesigning the workstation to make it more ergonomic.

Research at a cracker factory located in Medan, Indonesia has also been conducted by Andriani and Subhan (2016). This study aims to obtain an ergonomic work station through the design of a table and chair equipment. The design is done to get optimal working time to increase work productivity. The research describes the existence of a work station that is not ergonomic so that the operator works with ineffective movements and an unergonomic work posture. The results of the actual research contained five therblig movements, namely searching, reaching out, holding, carrying, and releasing. The standard time required is 4.89 minutes, while the work posture is obtained with level 7 and 6 with the action category shortly. The results of the research after the equipment design were carried out with a standard time of 0.98 minutes and the work posture obtained was mostly at level 1 in the safe category.

The rubber harvesting process on Punjung Island, Indonesia is still done manually starting from tapping activities to harvesting processes, it can be seen that the harvesting process can potentially cause complaints and injuries to joints (MSDs) (Anwardi et al., 2020). This study aims to produce a rubber harvesting aid that can reduce complaints and injuries to workers when taking latex from a bowl. The method used is the Ergonomic Function Deployment (EFD) to determine the criteria and dimensions of the tool that are following the needs of workers and tested using the Rapid Upper Limb Assessment (RULA) method. The results showed that the design tool could reduce complaints on the activity of reaching rubber from action level-3 to action level-2, while for rubber prying activity from action level-4 to action level-2. This happens because the design tool has dimensions of length 36 cm and a width of 16 cm, which can improve the way the work position is more ergonomic.

Santosa and Renawati (2016) have designed a tool for breaking the logs of cashew seeds that can be used by farmers by paying attention to ergonomic aspects so that farmers can work comfortably, safely, and easily in carrying out these breaking activities. With this tool, it is hoped that farmers will be able to increase their production capacity because farmers no longer need to use a bat to break cashew nuts one by one to get the cashew. Besides, the energy needed to complete this activity is very light, because the workload is no longer focused on the hands; it can be reduced by moving some of the workloads with leg movement activities.

Hasimjaya, Wibowo, and Wondo (2017) have also conducted research to obtain anthropometry for children aged 3- 4 years and used to determine ergonomic furniture sizes with users so that it can reduce discomfort and avoid the appearance of abnormalities due to errors and mismatches in using furniture. This study uses a quantitative method of survey explanation format. The results of this study are the body size of the Siwalankerto children aged 3-4 years and the size of the furniture that suits them based on the anthropometry.

III. RESEARCH METHODOLOGY

This research is a quantitative study using a biochar making machine as the research object. The instrument used in this research is literature study and observation, and the variables used are anthropometric data of Javanese men at productive age, which refers to the research results of

Ismianti, Herianto, and Ardiyanto (2019). The methodological steps of this study are shown in Figure 1.

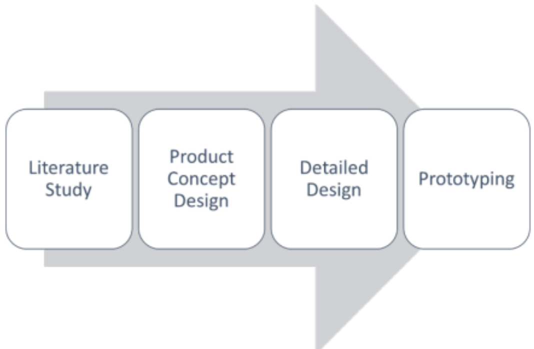

Figure 1. Research methodology

III.1. Literature Study

At this stage, a search for various written sources in the form of books, journals, proceedings, or documents that are relevant to the problem being studied is carried out. The information obtained from this literature study is used as a reference to strengthen existing arguments.

III.2. Product Concept Design

Product concept design is developed with the following process: establishing a mission, identifying needs and wants, establishing product specifications, creating a design concept, and finally, industrial design (Tontowi, 2016).

III.3. Detailed Design

Detailed design is the stage that is carried out after the concept design is completed. In discrete manufacturing products, detailed design is known as engineering drawing, which is used as a communication tool between the designer and the manufacturer. The process for making technical drawings on a biochar making machine can be done using the help of Computer-Aided Design (CAD) software.

III.4. Prototyping

After the detailed design in the form of engineering drawings (CAD) is completed, the next process is making a prototype. The prototype can be defined as a preliminary picture before the real product is made.

