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Densification of Coco Peat using Fabricated Hydraulic-Powered Brick-making Machine

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Abstract

Another material derived from coconut husks is coco peat. Coco peat can absorb water up to nine times its volume, making it an excellent growing medium for a variety of plants. However, due to its low density, handling, storage, and transportation of the material are impractical. To address this problem, a hydraulic-powered coco peat brick-making machine was developed to densify the material, providing coconut growers with a potential additional income by increasing the product's market value. The machine was assessed in terms of capacity, quality of coco peat bricks (CPB), and energy usage under various compression pressure levels (10 MPa, 15 MPa, and 20 MPa). At the lowest compression pressure of 10 MPa, the highest production capacity of 59 CPB per hour was recorded. However, as compression pressure increased, capacity decreased, resulting in lower production rates of 56 CPB per hour at 15 MPa and 51 CPB per hour at 20 MPa. The quality of CPB was evaluated based on its durability under a 1-meter drop test. Only CPB produced at 20 MPa were deemed high quality, achieving a retention rate of 96.57%. Lower compression pressures resulted in reduced material retention rates of 85.72% at 15 MPa and 76.50% at 10 MPa. Therefore, 20 MPa is recommended for producing high-quality CPB. With an initial cost of USD 2,466.40 and a yearly potential income of USD 12,511.40, the machine is cost-effective. To cover its costs, the machine must produce 4,320 CPB annually. At maximum productivity, the payback period is 46 working days, or approximately 0.18 years.

***Keywords**:* capacity, coco peat, energy consumption, quality of CPB

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1. Introduction

A by-product of defibering coconut husks is coco peat, also known as coir dust or fiber dust. It is composed of short, spongy fibers and dust that can collect, absorb, and retain significant amounts of water—up to nine times its weight—helping to mitigate the agricultural water crisis during the El Niño season (Abad *et al.*, 2002). Coco peat is an excellent alternative growing medium due to its high porosity and low sensitivity to biodegradation. When used as mulch, it also improves soil structure and provides nutrients to the soil, including macronutrients and micronutrients essential for plant development (Philippine Coconut Authority, 2003). The Philippines is the second-largest producer of coconuts in the world. However, the current utilization of coconuts is not fully realized, leaving significant room for development to reach the industry's full potential. The country's average annual nut production is about 14 billion, yet the utilization of husks remains minimal at just 8.5% (Department of Agriculture, 2022). If 30% of coconut husks from total production were collected and processed, approximately 562,000 MT of coco peat could be produced. This would enable the Philippines to surpass India and become the largest supplier of coco peat internationally (Salaverra, 2012).

Coco peat has many uses in the agricultural sector; however, it also poses issues related to storage and transport practicality, health, and the environment when left unprocessed and unutilized. Due to its low density (0.18 g/cc) and fluffy nature, it requires a large amount of storage space and is difficult to transport and handle. Moreover, the prolonged presence of massive coco peat piles in decortication centers can cause groundwater, land, and air pollution in nearby areas (Ravindranath *et al.*, 2016). Translating this coconut husk-defibering by-product into high-grade coco peat bricks (CPB) could address these challenges and provide additional income for coconut farmers. However, despite its enormous potential, decorticating facilities in provinces with extensive coconut plantations remain largely unaware of its value and continue to sell unprocessed and raw coco peat as a soil conditioner (Desiderio, 2013).

Another issue that needs to be addressed is the lack of appropriate machines for producing high-grade coco peat. Currently, there are no accessible technologies that small-scale coconut farmers can use to densify processed coco peat. Local coconut growers or processing facilities in the country cannot afford to purchase large-scale machinery with working capacities of 0.65 to 1 ton per hour, which are available abroad and cost between USD 14,458.20 and USD 25,514.50.

Hence, the study aimed to develop an affordable hydraulic-powered CPB-making machine for coco peat. Its specific objectives were to: (1) design and fabricate a hydraulic-powered brick-making machine for coco peat; (2) evaluate the machine's performance in terms of capacity, quality of CPB, and energy requirements as influenced by compression pressure; and (3) determine the cost of owning and operating the machine.

2. Methodology

2.1 Conceptualization of the Study

To increase the value of waste generated by the coconut industry, the need to develop a machine for producing CPB was realized. The market value of coco peat would improve if converted into CPB, providing an economic opportunity for coconut producers. Additionally, compressing coco peat into high-density CPB makes it easier to handle and transport than loose coco peat and is more cost-effective, as the product can last up to two years longer than conventional packaging (Ravindranath *et al.*, 2016). Thus, the development of a hydraulic-powered CPB-making machine that coconut farmers could use to densify preconditioned coco peat was undertaken.

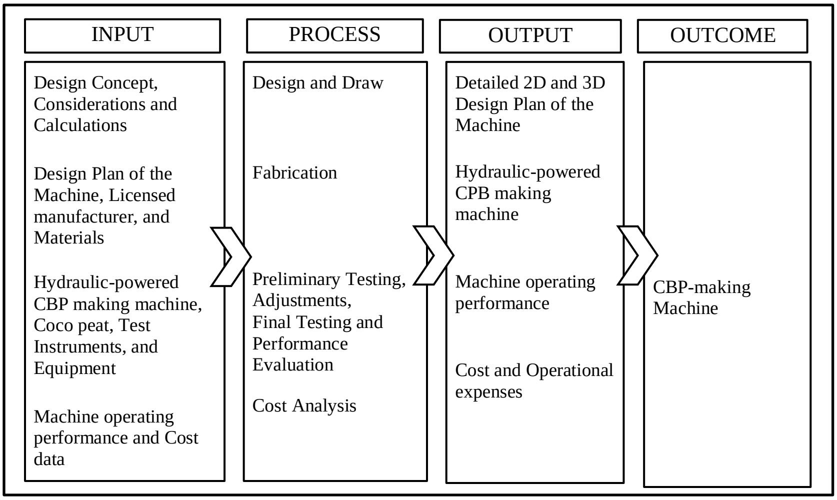

Figure 1. Conceptual framework

The machine design was completed by studying the coco peat benchmark data and relevant literature for the design process. The final test was conducted when functionality issues were observed in the fabricated machine. Additionally, the viability and cost of usage calculations were based on the machine's observed operational performance. Figure 1 shows the conceptual framework of the study.

