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Utilization of Environmentally Friendly Energy in Organic Fertilizer Processing Machine

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ABSTRACT

Agriculture is the primary livelihood for most of Indonesia's population, which has vast agricultural land. However, there remains a dependency on chemical fertilizers, which degrade soil quality compared to organic farming that can optimize plant health and productivity. The energy needs in the agricultural sector, including mechanization and fertilizer production, are critical but still heavily reliant on fossil fuels. It is, therefore, essential to reduce this dependency by utilizing environmentally friendly alternative energy sources. This study examines the use of solar energy to power machines in the process of producing organic fertilizer. The tools used in the study include a 100 Wp solar panel, solar energy conversion components, a 12 Volt 33 Ah battery, a ¼ Hp electric motor, a voltage and current meter, a temperature gauge, a sunlight intensity meter, and an organic fertilizer processing machine. The research method analyzes several variables, including sunlight intensity, power, voltage, current, charging time, and battery usage. The study found that the solar panel used was insufficient to power the ¼ HP motor, requiring the addition of three more solar panels and batteries to meet the motor's power requirement of 233 watts. Battery charging tests required 3 hours, and battery usage for machine operation without solar panel installation lasted 1 hour and 40 minutes, while battery usage for machine operation with solar panel installation lasted 6-7 hours.

1. INTRODUCTION

The use of organic fertilizers to enhance plant growth and ensure sustainability in agricultural land management needs to be increased. Manure alters the physical, chemical, and biological properties of the soil, which supports soil quality improvement and has a positive impact on better crop yields. Manure in the soil is a heterogeneous and dynamic component, consisting of molecules with various structures, decomposition rates, and turnover times, which adds value to soil quality (Fageria, 2012). Modern advancements have led humans to depend on plants to meet daily needs, which has impacted the intensification of agricultural production. The expansion of crop cultivation has resulted in decreased nutrient availability in agricultural soils, necessitating the addition of appropriate nutrients to enhance crop yields. The use of chemical fertilizers has significantly positively impacted global food needs. However, excessive use of chemical fertilizers can have negative effects, potentially causing long-term damage to agricultural soils, as has been studied by previous researchers (Yahaya *et al*., 2023).

The application of chemical fertilizers in rice-wheat cropping systems can maintain and enhance soil fertility; however, over time, it can deplete soil nutrients. Organic matter in the soil plays a crucial role in the nutrient cycling that supports long-term soil fertility. Long-term soil fertility can be improved through the balanced application of manure (Bhatt *et al*., 2019). Plant nutrition is crucial for plant growth, enabling the production of healthy crops vital for human health. Therefore, plant nutrients are a key component of sustainable agriculture. Research on improving yields of nutritious food crops largely depends on the fertilizer used to supply nutrients to the plants. This has been previously studied by Chen (2006).

Research on solar panels has advanced rapidly and is now applied on a large scale in agriculture, including the use of solar panels for tractors. The trend of using fossil fuels in agricultural machinery is increasing, making it crucial to reduce agriculture's dependence on fossil fuels, which have negative environmental impacts. Therefore, the adoption of infrastructure supporting alternative energy sources is becoming increasingly important. Renewable energy sources are highly suitable for agricultural activities. This technology, which converts solar energy through solar panels, can reduce the use of oil-based fuels in agriculture by providing a more efficient and sustainable method of electricity generation, thus helping to reduce environmental pollution. With the rising need for electrification in modern agriculture, the use of solar panel technology in this sector is becoming more relevant. This study evaluates the integration of solar panel technology with electric agricultural tractors and robots, as well as the impact of solar panel light intensity on the torque of electric motors (Gorjian *et al*., 2021).

The processing of goat manure is still done manually by farmers in rural areas, often through grinding, and some also use mechanical methods with gasoline or diesel engines, which can be costly and difficult for rural farmers to access. An effective energy solution that can address this long-term issue is to utilize alternative and renewable energy sources available. Solar energy is a promising option due to its abundant availability. Solar power is more competitively priced compared to other energy sources and can support the livelihoods of millions of underprivileged people in Indonesia. Research on solar energy devices can provide significant benefits for the environment and the economy in developing countries (Devabhaktuni *et al*., 2013).

