Green Coal Machine: Innovative Solution for Processing Organic Soil Enhancer from Compost and Coal Testing Waste

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***Abstract*— The Eco Green Campus Program adopted by Sepuluh Nopember Institute of Technology (ITS) aims to create a campus that is sustainable and environmentally friendly with a focus on cultivating healthy organic soil. However, tillage Organic soil require organic materials which are quite expensive and difficult to obtain, such as organic fertilizer. Therefore, innovative solutions are needed through utilization of abundant local resources such as remaining coal samples with compost that called Green Coal which was made into quality organic soil enhancer. Coal has very complete nutrients and can be used as fertilizer. In addition, the use of coal as fertilizer can reduce the potential for degradation of the quality of agricultural land. In order to meet the needs in ITS parks, coal from the rest of the laboratory testing samples can also be used as a source of soil fertilizer. However, the results of the production is still lacking by number so sometimes the compost is applied though its still half ripe. To increase its effectiveness, organic compost waste is used as a soil conditioner through the use of coal. ITS has succeeded in developing a soil enhancer product named Green Coal from residual coal sample. However, the process of making Green Coal is done manually and is constrained by time constraints. Therefore, in this research, a 3-in-1 Green Coal machine was carried out to increase the efficiency of Green Coal production. The 3-in-1 Green Coal machine consists of a chopping machine, a sieving machine and a mixing machine in one machine so it can simplify processes, cost and time efficiency in the production process. The results of this research showed that a 3-in-1 Green Coal machine can produce 10 kg/minute of Green Coal soil enhancer products.**

Keywords: Green coal, Organic soil enhancer, 3-in-1 machine

I. INTRODUCTION

ONE of the important aspects in ITS Eco Green Campus program is organic soil processing to support optimal plant growth. However, organic soil processing usually requires sufficient expensive organic matter and difficult to obtain, such as organic fertilizers. Chemical and mineral fertilizer usage revolutionized the agriculture sector and doubled global crop yields since early 1900 [1]. Organic solid waste is a valuable biomass resource that contains bioavailable organic materials, but it also poses environmental challenges as a potential pollutant, serving as a source and sink for greenhouse gas emission [2] [3][4]. Therefore, innovative solutions needed so that can process abundant local resources such as remaining samples of coal and organic waste to be used as quality organic soil enhancer.

Coal has contents that make it possible to be used as fertilizer, because the nutrients in coal are very complete. Low-rank coals, encompassing lignites, brown coals, leonardites (highly oxidized lignites), and peats, emerge as fossil fuel resources through carbonization processes, with their global reserves estimated at approximately 500 billion tonnes [5]. Lignite boasts a rich concentration of humic substances and oxygen-containing functional groups, making it an ideal and sustainable carbon matrix and porous carrier for crucial plant nutrients like nitrogen, phosphorus, and potassium [6]. The use of coal as fertilizer can reduce the potential for degradation of agricultural land quality. This degradation can occur due to the application of agricultural methods in Indonesia which only return nutrients to the soil including 3 elements, such as Nitrogen, Phosphorus and Potassium. In fact, in one planting cycle there are 23 soil elements that need to be absorbed by plants. Damage or decreasing soil quality has an impact on the tendency of decreasing productivity and nutritional content of food commodities.

Based on its characteristics and implementation, there are several advantages from using coal as fertilizer, namely: 1. Soil fertility and nutrient requirements for plants can be maintained; 2. The nutrient content of the fertilizer is relatively the same as the plant content; 3. The best raw materials for fertilizer come from plants and must be available in large quantities; 4. Fertilizer can be made in a short time, on a large and massive scale and at low cost; and 5. Not changing habits in the application.

To divert organic waste from landfills, composting is among the implemented strategies [7]. In order to meet the needs of organic farming, apart from processing organic waste such as leaves, tree twigs and plant residues, coal from remaining test

samples in the laboratory can also be used as a source of compost. Composting is an appropriate treatment method for the harmless resource utilization of green waste [8]. Compost containing high concentrations of organic matter can significantly reduce soil pH, improve nutrient absorption, and promote plant growth [9]. However, the production results are still low, so sometimes the compost is applied even though it is still half-cooked. To increase its effectiveness, the organic waste compost is used as a soil conditioner through the use of coal, so that it becomes an organic soil enhancer product called "Green Coal".