2.2 Design of Components

The technology comprises four assemblies: (a) hopper assembly, (b) frame and molding box assembly, (c) lock and cover assembly, and (d) hydraulic system and molding block assembly. Figure 2 shows the hydraulic-powered CPB-making machine designed for coco peat.

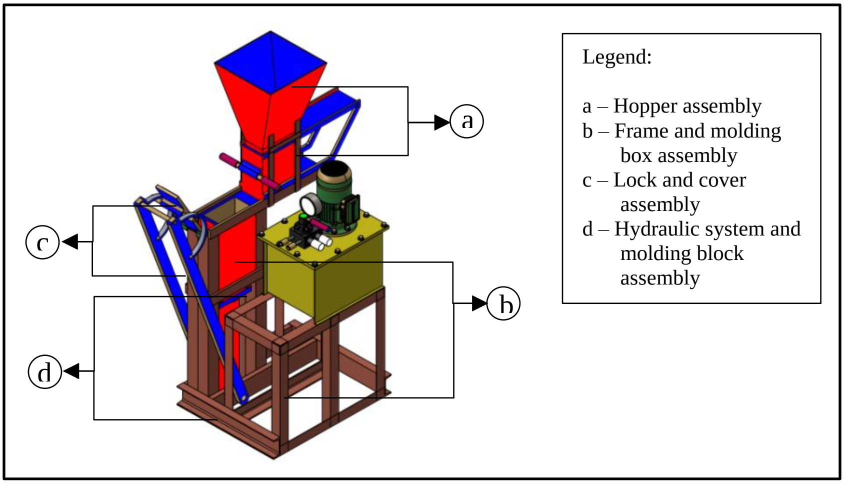

Figure 2. Hydraulic- powered CPB making machine

2.2.1 Hopper Assembly

The hopper design was a truncated pyramid, consisting of two parts: the upper part and the lower part (Figure 3). It was constructed using a metal plate framed with a flat bar and equipped with a tubular steel bar welded horizontally as a handle. The handlebar was covered with rubber for a better grip and comfort for the operator. By sliding the lower hopper, the calculated volume of coco peat was transferred to the molding box.

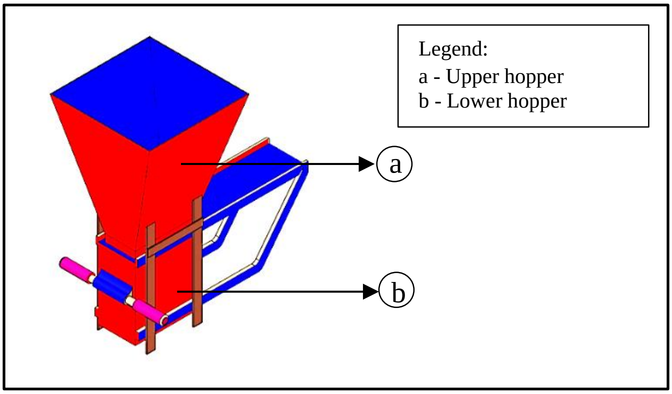

Figure 3. Hopper assembly

2.2.2 Frame and Molding Box Assembly

The frame and molding box (Figure 4) was constructed with angular bars welded together to form the design plan. The molding box, where the loose coco peat transforms into CPB, is permanently fixed to the frame. Its size was determined by the premium CPB dimensions of 10 cm x 20 cm and its 7:1 compression ratio (PNS/BAFPS 74:2009) (Layese *et al.*, n.d.). The height of the molding box was determined by the compression ratio.

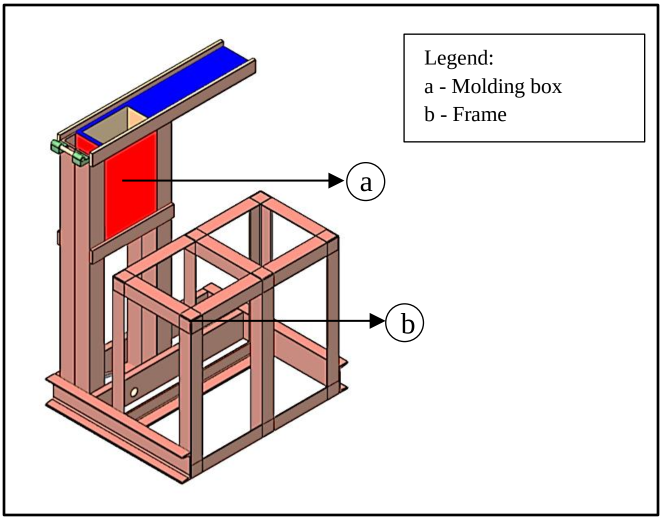

Figure 4. Frame and molding box assembly

2.2.3 Lock and Cover Assembly

The lower part of the lock is made from a 10 mm metal plate and installed vertically. It is fastened to the base of the frame using a stainless-steel shaft. Pulling the lock uncovers the molding box. Figure 5 shows the lock and cover assembly of the machine.