Solar energy is beginning to be utilized for processing fertilizers, particularly organic fertilizers, which are commonly applied in the processes of drying, fermentation, and composting. This research aims to use a 100 Wp solar energy system to assist farmers in crushing or grinding goat manure, thereby accelerating the absorption of fertilizers by plants compared to intact manure. The study of multifunctional solar-powered agricultural machines can be applied across various agricultural fields, helping to reduce the costs associated with fossil fuel usage. This machinery can be utilized for seed sowing, watering, and mowing grass, which helps reduce the costs of unskilled labor in the agricultural sector, improves production efficiency, and speeds up the processes of fertilizing and mowing, research in these areas has been conducted by Chadalavada (2021).

Environmentally friendly energy is key to addressing economic issues in rural areas with limited access to energy sources. The use of solar panels helps farmers save on production costs in the agricultural sector, such as irrigation and the operation of solar-powered agricultural machinery, including organic fertilizer processing machines and lighting. Solar panel technology enables farmers to irrigate and operate equipment at a lower cost because sunlight is freely available year-round. Solar energy can strengthen farmers' efforts in processing agricultural products, thereby increasing selling prices and farmers' income. Utilizing this renewable energy opens up broader and more sustainable economic access for rural communities, playing a role in reducing poverty factors. Photovoltaic devices can provide benefits for the environment and rural economies, making it necessary to study solar technology more extensively in various applications. Research on the benefits of solar energy for the environment and rural economies can be conducted by (Pratap *et al*., 2014). Previous research on the use of organic fertilizers powered by a 100 Wp solar panel focused on the application of portable solar-powered organic waste shredding technology, as well as a plant control monitoring system for organic fertilizers use (Ashari *et al*., 2024; Mardiyanto, 2019).

Reducing the use of fossil fuel-based energy compels us to find new ways to generate electricity sustainably, to address future energy challenges as well as related environmental issues. This effort aims to tackle various problems in the agricultural sector to enhance agricultural productivity and support Indonesia's economy. As a strategy to address future energy challenges, a modular solar energy approach can be adopted to meet sustainable energy needs in Indonesia. Considering these issues, we analyzed the use of solar energy as an alternative to help small-scale farmers power motors for manure crushing machine, thereby reducing their reliance on gasoline

2. MATERIALS AND METHODS

2.1. Materials

The materials used in this research include organic fertilizer obtained from goat farms in rural areas. The preparation stages of the manure start from collecting it from goat pens, drying, crushing, or grinding, mixing it with other media such as rice husks and cocopeat, to the packaging and marketing process. In the crushing stage, solar energy is used to power the manure crusher motor, with the aim of easing the workload of rural farmers.

2.2. Tools

The main equipment used in this research consists of a livestock waste crusher machine powered by a 1/4 HP DC electric motor, which drives the waste crusher shaft through a V-belt, along with a 100 Wp solar panel. The specifications of the electric motor used are 1/4 HP/186 Watts, with a rotational speed of 1450 RPM and a voltage of 220 volts. To operate this 1/4 HP electric motor, a 220-volt AC voltage is required, which comes from the inverter output. The inverter input is sourced from a 33 Ah 12-volt battery. The battery is charged by the solar panel. The specifications of the 100 Wp polycrystalline solar panel are as follows: Maximum Power (Pmax) of 100 W, Optimal Operating Voltage (Vmp) of 17.6 V, Optimal Operating Current of 5.7 A, and dimensions of 1002 x 670 x 35 mm. The specifications of the Zeus brand solar panel battery are as follows: Capacity: 12 volts 33 Ah, equipped with a light intensity meter, an inverter to convert DC to AC voltage, a tachometer, a multimeter, and a temperature sensor.