The process of making Green Coal soil enhancer is done manually, start from chopping to packaging. However, this processing process is constrained limited time because it has to be done manually. In facing the increasing demand, it is necessary to use a 3-in-1 machine that can speed up, simplify processing and produce homogeneous soil enhancer. In this context, the Green Coal machine is presented as an innovative solution that utilizes remaining coal samples as raw material for organic soil processing. Thus, the Green Coal machine can help overcome the problem of coal waste while increasing the availability of organic material for environmentally friendly organic soil processing.

II. METHODS

The research method used in developing the Green Coal Machine: Innovative Solution for Processing Organic Soil Improvement from Compost and Leftover Coal Samples for the ITS Eco Green Campus can involve several stages, starting from literature study. This stage was carried out with the aim of collecting information related to the processing of waste and organic materials such as compost and remaining coal samples, as well as the technology that can be used to process these materials into Green Coal Machines. Literature studies were also carried out to understand the basic concepts of the Green Coal Machine and the tools needed to make the machine.

The second stage is Green Coal Machine Design, which involves designing a Green Coal machine which consists of several components, such as a chopping machine, mixer machine and sieving machine. Biomass comminution equipment have been classified into knife mills, hammer mills and disc mills. Chopping is required for either use, and reducing the shearing force has been regarded as one of the most efficient methods to save energy [10]. Hussein, et al [11] developed a hammer mill suitable for laboratory and commercial use which had a crushing efficiency of 94.7%. Adekomaya and Samuel [12] reported the design of a hammer mill with crushing efficiency of 94% that reduces processing losses and eliminates health hazard experienced by the operator. Machine design must consider aspects of ergonomics, efficiency and production feasibility.

The third is making a prototype: After the design of the Green Coal Machine is complete, the next stage is making a machine prototype. At this stage, testing is carried out on the Green Coal Machine prototype to ensure that the machine can function properly and according to the desired design.

The final stage is testing and evaluation: This stage is carried out by testing the Green Coal Machine on a small and large scale to ensure the effectiveness and efficiency of the machine in processing organic materials into a Green Coal Machine. Evaluations are carried out on production results, the quality of the Green Coal Machine, and the production costs required.

In general, the prototype of the Green Coal Machine is explained as follows: The soil amendment material is put into the chopping tube and the material that is fine and passes the filter will fall into the sieve tube in the mixing tube. During the mixing and sieving process, the tube will rotate until all soil amendments that have passed through the sieve size have been processed and the remaining material that does not pass through can be taken from the sieve tube. Trials were carried out directly on a 3-in-1 prototype machine for processing soil amendments, producing soil amendments with a crumbly and homogeneous texture.

III. RESULTS

The design of the 3-in-1 Green Coal machine, which consists of a chopping machine, a sieving machine and a mixing machine, takes into account aspects of ergonomics, efficiency and production feasibility. The results of designing the 3-in-1 Green Coal machine structure are as follows:

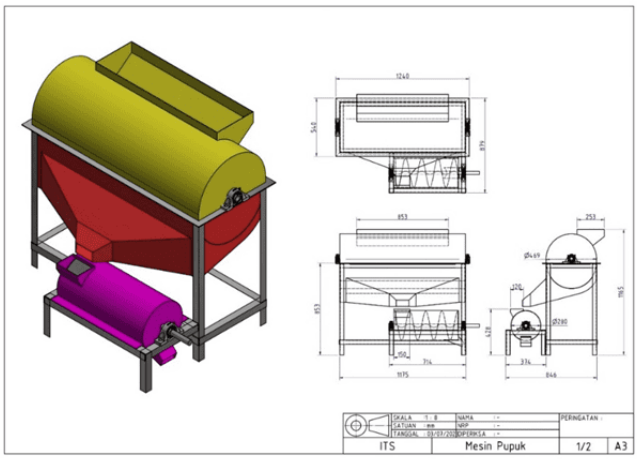

Fig. 1. Green Coal Machine Prototype Design Model

The overall height of the machine is 116.5 cm with a yellow tube component containing a chopping knife, then a tube under the red chopping machine as a sieving machine, where the material that passes through the sieving machine will enter the mixing machine. In the mixing machine tube, the output can be adjusted to regulate the length of the mixing process. In this way, the compost and coal materials will be completely mixed homogeneously.