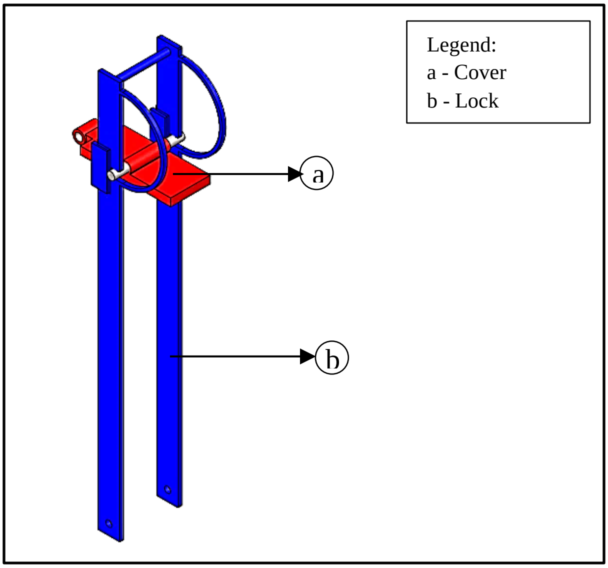

Figure 5. Lock and cover assembly

Shown in Figure 6a is the simulation analysis for stress in the lock component using SolidWorks 2013 (CAD Software), indicating that the maximum stress the component could experience across its section is 48 MPa (red), while the minimum stress is 0.000095 MPa (blue). Hence, the design and material used (ASTM A36) for the component, with a yield strength of 250 MPa, are concluded to be safe based on the analysis, with a factor of safety (FOS) distribution of 5.1 (Figure 6b).

The cover counters the pressure from the upward-moving piston to form the CPB. For the locking and unlocking mechanism, a steel pipe filled with ball bearings is fixed at the top of the cover and rolled along the curvature, reaching the other end.

Name	Type	Min	Max
Stress1	VON: von Mises Stress	9.539e-05 N/mm^2 (MPa) Node: 10455	4.868e+01 N/mm^2 (MPa) Node: 17376

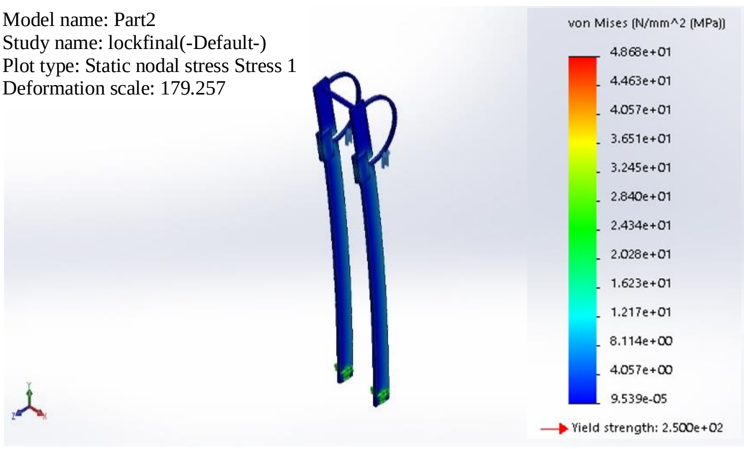

Figure 6a. Design analysis of lock: stress analysis

Name	Type	Min	Max
Factor of Safety1	Automatic	5.135e+00 Node: 11356	2.621e+06 Node: 10345

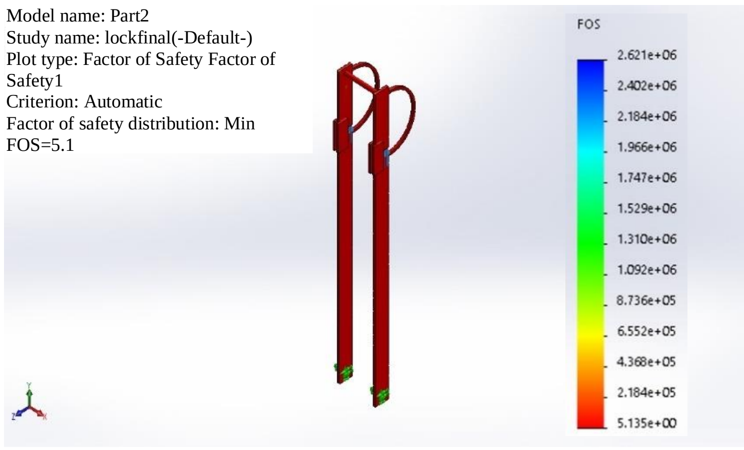

Figure 6b. Design analysis of lock: factor of safety analysis

With the compression force exerted by the piston rod, the maximum stress the cover plate could experience across its section is 198 MPa (red), and the minimum stress is 0.0014 MPa (blue), as shown in Figure 7a. Thus, the design size and material for the shaft (AISI 4340) plate, with a yield strength of 710

MPa, and ASTM A36 with a yield strength of 250 MPa, are safe with FOS distribution of 1.3. Shown in Figure 7b is the FOS analysis, in which the maximum FOS was calculated to be 3 (blue) and the minimum FOS is 1.25 (red).