2.3. Solar Panel Assembly for Organic Fertilizer Processing Machines

The assembly sequence for solar panels and electric motors for organic fertilizer processing machines is presented in Figure 1 and Figure 2.

Figure 1. Assembly of research equipment

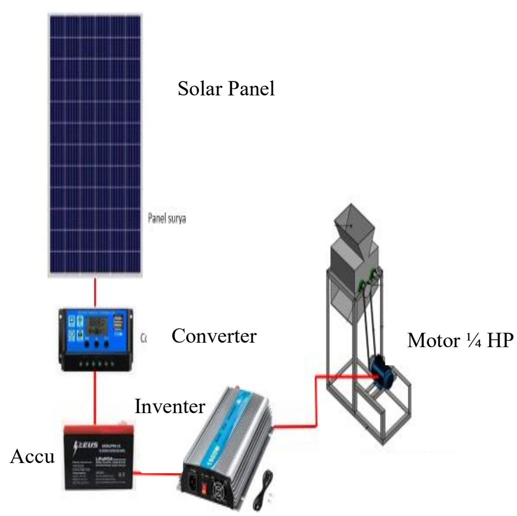

Figure 2. Solar panel installation and engine assembly

2.4. Variables and Measurements

Variables and measurements for solar panel performance included light intensity measured using light intensity meter, voltage and current using multimeter, and generated power using wattmeter. Battery charging and discharging (usage) were also observed by measuring voltage and current, both at initial and final conditions, as well as time required. Detail variables and methods were summarized in Table 1.

Table 1. Variables to analyze the performance of 100 Wp solar panel used in the experiment

Variable testing	Measurement method	Unit
Ligth Intensity	Light intensity meter	W/m^2
Voltage (V)	Multimeter	volt
Current (I)	Multimeter	A
Power (P)	Wattmeter	W
Battery Charging-Discharging		
Initial and final voltage	Multimeter	volt
Initial and final voltage	Multimeter	A
Time required for charging-discharging	Stop watch	hour

3. RESULT AND DISCUSION

3.1. Solar Panel Testing

The panel testing data is presented in Table 2. Based on Figure 3 and Table 2, the test data shows that sunlight intensity has a significant effect on the voltage produced. When the sun is at its peak during midday, the panel generates a higher voltage of around 20 volts compared to the morning and evening, which produce 16 and 17 volts, respectively. This study resulted in the highest power output of 100 watts from the panel, compared to previous studies on solar cell conversion efficiency, which found the maximum power output to be 64.59 watts (Nisrina *et al*., 2024). Meanwhile, the findings on the effect of the sun's angle on sunlight intensity are consistent with previous studies conducted by Mamun *et al*. (2022); Yilmaz *et al*. (2015); Kacira *et al*. (2004).

Table 2. Solar panel testing data

Number	Time	Light intensity (W/m^2)	Temperature (°C)	Input voltage (V)	Input current (A)	Power (W)
1	09:00	750	33	17.1	5	85.5
2	09:20	750	33.7	17.1	5	85.5
3	09:40	780	34.4	17.6	5	88
4	10:00	770	34.9	18	5	90
5	10:20	770	35.1	18.5	5	92.5
6	10:40	770	35.7	18.9	5	94.5
7	11:00	790	36	19.1	5	95.5
8	11:20	860	36	19.6	5	98
9	11:40	870	36	19.9	5	99.5
10	12:00	840	37.1	20	5	100
11	12:20	870	37.5	20	5	100
12	12:40	870	37.8	20	5	100
13	13:00	860	37.8	20	5	100
14	13:20	890	37.8	20	5	100
15	13:40	890	37.8	20	5	100
16	14:00	870	37.8	20	5	100
17	14:20	880	37.8	20	5	100
18	14:40	790	37.8	19	5	95
19	15:00	801	37.6	18.9	5	94.5
20	15:20	793	36.4	18.1	5	90.5
21	15:40	790	35.6	17.8	5	89
22	16:00	770	35.1	17.3	5	86.5
23	16:20	760	34.8	17.1	5	85.5
24	16:40	760	34.1	16.6	5	83
25	17:00	760	34.1	16.1	5	80.5