IV. FINDING AND DISCUSSION

IV.1. Overview of the Making Process of Biochar

The raw material for biochar in the form of coconut shells is dried beforehand to dry because the reduced water content in the coconut shells will accelerate the pyrolysis process. The Pyrolyzer tool used here is Rotary Drum Pyrolizer (RDP) or pyrolizer with a rotating barrel system. The advantage of this tool is that the combustion heat is evenly distributed on all sides of the barrel wall (Herlambang et al., 2017). With even heating, the pyrolysis time will be relatively short and the results obtained from biochar will be perfect. This RDP is also equipped with a cover so that the heat released into the environment will be reduced. The combustion source used is a gas stove with a horizontal evenly ignition so that the sides along the barrel wall will be exposed to fire. The combustion process lasts for about 5 hours, with a temperature of approximately 300ºC – 500ºC.

IV.2. Product Concept Design

Setting Mission

A product to be made, at an early stage, needs to define its mission. This mission contains seven points, namely (a) a brief description of the product, (b) the benefit proposition, (c) the purpose of the manufacture, (d) who is the primary target market, (e) who is the secondary target market, (f) what assumptions need to be taken, and (g) who are the stakeholders (Tontowi, 2016). This mission assignment serves as a guide for the product's journey to the market. The mission of the biochar making machine is presented in Table 1.

Table 1. The mission of Biochar Making Machine

Number	Mission	Description
1	Product brief description	Biochar Making Machine
2	Benefit proposition	Evenly combustion on all sides of the barrel wall so that the pyrolysis time will be relatively short and the results of the biochar obtained will be perfect.
3	Purpose of making	To design an ergonomic biochar-making machine to minimize fatigue and work accidents.
4	Primary target market	Farmer
5	Secondary target market	Agricultural industry
6	Assumption	The anthropometry used was male Javanese at a productive age
7	Stakeholders	Farmer

Identifying Needs and Desires

Data or information on needs and wants can be obtained from two sources, namely internal sources and external sources (Tontowi, 2016). Internal sources are information derived from existing products to be developed. Information can be in the form of information about deficiencies that exist in existing products. This deficiency can be interpreted as a Product Opportunity Gap (POG) concept by Cagan and Vogel (2002). Based on the identification of needs, Table 2 describes the requirements of a biochar making machine.

Table 2. Identification of the Need for a Biochar Making Machine

Needs
Evenly burning
Short pyrolysis time
Adjustable temperature
Affordable and inexpensive materials and equipment
Equipment/systems that are easy to maintain
Easy to operate machine/system
Practical and easy to move (portable)

External sources are information that comes from outside the product itself. This information can be technology and SHE IS FATER (Tontowi, 2016; Nursubiyantoro, Ismianti, and Wibowo, 2020). SHE IS FATER is information that considers SHE (Safety, Health, Environment), (2) Innovation and intellectual property rights, (3) Standard of the product, (4) Function, (5) Aesthetics, (6) Trends of the product, (7) Ergonomics, (8) Regulation.

Defining Product Specifications

User needs are generally expressed in the form of "layman or user" which must then be converted into a specification language. Specifications or also known as product specifications are defined as precision descriptions that describe what the product must describe (Tontowi, 2016). The preparation of specifications in this study is based on the need for these new products because similar products are not yet on the market and anthropometric data on Javanese men at productive age has been produced by Ismianti, Herianto, and Ardiyanto (2019). From the data, the percentile is calculated to be used in determining the size of the machine facilities. So that later it can be used ergonomically. Researchers used three percentile levels in the design of this biochar making machine. Table 3 shows a list of metrics.

Table 3. Metrics

Metrics Number	Metrics	Percentile	Dimensions	Units
1	Upright height	P50	171	cm
2	Standing shoulder height	P50	141	cm
3	Standing elbow height	P50	106	cm
4	Palm length	P5	17,45	cm
5	Forearm length	P5	22,96	cm

Creating Design Concepts

The next step is to create a design concept based on the specifications of the results of Step 3. In this study, the product design concept that has been made has considered needs, technology, and SHE IS FATER. The design concept of this study is illustrated in Figure 2.