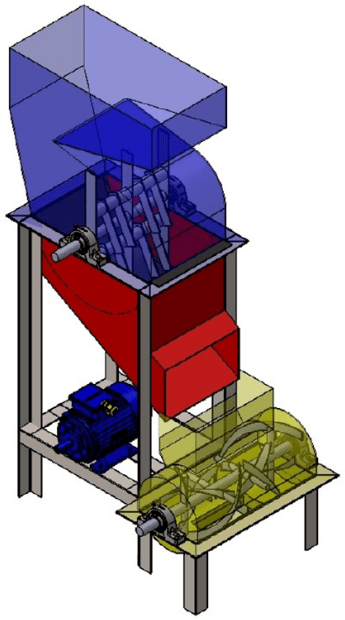

Fig. 2. Green Coal 3-in-1 Machine Design

The chopping and filtering machine frame is made of stainless steel with an angled structure of 4 x 4 cm, each corner has a height of 0.8 meters, a length of 0.4 meters and a width of 0.25 meters, as shown in the following picture:

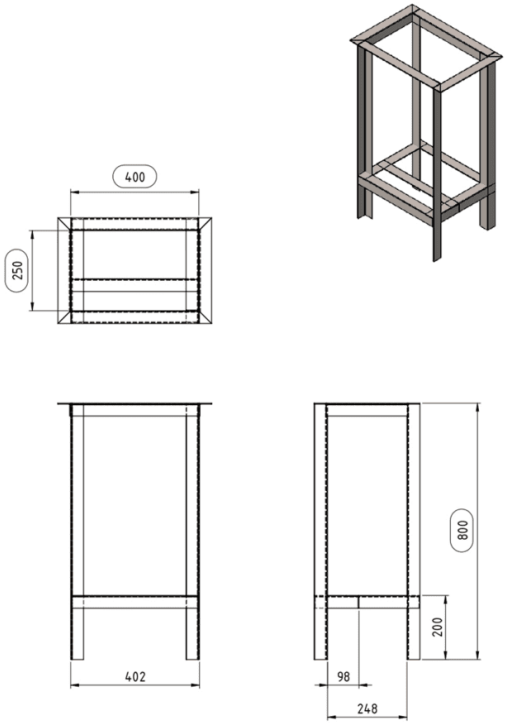

Fig. 3. Shredding and sieving machine framework

Meanwhile, for the mixing machine, the frame is also made of stainless steel with an angled structure of 4 x 4 cm, each corner has a height of 0.2 meters, a length of 0.4 meters and a width of 0.23 meters.

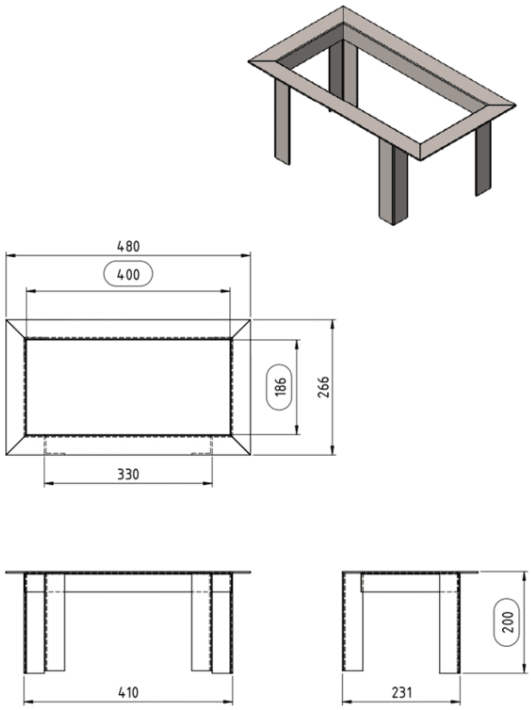

Fig. 4. Mixing Machine Framework Structure

The chopper mechanism uses a single-axis rotary knife consisting of 8 knives as shown in Figure 5, where the part of the knife is directly adjacent to the filter so that all the compost and coal mixture that has passed the chopping and sizing will pass directly through the sieve. After going through the sieve, to ensure the homogeneity of the Green Coal, the material goes directly into the mixing chamber and will be stirred by a knife as shown in Figure 6.