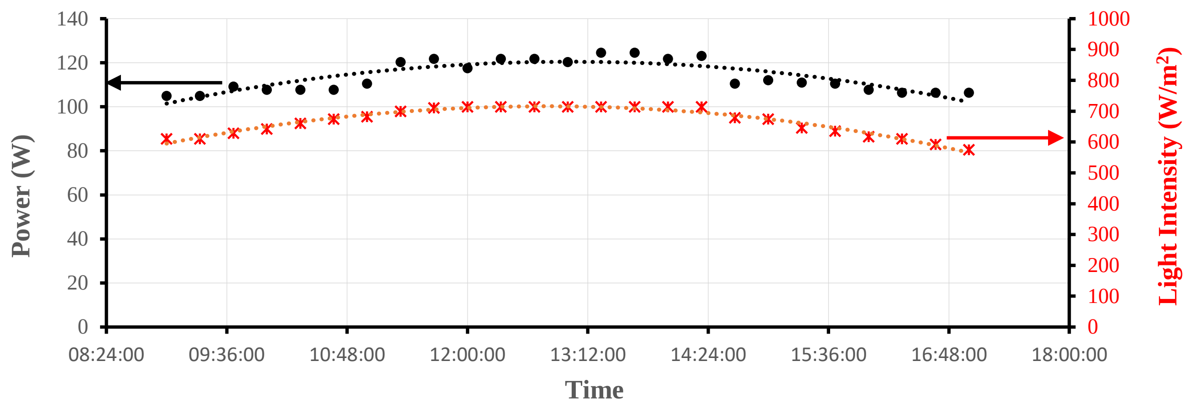

Figure 3. Solar panel test analysis graph of power and light intensity

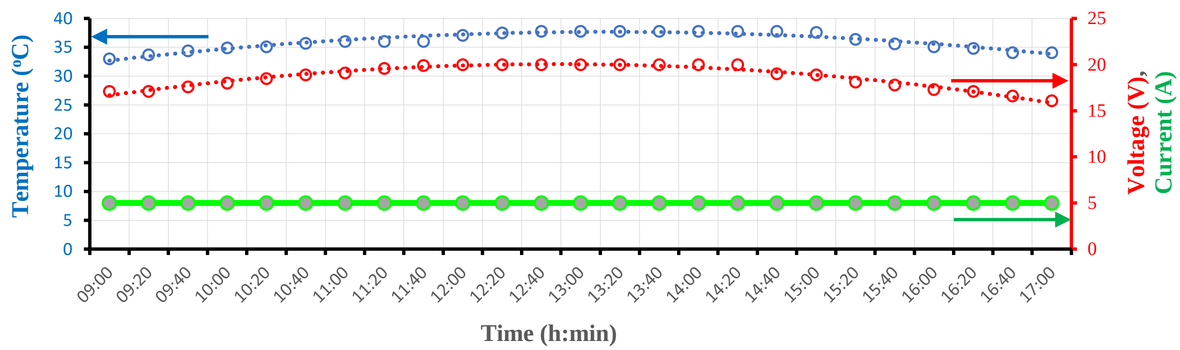

Figure 4. Solar panel test analysis graph of temperature, voltage, and current

3.2. Solar Panel Performance for Manure Crusher

Based on Figure 5, Figure 6, and Table 4, the testing data and graphical analysis of the manure crusher machine are presented. The sunlight intensity obtained was sufficient for normal levels, but the limitation lies in the panel's capacity, resulting in a lower power output for larger-scale farming since the panel generates less than 400 watts, and the battery is only 12 volts, which limits its ability to store much power. The motor used for processing organic fertilizer is a ¼ horsepower motor, requiring a torque of about 3 Nm with a power output of 186 watts and a current requirement of 2 amperes. This solar-powered processing machine still has a relatively small capacity, but it can be utilized by small-scale farmers to process manure fertilizer. During testing, the machine took 5 minutes to process 2 kg of manure, with a capacity of 24 kg/hour, as presented in Figure 3, Figure 4, and Table 3 below. Test data for organic fertilizer processing machines with solar panels are presented in Table 3.