Name	Type	Min	Max
Stress1	VON: von Mises Stress	1.401e-04 N/mm^2 (MPa) Node: 12338	1.988e+02 N/mm^2 (MPa) Node: 10395

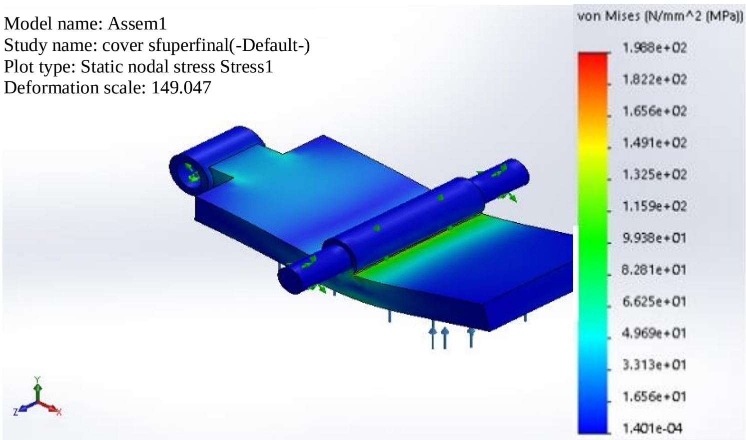

Figure 7a. Design analysis of cover: stress analysis

Name	Type	Min	Max
Factor of Safety1	Automatic	1.258e+00 Node: 10395	3.000e+00 Node: 11095

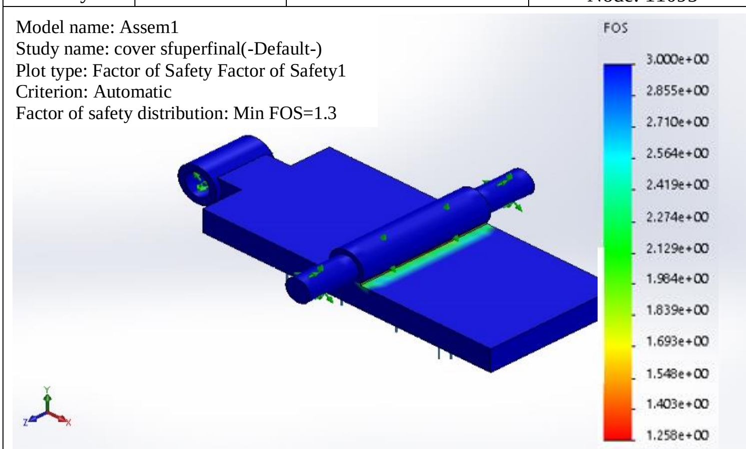

Figure 7b. Design analysis of cover: factor of safety

2.2.4 Hydraulic System and Molding Block Assembly

The selection of cylinder capacity was determined using Pascal's principle of fluid pressure. After determining the size of the cylinder, the volumetric capacity and power output of the motor pump were computed using Equations 1 and 2, as demonstrated by Kannan (2011).

$$Q = A \ x \ S/t \tag{1}$$

where:

Q = *flow rate of the hydraulic fluid* (cm^3/s);
S = *length of stroke* (cm); t = *time* (s)

$$kW = (Qx \ P)/10 \tag{2}$$

where:

kW = *power output* (kW);
Q = *flowrate* (cm^3/s);
P = *pressure* (N/cm^2)

The molding block was a solid rectangular part that moved upward with the piston rod to transfer the compression force to the coco peat (*Figure 8*). It was connected to the piston rod by a bolt and positioned at the bottom of the molding box, with a 5 mm thickness portion slightly introduced at the interface. It was constructed using an ASTM A36 metal plate and an AISI 1010 shaft with a diameter of 25 mm (25 mm Ø).

The electric hydraulic system consisted of: (a) a motor pump for delivering a constant volume of hydraulic oil to the cylinder, (b) a hydraulic oil tank as a reservoir, (c) a filter to remove dust or pressure, (d) a relief valve that redirects excess fluid back to the tank, (e) a control lever that directs the fluid flow, and (f) a hydraulic cylinder and piston rod for the extension of the compression force.

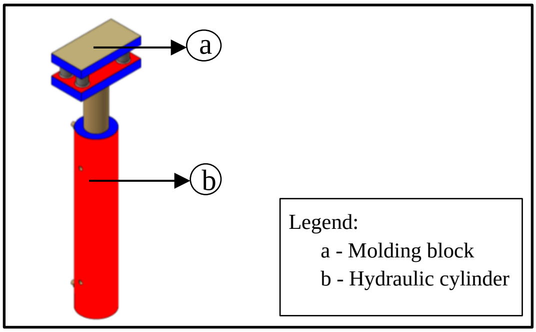

Figure 8. Electric hydraulic system and molding block assembly

Shown in Figure 9a is the stress analysis of the molding block, which shows that the maximum stress experienced by the component across its section is 179 MPa (red), while the minimum stress is 189 MPa (blue). Hence, the design and material used for the component, with yield strengths of 250 MPa and 710 MPa, are concluded to be safe with FOS distribution of 1.4. Shown in Figure 9b is the FOS analysis simulation result, which shows that the highest FOS is 3 (blue) and the lowest is 1.39 (red).