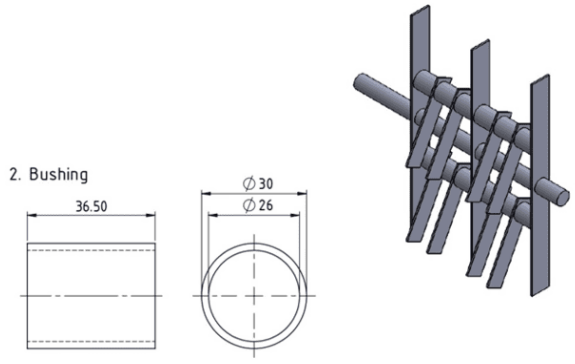

Fig. 5. Bushing components

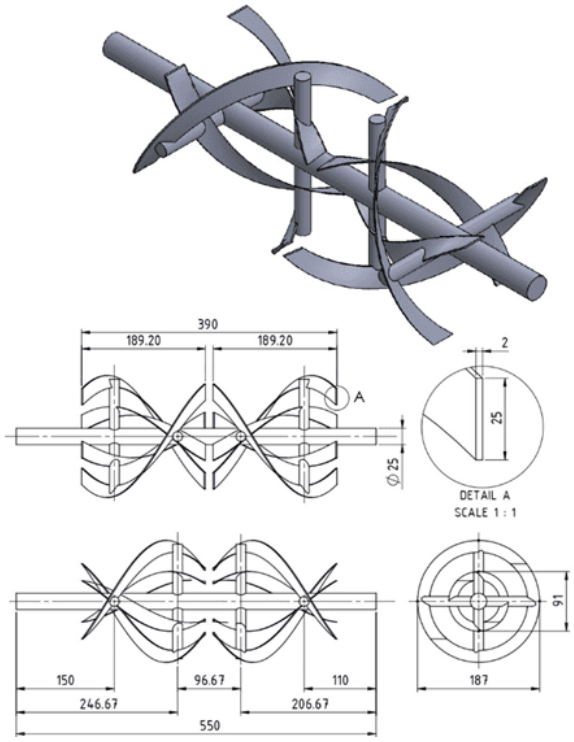

Fig. 6. Mixing Components

The results of chopping, sieving and mixing will come out through the outlet and be collected in a container placed below the outlet. From this design, a Green Coal machine was created with the following results:

Fig. 7. Side view of the 3-in-1 Green Coal Machine

Fig. 8. Front view of the 3-in-1 Green Coal Machine

The 3-in-1 Green Coal machine is made portable with 2 wheels on the 2 corners of the machine frame so it can be moved easily. With the main drive being a 220 Volt engine with a chopping speed of 1450 RPM, it can be operated indoors or outdoors. The driving motor has a voltage specification of 220 Volts, Horsepower 1.5 hp and a motor rotation speed of 1480 RPM. For stirrer rotation using a gearbox with a ratio of 1:30, it can be calculated:

Mixer Speed = N/30
Mixer Speed = 1450 rpm /30
Mixer Speed = 48,3 rpm

So the rotation output from the gearbox is 48.3 rpm with a pulley ratio of 1:1 between the gearbox and the stirrer. Meanwhile, the torque on the chopper motor is as follows:

T=((5252 x P))/N
T=((5252 x 1,5 HP))/(1480 rpm)
T=7878/1480
T=5,32 Nm

with:
T =Torque (Nm)
P = Horsepower (HP)
N = Motor rotation speed per minute (rpm)

where 5252 is a constant value for motors in HP (horsepower) units. The chopper motor has a torque of 5.32 Nm, this is because the chopper does not require a large torque, but only requires high speed to chop light work objects such as compost. The 3-in-1 Green Coal machine production capacity test was carried out with an input mass of 5 Kg per batch. The results of

the production capacity trial are as listed in the following table:

TABLE I
THE 3-IN-1 GREEN COAL MACHINE PRODUCTION CAPACITY TEST RESULT

Test number	Input (Kg)	Mixed Moisture	Operating Time (s)
1	5	Moist	30
2	5	Dry	25
3	5	Moist	30
4	5	Moist	30
5	5	Moist	30
6	5	Moist	30
7	5	Very Moist	35

From the Table 1 above, it can be seen that humidity affects the speed of the 3-in-1 Green Coal machine operation process. The drier the raw material used, the faster the operation time required, and vice versa, the more humid it is, the longer the operation time will be required. This is because, damp materials cause the material to stick to machine components because there are soil components in the compost material, which slows down the process of sieving.