Table 3. Test data for organic fertilizer processing machines with solar panels

Time	Light intensity	Load (kg)	Motor speed (Rpm)	Blade speed (Rpm)	Current (A)	Voltage (Volt)	Power (W)	Torque (Nm)	Work time (min)
08.00	680	2	2500	1215	2	180	360	2.6	5
09.00	740	2	2500	1225	1.9	186	353.4	2.7	5
10.00	800	2	2500	1225	1.9	190	361	2.8	5
11.00	880	2	2500	1225	2	186	372	2.9	5
12.00	890	2	2500	1255	2	186	372	2.9	5
13.00	890	2	2500	1235	2	186	372	2.9	5
14.00	870	2	2500	1230	1.9	181	343.9	2.8	5
15.00	760	2	2500	1210	1.9	180	342	2.7	5
16.00	700	2	2500	1220	1.9	180	340	2.7	5

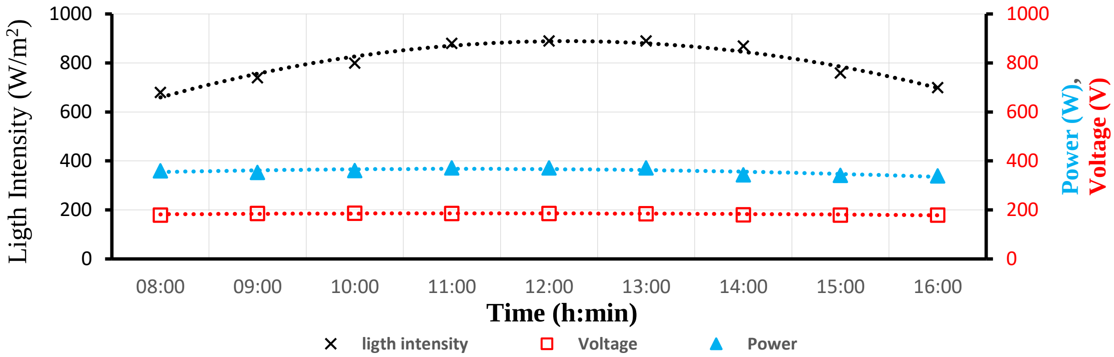

Figure 5. Graphic analysis of light intensity, voltage and power of solar panel during manure crushing operation