Name	Type	Min	Max
Stress1	VON: von Mises Stress	1.842e+05 N/mm^2 (MPa) Node: 11388	1.797e+08 N/mm^2 (MPa) Node: 10615

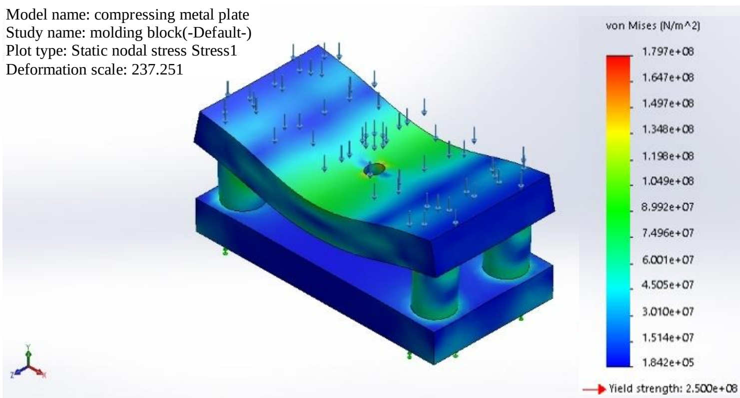

Figure 9a. Design analysis of molding block: stress analysis

Name	Type	Min	Max
Factor of Safety1	Automatic	1.392e+00 Node: 10460	3.000e+00 Node: 12155

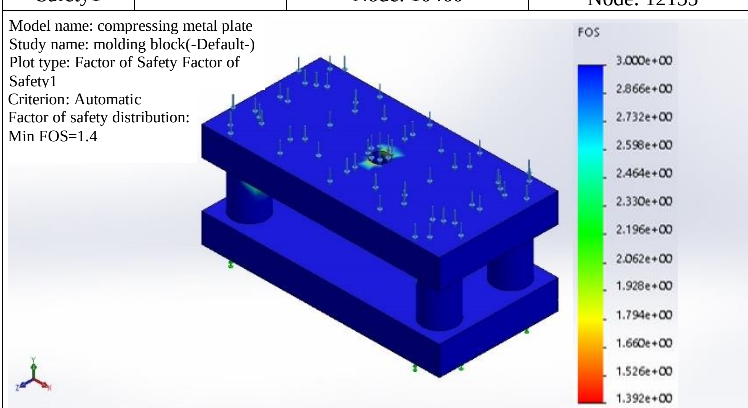

Figure 9b. Design analysis of molding block: factor of safety analysis

2.3 Determination of Moisture Content

The moisture content of coco peat is a significant factor to determine, as it affects the compressibility of the material. Characterization of coco peat at different moisture contents was conducted to serve as a reference in the field, in case a specialized moisture meter for coco peat is unavailable. The results of the subsequent method were also used to determine the moisture content of coco peat during the drying operation.

A substantial amount of coco peat, about 5 cm in thickness, was placed and dried in full sunlight for almost two hours, mixing every ten minutes while taking samples. The moisture content of the samples was determined using the oven-drying method, while characteristics were established by the feel-and-touch method (Klocke and Fischbach, 1984). These characteristics were then used as a reference during actual field drying. The trendline model, established using the moisture data and the time of sample collection, generated the exponential decay shown in Equation 3 with $R^2 = 0.9632$. Figure 10 shows the trendline of moisture content vs. time.

$$y = 72.514x\text{-}0.373 \qquad (3)$$

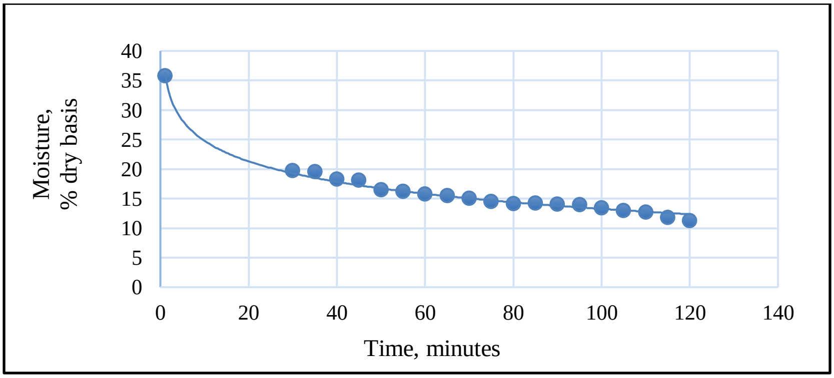

Figure 10. Trendline of moisture content vs. time

After drying in direct sunlight for around 40 to 60 minutes, the optimum moisture content of 16% (Bulaong *et al.*, 2012) was reached. The characteristics observed at this moisture content were that the color was brown, not reddish-brown or light brown; it could be shaped into balls that crumbled easily; the fibers did not expand back immediately when released from squeezing; neither tiny nor fine particles attached to the hand; and the particles felt light. Figure 11 shows the feel-and-touch method for coco peat.

Figure 11. Feel and touch method of coco peat

2.4 Principle of Operation

The operation starts as soon as the electric motor is turned on. Coco peat is loaded into the upper hopper and falls into the lower hopper. The lower hopper should then slide back and forth until the molding box is filled with coco peat. Pushing the lock enables secure covering of the coco peat in the molding box, allowing compression to begin. The operator should then control the lever to gradually extend the piston until the desired compression pressure is reached. The pressure can be monitored using the built-in pressure gauge in the system. Releasing the control lever will allow the piston to retract. The lock should then be pulled to uncover the molding box and release the CPB. The lever is controlled again to initiate another upward movement of the piston.

2.5 Performance test and evaluation

The coco peat used in the evaluation was of fine standard grade (PNS/BAFPS 74:2009). The coco peat was at least six months old, washed as necessary to reduce its salt content, sieved through a mesh with a size of 5 mm, and dried to the desired moisture level of 16%.