Fig. 9. Input channel when filled with 5 kg of green coal

Fig. 10. 3-in-1 Green Coal Machine Output

As shown in Figure 10, the resulting output is well chopped and homogeneous mixed with fine compost and coal. Overall, the specifications of the 3 in1 Green Coal machine are as follows:

TABLE II
THE 3-IN-1 GREEN COAL MACHINE SPECIFICATIONS

Dimension	480 x 708 x 1250 Mm
Heavy	± 90 Kg
Power	1,118 Watt
Voltage	220 Volt
Counter speed	1450 rpm
Mixing speed	48 rpm
Production capacity	10 Kg/minute

IV. CONCLUSION

Based on the results of testing and analysis of the tools carried out, it can be concluded that the machine can work to produce Green Coal soil enhancer products that are homogeneous and match the targeted size. The knife chops the compost perfectly and passes straight through the sieve which is then processed by the mixing machine. With a combination of chopper, siever and mixer in one machine, it can shorten the time and steps required in the production process, as well as reduce production costs. The average time required to process coarse compost into Green Coal products is 30 seconds for every 5 Kg of input, because the capacity of the input channel once fully entered is 5 Kg. The fastest time needed to process is 25 seconds for a raw material capacity of 5 kg Green Coal, while the longest time is 35 seconds. This is influenced by the humidity of the raw material, so this machine is recommended for organic compost materials from twigs, leaves and other organic materials with moderate humidity. This machine is not suitable for processing organic materials from food waste and materials with high humidity because it can slow down the sieving process. This machine needs to be developed for processing materials with high humidity.

REFERENCE

[1] Y. A. Y. Abdellah, Y. Sen Luo, S. S. Sun, X. Yang, H. Y. Ji, and R. L. Wang, "Phytochemical and underlying mechanism of Mikania micrantha Kunth on antibiotic resistance genes, and pathogenic microbes during chicken manure composting," *Bioresour Technol*, vol. 367, Jan. 2023, doi: 10.1016/j.biortech.2022.128241.

[2] R. Thangarajan, N. S. Bolan, G. Tian, R. Naidu, and A. Kunhikrishnan, "Role of organic amendment application on greenhouse gas emission from soil," *Science of the Total Environment*, vol. 465. pp. 72–96, Nov. 01, 2013. doi: 10.1016/j.scitotenv.2013.01.031.

[3] E. Sinha *et al.*, "Implication of imposing fertilizer limitations on energy, agriculture, and land systems," *J Environ Manage*, vol. 305, Mar. 2022, doi: 10.1016/j.jenvman.2021.114391.

[4] T. M. W. Mak, X. Xiong, D. C. W. Tsang, I. K. M. Yu, and C. S. Poon, "Sustainable food waste management towards circular bioeconomy: Policy review, limitations and opportunities," *Bioresource Technology*, vol. 297. Elsevier Ltd, Feb. 01, 2020. doi: 10.1016/j.biortech.2019.122497.

[5] E. Sarlaki *et al.*, "Improving sustainability and mitigating environmental impacts of agro-biowaste compost fertilizer by pelletizing-drying," *Environmental Pollution*, vol. 285, Sep. 2021, doi: 10.1016/j.envpol.2021.117412.

[6] M. Rashid *et al.*, "Carbon-Based Slow-Release Fertilizers for Efficient Nutrient Management: Synthesis, Applications, and Future Research Needs", doi: 10.1007/s42729-021-00429-9/Published.

[7] S. Brown, "Greenhouse gas accounting for landfill diversion of food scraps and yard waste," *Compost Sci Util*, vol. 24, no. 1, pp. 11–19, Jan. 2016, doi: 10.1080/1065657X.2015.1026005.

[8] K. Yu *et al.*, "Application of quadratic regression orthogonal design to develop a composite inoculum for promoting lignocellulose degradation during green waste composting," *Waste Management*, vol. 79, pp. 443–453, Sep. 2018, doi: 10.1016/j.wasman.2018.08.018.

[9] W. Y. Chia *et al.*, "Sustainable utilization of biowaste compost for renewable energy and soil amendments," *Environmental Pollution*, vol. 267. Elsevier Ltd, Dec. 01, 2020. doi: 10.1016/j.envpol.2020.115662.

[10] V. D. Vu, T. T. Nguyen, N. H. Chu, Q. H. Ngo, K. T. Ho, and V. Du Nguyen, "Multiresponse optimization of cutting force and cutting power in chopping agricultural residues using grey-based Taguchi method," *Agriculture (Switzerland)*, vol. 10, no. 3, Mar. 2020, doi: 10.3390/agriculture10030051.

[11] T. Hussain Mohamed, A. Osama Elashhab, M. Adly, H. A. Radwan, A. O. Elashhab, and M. Y. Adly, "DESIGN AND EVALUATE OF A SMALL HAMMER MILL." [Online]. Available: https://www.researchgate.net/publication/295549563

[12] O. Adekomaya, "Design and Development of a Petrol-powered Hammer mill for rural Nigerian Farmers," 2014. [Online]. Available: https://www.researchgate.net/publication/291357548