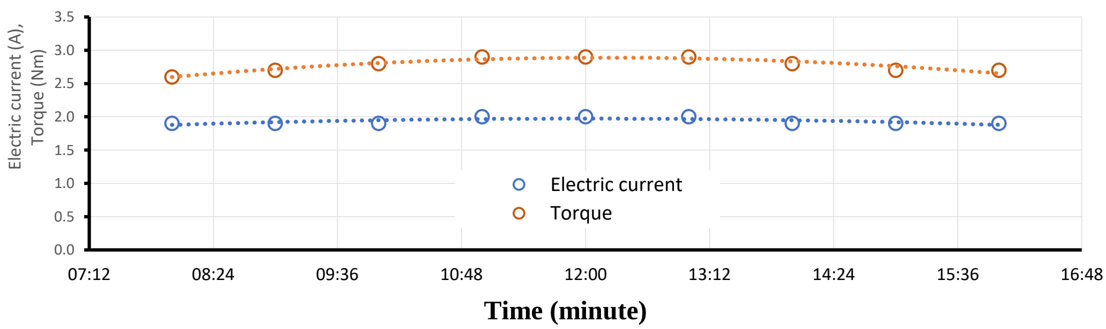

Figure 6. Electric current and torque of crushing machine

3.3. Solar Panel Performance Analysis

3.3.1. Analysis of temperature, input voltage and incoming current on the battery

The analysis of the influence of solar heat intensity on the power, current, and output generated by the panel is shown in Table 4 and Figures 3 and 4 below. Solar heat plays a significant role in determining the results obtained from the solar panel, including the amount of power, current, and voltage. As light intensity increases, more energy reaches the solar cells, which causes an increase in the electric current. The voltage may also increase, although it typically rises at a slower rate than the current. The combination of the increases in current and voltage subsequently results in higher power output, since power is a product of current and voltage. The highest power of 100 watts was achieved with a light intensity of 890 W/m², while the highest voltage was 20 volts, and the current generated was 5 amperes at a temperature of 37.8°C. Previous studies investigating the impact of sunlight intensity on the electricity produced by solar panels have explored the relationship between solar intensity and the output power, researched by Perraki & Kounavis (2016); Chaichan & Kazem (2016). The performance parameters of solar panels studied by previous researchers indicate that the intensity of sunlight is linearly related to temperature variations. As sunlight intensity and temperature increase, the maximum output power also increases (Zaini *et al*., 2015). Sunlight intensity and temperature play a crucial role in the solar panel conversion process. This study was conducted by previous researchers, who found that the solar panel's output power depends on sunlight intensity (Aish, 2015).

3.3.2. Analysis of solar light intensity produced by solar panels

Figure 2 shows that sunlight intensity is affected by the sun's conditions in both the morning and evening, as well as during cloudy weather. Although sunlight intensity should be optimal between 10:00 AM and 2:00 PM, cloudy conditions can reduce the solar panel's efficiency in capturing sunlight. Figure 3 presents a graph of sunlight intensity, which shows that in the morning and evening, the intensity is around 750 W/m², with the highest intensity recorded at

1:20 PM, reaching 890 W/m². Sunlight intensity is highly dependent on weather conditions. This study aligns with previous research that investigated sunlight intensity on photovoltaic systems under hot and cloudy conditions to determine the impact of temperature and sunlight intensity changes on the surface of solar panels (Masthuta & Abdullah, 2024).

The electrical performance parameters of photovoltaics and the identification of the factors influencing them have also been studied by previous researchers, who investigated the effect of solar radiation on solar panel performance. They found that an increase in light intensity can lead to an increase in maximum power output (Li *et al*., 2021). The sun's angle significantly influences the power requirements of electric current and the torque needs of machines. The intensity of sunlight affects the amount of electricity generated and can also impact the torque produced by the machine. In reality, sunlight intensity can be influenced by weather conditions, such as clouds, which can reduce the heat available, thus hindering the optimal performance of the machine's torque.

Additionally, previous studies have examined the effects of solar panel conditions and other factors that can influence solar panel efficiency. One finding indicated that the highest solar panel intensity occurs at 1:30 PM, with an intensity of 1544.2 W/m². Conversely, during overcast conditions, the intensity drops drastically to 355 W/m². This finding was researched by Song *et al*. (2016); Elminir *et al*. (2001).

Research on the utilization of solar panels for processing organic fertilizer using a 100 Wp system aligns with other studies that also utilize solar panels for food processing, such as coconut grating machines. Findings indicate that the intensity of light received on the surface of the solar panels can significantly affect the current generated for charging batteries. When the solar panels are tilted at an angle of 30 degrees toward the sun, the highest current value occurs at 11:00 AM. However, starting at noon, the generated current begins to decline. It is deemed that one solar panel is sufficient for charging the battery (Jagad & Praswanto, 2021).