The treatment factor for the evaluation was based on a prior study by Tam-awen and Piscador (2016), in which 10 cm x 10 cm CPBs with a 4:1 compression ratio was produced using 4 MPa compression pressure. However, this study aimed to produce CPBs of standard size (10 cm x 20 cm) at an acceptable compression ratio; hence, the minimum compression pressure was doubled as the reference with an allowance. Consequently, a preliminary test was conducted to validate the assumption and determine the appropriate levels of compression pressure. Finally, 10 MPa, 15 MPa, and 20 MPa compression pressures were found to be most efficient for the final test and evaluation. Each treatment was replicated three times. The developed machine was assessed in terms of its bricking capacity, quality of CPB, and energy requirement.

2.5.1 Bricking Capacity

The bricking capacity (Equation 4) was determined by tracking how long it took from the loading of coco peat into the hopper until the specified quantity of CPB was produced, or by counting how many CPBs were produced in a fixed amount of time.

$$bc = nb \div t \tag{4}$$

where:

bc = bricking capacity (CPB per hour);
nb = number of CPB;
t = operating time (hours).

2.5.2 Energy Consumption

The energy consumption (Equation 5) is the ampere reading multiplied by the voltage of the single-phase connection, then multiplied by the time of operation.

$$e = (a.v).t \tag{5}$$

where:

e = energy consumption (kilowatt-hour);
a = ampere reading (ampere);
v = voltage (voltage);
t = operating time (hours).

2.5.3 Quality of Coco Peat Bricks

The CPB was dropped from a height of 1 meter, landing on a concrete surface, as demonstrated by Mousa *et al*. (2017), to test its drop resistance. The ratio of the mass of coco peat before and after the drop test serves as the measure of durability. According to EN ISO 17831-2:2015, compacted biomass with a durability of greater than 95% is of excellent quality, while less than 90% is considered lower quality. Durability was computed using Equation 6:

$$du\ \% = (ma \div mb) \times 100 \tag{6}$$

where:

du% = mechanical durability (%);
mb = mass of CPB before test (grams);
ma = mass of CPB after test (grams).

2.5.4 Statistical Analysis

Analysis of Variance (ANOVA) in a Completely Randomized Design (CRD) was used to statistically assess the collected data. The Least Significant Difference (LSD) test was used for comparison of the treatment means for bricking capacity and energy consumption, while a one-sample t-test was used to determine the difference from the 95% value of the mean durability for each treatment (Gomez and Gomez, 1984).

2.5.5 Cost Analysis

The cost of using the machine was determined by calculating all the expenses and making assumptions about the necessary parameters. Costs were categorized into fixed costs and variable costs.

Fixed costs included depreciation, interest on investment, repair and maintenance, and tax, insurance, and shelter. The straight-line method was used to calculate depreciation, considering a 10-year machine lifespan, a 10% salvage value, and a purchase price of USD 2,466.40. The repair and maintenance cost were fixed at 10% of the purchase price, while 10% and 2% of the purchase price were allocated for interest on investment and tax, insurance, and shelter, respectively.

Variable costs included electricity costs, labor costs, and the cost of buying coco peat. The electricity cost was determined by multiplying power consumption per brick by the electricity rate in Nueva Ecija, Philippines. For labor costs, the number of working days for 2019 (261 days) and the minimum labor wage in Nueva Ecija, Philippines (USD 5.95) were used as the basis. The coco peat price was based on the cost of unprocessed coco peat in the defibering centers.

Annual cost is the total of fixed costs and annual costs. The revenue was computed in terms of USD per brick. The cost of unprocessed coco peat was subtracted from the price of the brick to determine the revenue for each brick produced. The break-even point and payback period were calculated to define when total costs and revenue would be equal and to determine how much time was required to recover the investment in the machine. Both were affected by any changes in the values of the aforementioned costs. Equations 7–12 were used to compute the operating cost of the machine (Hunt, 2001):

$$\mathrm{AF}C = D + I + TIS + R\&M \tag{7}$$

where:

AFC = Annual Fixed Cost (Php/yr);
D = depreciation cost (Php/yr);
I = interest on investment (Php/yr;
R&M = Repair and Maintenance Cost (Php/yr)

$$TIS = (T+I+S\ )x\ Pp,\ Php/yr \tag{8}$$

where:

TIS = Tax, Insurance & Shelter (Php/year);
S = Shelter (%);
T = Tax (%); Insurance (%);
Pp = Purchase price (Php)

$$AVC = EC + LaC + PC \tag{9}$$

where:

AVC = Annual Variable Cost(Php/yr);
EC = Electricity Cost Cost (Php/yr);
LaC = Labor Cost (Php/yr);
PC = Cost of buying Coco peat (Php/yr)

$$AC = AFC + AVC \tag{10}$$

where:

AC = Annual Cost(Php/yr);
AFC = Annual Fixed Cost (Php/yr);
AVC = Annual Variable Cost (Php/yr)

$$BEP = \frac{AFC}{R\text{-}\frac{AVC}{C}} \tag{11}$$

where:

BEP = *Break-even Point (number of bricks);*
R = *Revenue (Php/brick);*
C = *Bricking Capacity (brick/yr);*
AVC = *Annual Variable Cost (Php/yr);*
AFC = *Annual Fixed Cost (Php/yr)*

$$PP = (IC - SV)/ANI \tag{12}$$

where:

PP = *Payback Period (year);*
IC = *Investment cost (Php);*
SV = *Salvage Value (Php);*
ANI = *Annual Net Income (Php/yr)*

3. Results and Discussion

3.1 Machine Description

Figure 12 shows the locally fabricated CPB-making machine, and subsequently, Table 1 provides the detailed specifications of each machine component. The machine could be operated by two people: one for loading the coco peat and collecting and piling the CPB, and the other for operating the control lever. The total weight of the machine was approximately 150 kg; therefore, the components were designed to be detachable and temporarily joined for easy maintenance and transport.