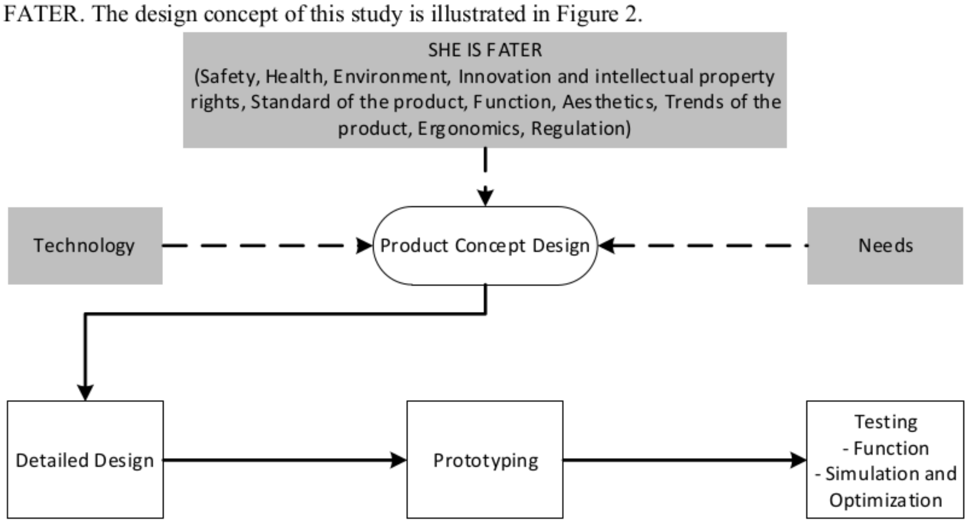

Figure 2. The concept of product and process design in this research

Industrial Design

According to the IDSA (Industrial Designer Society of America), industrial design is defined as a professional service in terms of the creation and development of concepts and specifications to optimize function, value, product appearance, and systems to provide benefits to users and manufacturers. To test whether the industrial design of the product is being worked on fulfills the need for ergonomic and aesthetic aspects, so it can be done by testing it using the following questions (Tontowi, 2016):

a) *Ergonomics needs:*
   1. Is the product easy to use and easy to care for?
   2. How many users in this product?
   3. Does the product have a novelty?
   4. Is the product safe to use?

b) *Aesthetic needs:*
   1. Is there any differentiation in the product?
   2. Do the people, who use the product, feel proud, and have a better image?
   3. Does the aesthetic aspect motivate the product development team?

After answering these questions, the product design of the biochar making machine can be said to be quite good and attractive to users when viewed from the ergonomic and aesthetic aspects.

IV.3. Detailed Design

The process for making technical drawings on biochar making machine is carried out using Computer-Aided Design (CAD). CAD drawings cannot be displayed in this paper for research purposes.

IV.4. Prototyping

After the detailed design in the form of engineering drawings (CAD) is completed, the next process is making prototype a and refining it into prototype b. Both of these prototypes were made following technical drawings. The process of making a prototype for a biochar making machine can be started by manufacturing components or parts, then assembling them into chunks. The chunk is assembled with other chunks into modules. The modules are assembled to become a prototype.

After prototype a is completed, testing is then carried out to make sure that the prototype is functioning as planned. The results of the prototype a test are then used as input in making the prototype b. Given that the prototype is a prototype that is ready to be used as a reference for the final product and a reference in designing the production system, this prototype must be more detailed. The testing required includes a functional test and a display test.

The designed biochar making machine is a Rotary Drum Pyrolizer (RDP) or a pyrolyzer with a rotating barrel system. This tool is equipped with a temperature control device and a rotary lever on the outside of the tool. The advantage of this tool is that the combustion heat is evenly distributed on all sides of the barrel wall. With even heating, the pyrolysis time will be relatively short and the results of the biochar will be perfect. The Rotary Drum Pyrolizer used here is also equipped with a cover, so that the heat released to the environment will be reduced. The gas stove is a combustion source that is used with evenly horizontal ignition so that the sides along the barrel walls will be exposed to fire. The Pyrolizer Rotary Drum Tool is made based on several references to existing pyrolysis tools; then, a redesign is carried out and the addition of several tools in the pyrolysis process. Besides, the pyrolysis device used is not too large in volume and is also portable, so it will be easy to operate in various places and locations.

(a) Combustion tube (b) Temperature levers and controls

Figure 3. Rotary drum pyrolizer (RDP)

(a) Rotary Drum Pyrolizer with Lid (b) Source of Combustion

Figure 4. Rotary Drum Pyrolizer Tool Components

V. CONCLUSION AND FURTHER RESEARCH

The pyrolysis machine that has been made emphasizes the use of pre-owned stuff that is easily available. For the efficiency of this machine, there may still be heat lost to the environment, so it is necessary to make a heat barrier that is more effective than what has been made. Then this machine is also not designed for a large industrial scale considering the capacity of raw materials that can be accommodated in this pyrolyzer is only around 50-100 kg of coconut shell. In addition to coconut shell pyrolysis, this tool can also be used to make biochar from various kinds of biomass. The length and heat load used will certainly differ depending on the materials used. For further research, it is hoped that it can design a biochar making machine that can optimally convert coconut shell and other biomass materials into biochar. In further research, cutting tools can be added to the machine so that it can produce coarse biochar and fine biochar. As an alternative, large-scale industrial biochar making machines can be designed.

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