Figure 7 and Figure 8 illustrates the relationship between solar l and the torque and current required by the organic fertilizer processing machine. The torque and electrical current needed by the machine are influenced by the energy produced by the panel. The maximum torque of 3 Nm occurs at 13.00 with a light intensity of 890 W/m², while the highest current is 2 amperes. Previous research on dual-powered chopping machines, focusing on torque and sunlight intensity, found that their machine had a torque of 7 Nm, with a cost-effective design and a chopping blade speed of 340 Rpm. This machine was more cost-effective compared to machines using other energy sources (Pratap *et al*., 2014). Another study by Lutade *et al*. (2020) involved designing a small solar-powered leaf collector unit. This unit was developed and tested to evaluate its performance in collecting and shredding leaves using various techniques. The machine is designed to gather leaves and process them into useful products without harming the environment, utilizing solar energy (Lutade *et al*., 2020). Solar radiation and the resulting current align with previous research, which observed that light intensity affects the maximum current, increasing as light intensity rises.

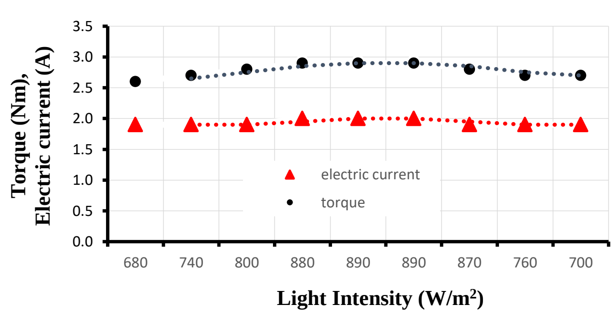

Figure 7. Torque and electric current

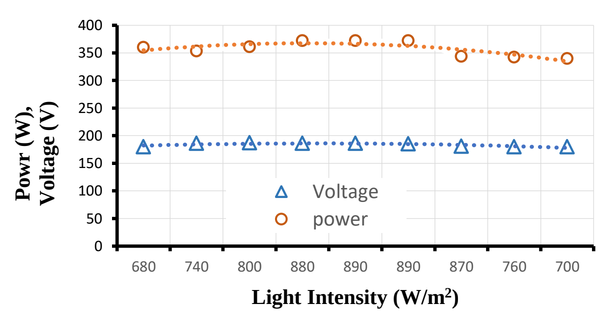

Figure 8. Power and voltage

3.3.3. Analysis of the Impact of the Sun's Angle on Light Intensity

The findings of this research indicate that the highest output from the 100 Wp solar panels occurs at a solar radiation intensity of 700-890 W/m² between 11:00 AM and 2:00 PM, with a peak power of 100 watts at noon, as presented in

Table 3. This output is insufficient to meet the power requirements of the motor driving the machine, which needs 186 watts. Therefore, a 12V 33Ah battery stores energy from the panel. The results show that the battery charging process takes 3 hours and 20 minutes, and the battery can operate for 1 hour and 41 minutes without the solar panel installation. In contrast, when the battery is connected to the solar panel, it operates for 6 to 7 hours, as detailed in Table 4.

Table 4. Battery testing conditions with a 20 kg load

Testing (days)	Battery Charging		Battery Usage		Battery Test (h)	v_0 (volt)	v_1 (volt)	i_0 (A)	i_1 (A)
	Time	Duration (h)	Time	Durasi (h)					
1	09.00-12.21	3.21	13.00-14.42	1.42	6.47	12	10.5	33	15.52
2	08.30-11.45	3.15	12.00-13.47	1.4	7.02	12	10.8	33	15.54
3	08.00-11.30	3.3	12.00-13.38	1.4	7.08	12	10.8	33	15.52
4	07.30-11.02	3.32	11.30-13.42	1.42	6.52	12	10.6	33	15.54
5	09.00-12.03	3.03	12.30-14.14	1.44	6.56	12	10.8	33	15.51

Note: v_0 : initial voltage; v_1 : final voltage; i_0 : initial current; i_1 : final current

Photovoltaic energy is an environmentally friendly energy source; however, it fluctuates, raising concerns about electricity costs. The power generated is unstable due to the inconsistency of sunlight intensity. One option to reduce these costs is to adjust the tilt angle of photovoltaic panels at the optimal location to stabilize solar panel production. A steeper tilt angle can generate more energy. However, for permanent photovoltaic systems, there is an optimal angle combination that can maximize total energy output. Previous research on panel tilt angles has also studied the effects of deviations from the optimal angle, the market value of solar panels at various tilt angles, historical solar radiation data, and electricity prices that can be calculated hourly, as investigated by Hartner *et al*. (2015).