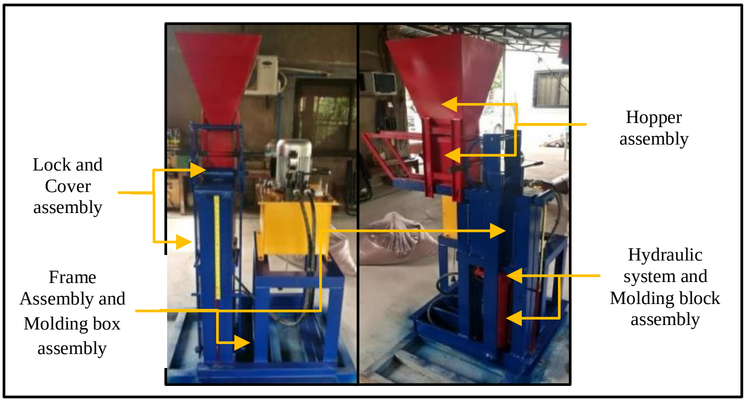

Figure 12. Fabricated CPB-making machine

Table 1. Detailed Specifications of CPB-making Machine Components

Components	Specification
Hopper assembly	
Upper hopper	
Capacity, *li*	18.77
Height x Width x Length (cm)	42.5 x 35 x35
Weight, kgs	3.5
Lower hopper	
Capacity, li	5
Height x Width x Length (cm)	25 x 10 x 20
Weight, kgs	10.5
Frame and molding box assembly	
Height x Width x Length (cm)	100 x 60 x 60
Weight, kgs	72
Lock and cover assembly	
Height x Width (cm)	127 x 23
Weight, kgs	10
Molding block	
Height x Width x Length (cm)	10 x 10 x 20
Weight, kgs	6
Electric hydraulic system	
Motor pump	
Capacity (li/min)	0.7 – 5
Pressure (MPa)	7 – 70
Motor output (kW)	1.5
Hydraulic cylinder	
Capacity (tons)	30
Piston rod travel length (cm)	40

3.2. Machine Performance

3.2.1 Bricking capacity

The ratio of the total number of CPBs produced per unit of time is the bricking capacity. Table 2 presents the bricking capacity at various compression pressures. In the "mean" column, bricking capacity was recorded as highest using 10 MPa, with a mean value of 59 CPB/hr, followed by a compression pressure of 15 MPa with an average of 56 CPB/hr, and the lowest recorded using a compression pressure of 20 MPa, with a mean value of 51 CPB/hr. A pairwise comparison of averages revealed that compression pressure has a significant impact on bricking capacity.

Table 2. Bricking capacity on various compression pressures, CPB/hr

	Replication			
MPa	1	2	3	Mean
10	59	59	59	59[a]
15	56	57	56	56[b]
20	53	51	50	51[c]

**Means of different letters are significantly different*

At a 95% confidence interval, the compression pressure showed a highly significant impact on the resulting bricking capacities, with a p-value (Pr(>F)) of 0.0002, as shown in Table 3.

Table 3: Analysis of variance of bricking capacity as influenced by various compression pressure

	Df	SS	MS	F-value	Pr (> F)
Pressure	2	90.88	45.44	51.12	0.0002
Error	6	5.33	0.88		
Total	8	96.22			

It takes some time to reach a compression pressure of 20 MPa, which extends the time needed to produce the CPB. As a result of the extra time, the capacity at the highest pressure decreased, while the capacity at lower compression pressures increased.

3.2.2 Quality of coco peat bricks

The durability of the CPB served as a gauge of its quality. According to EN ISO 17831-2:2015, high-quality compacted biomass must retain at least 95% of its mass during testing to be considered high quality; otherwise, it is categorized as low quality (below 90%).

Analysis of variance showed a significant effect ($p < 0.05$) of compression pressure on the resulting quality of the produced CPB (Table 5). The one-sample t-test revealed that the mean durability is significantly lower (indicated by the negative t-value) than the hypothesized value of 95 ($p = 0.0041, 0.0079$) for compression pressures of 10 MPa and 15 MPa, leading to the rejection of the null hypothesis. The true mean durability is likely closer to the observed means of 76.50 and 85.72 (Table 4). On the other hand, the result showed that the mean durability at 20 MPa is significantly higher (indicated by the positive t-value) than the hypothesized value of 95 ($p = 0.0182$), leading to the rejection of the null hypothesis (Table 6). The true mean durability is likely closer to the observed mean of 96.57 (Table 4).

Table 4. Quality of CPB on various compression pressure, CPB/hr

MPa	Replication			Mean
	1	2	3	
10	74.35	76.69	78.46	76.50[c]
15	86.77	86.31	84.09	85.72[b]
20	96.21	96.54	96.95	96.57[a]

**Means of different letters are significantly different at a 95% confidence interval*

Table 5: Analysis of variance of quality of CPB as influenced by various compression pressure

	Df	SS	MS	F-value	Pr (> F)
Pressure	2	605.32	302.66	140.96	0.0000
Error	6	12.88	0.88		
Total	8	618.20			

The result is consistent with the findings of a study that states an increase in pressure would cause biomass particles to come into contact with one another, leading to elastic and plastic deformation, which enhances interparticle interaction (Sudhagar *et al.*, 2003).