The battery charging process using a 100 Wp solar panel is presented in Table 5. The charging process of a 12V 33Ah battery using the solar panel operated optimally for 3 hours and 20 minutes, with 5 days of testing producing a significant amount of energy. However, the charging duration is influenced by the intensity of sunlight. Observations showed that the battery, used to power a 1/4 Hp DC motor, could operate for 1 hour and 41 minutes in the organic fertilizer processing operation. The energy stored in the battery is sufficient to run the 1/4 HP motor for 1 hour and 41 minutes, but this finding is insufficient for an 8-hour work period. Therefore, for large-scale operations, it is necessary to increase the capacity of the battery and solar panel to store enough energy for 8 hours of operation. These findings are consistent with previous research on the application of a 100 Wp solar panel for a 12V 33Ah battery to operate a 12V electric motor on a small-scale briquette press machine, as studied by other researchers (Risky *et al*., 2020).

This study produced findings as presented in Figures 6, 7, and 8, illustrating the effects of the sun's angle on the voltage, current, and power generated by solar panels. When the sun's angle approaches 90 degrees, sunlight strikes the panels directly, resulting in the highest voltage output of 186 volts and a maximum current of 2 amperes. Under these conditions, the solar panels capture solar energy very efficiently, leading to a peak power output of 372 watts. However, during the early morning and late afternoon when the sun is at a lower angle, sunlight hits the panels at an oblique angle, causing a reduction in the intensity of light received by the panels. This reduction affects the voltage, current, and power output, as shown in Table 4. Test data for organic fertilizer processing machines with solar panels. Research on the tilt angle of panels can also be studied by Kacira *et al*. (2004) who observed, correct tilt angle for the panels was determined by finding the angle that maximizes intensity on the photovoltaic surface. The researchers' observations aimed to determine the accurate monthly tilt angle for photovoltaic panels, which varies throughout the year according to seasonal optimal angles, with tilt angles differing by 1.1% and 3.9%, respectively (Kacira *et al*., 2004). A study on how the angle of solar panels affects the generated power has also been conducted by previous researchers, focusing on the optimization of solar panel tilt angles. This study analyzes the actual tilt angle required to achieve optimal solar intensity. It is assumed that the collector surface faces the equator, based on daily global and diffuse solar radiation data on a horizontal surface. The analysis revealed that the optimal tilt angle varies monthly, and throughout the year, the optimal tilt angle is nearly equal to the latitude (Benghanem, 2011).

4. CONLUSION

The results of this study found that a 100 Wp solar panel is insufficient to operate a 1/4 HP electric motor because the motor's power requirement (approximately 233 watts) exceeds the maximum output of the solar panel. To address this issue, an additional three solar panels, each rated at 100 Wp and connected in parallel, are needed to generate around 300 Wp to meet the motor's power requirements. Another alternative is to use batteries to store energy from the solar panels. The solar panel can charge a 12V 33Ah battery to supply power to the motor. The current required by the motor is estimated to be around 19.43 amps. Based on theoretical analysis, this battery can run the motor for approximately 1.7 hours. However, field tests indicate that the motor operates for about 1.4 hours on a full charge. If the motor operates continuously for more than one hour, a larger battery capacity and more frequent recharging will be necessary to ensure an adequate power supply. Testing the battery's operating time with the solar panel installation shows that it takes about 6 to 7 hours for the battery to deplete while charging the battery requires approximately 3 hours and 20 minutes. Therefore, this research is recommended for small-scale farmers or individuals.

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