Table 6. One sample t-test of mean durability of various compression pressure

MPa	Df	T-Value	Pr(>T)
10	2	-15.54	0.0041
15	2	-11.21	0.0079
20	2	7.32	0.0182

**h0: mean = 95*

3.2.3 Energy consumption

Table 6 presents the results of the calculated energy consumption of the machine at different compression pressures. The energy demand of the machine is directly proportional to the current, voltage, and total operating time. An increase in current, voltage, or time results in an increase in energy demand. As stated in the results of machine capacity, operating hours increase as the compression pressure rises; therefore, energy demand also increases as the compression pressure increases.

A pairwise comparison of means showed that compression pressure has a significant impact on energy demand, as indicated by the corresponding letter. The highest compression pressure applied (20 MPa) required the most energy to operate the machine, with a mean value of 0.356 kW-hr, followed by 15 MPa with an average of 0.291 kW-hr. The lowest energy requirement was recorded using 10 MPa, with a mean value of 0.246 kW-hr.

Table 7. Energy demand on various compression pressures, kW-hr

MPa	Replication			Mean
	1	2	3	
10	0.256	0.234	0.248	0.246[c]
15	0.287	0.297	0.289	0.291[b]
20	0.345	0.356	0.368	0.356[a]

**Means of different letters are significantly different*

At a 95% confidence level, analysis of variance revealed that compression pressure, with a Pr(>F) value of 0.0000, has a highly significant influence on the durability of CPB, as shown in Table 8.

Table 8. Analysis of variance of energy consumption as influenced by various compression pressure

	Df	SS	MS	F-value	Pr (> F)
Pressure	2	0.0185	0.0092	97.42	0.0000
Error	6	0.0006	0.0001		
Total	8	0.0190			

Figure 13 shows the coco peat CPB produced using the fabricated brick-making machine. The CPBs produced were of standard size (20 cm x 10 cm) with an average compression ratio of 4.75, which can be considered to have higher quality compared to the CPBs produced using the machine developed by Tam-awen and Piscador (2016), an undergraduate research study in which the CPB dimensions were not of standard size (10 cm x 10 cm) and the compression ratio was lower.

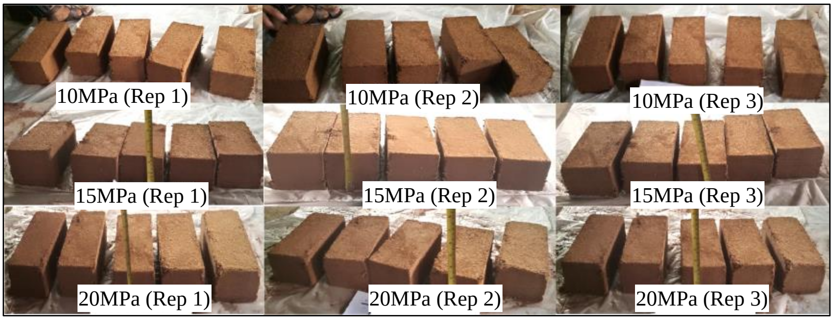

Figure 13. CPB is produced using the fabricated hydraulic brick-making machine.

3.3 Cost Analysis

The cost of the hydraulic-powered brick-making machine for coco peat is USD 2,466.40, with an annual operating cost of USD 3,959.20, which includes an Annual Variable Cost (AVC) of USD 3,305.63 and an Annual Fixed Cost (AFC) of USD 653.60. At maximum operating capacity, the machine can produce 91,350 CPB per year, requiring 8 hours of operation per day over 261 days. To break even, the machine would need to produce 4,320 CPB annually. The machine's payback period will be 0.18 years, or 46 working days, at maximum operating capacity. Owning the machine would benefit the farmer with an annual profit of USD 12,511.40. Figure 14 shows the cost curve of operating the machine.

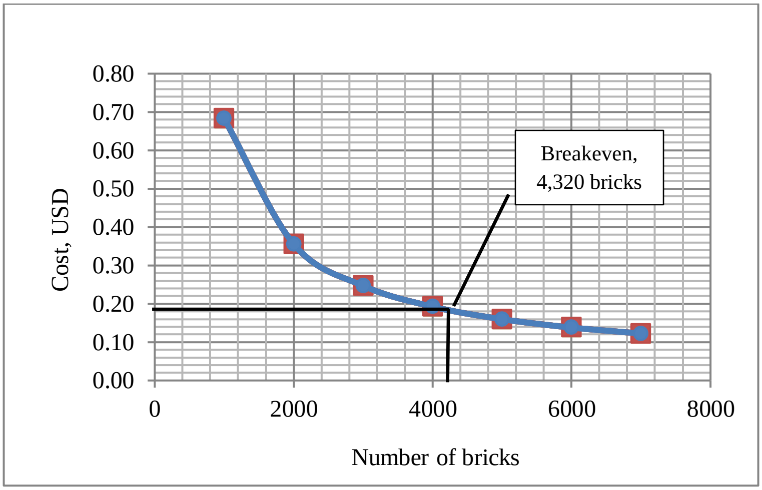

Figure 14. Cost curve

4. Conclusion and Recommendation

The hydraulic-powered brick-making machine for densification of coco peat can produce high-quality coco peat CPB at a capacity of 51 CPB per hour using 20 MPa compression pressure. The quality of the CPB produced has a 96.57% retention rate, meeting the high-quality compacted biomass standard, while the energy consumption is 0.356 kW-hr. Furthermore, the machine is affordable at USD 2,466.40. Given that the maximum brick output would reach 91,350 CPB at a cost per brick of USD 0.18, the farmer would benefit by USD 12,511.43 annually. The number of CPBs needed to reach breakeven is 4,320 per year, with a payback period of 0.18 years, or 46 working days.

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