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Development of Mixing and Pressing Processes of Split-Gill Mushroom Spawn Blocks

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Abstract

This study aims to develop the mixing and pressing processes of split-gill mushroom spawn blocks through the development and construction of a semi-automatic mushroom spawn mixing. The developed machine uses a 0.5 hp motor to drive the mixing tank and the press cylinder, which are connected to a 1:60 reduction gear. The results show that the semi-automatic mushroom spawns mixing and pressing machine developed in this study are within the standard ranges, that the split-gill mushroom spawn blocks with an average weight of 598 g, an average height of 10.2 cm, and an average density of 0.33 g/cm^3. As for production capacity, manual pressing produced 40 mushroom spawn blocks per hour while the developed machine produced 112 mushroom spawn blocks per hour, which is 2.8 times faster.

Keywords: machine, split-gill mushroom, mixing process, mushroom spawn block pressing

1. Introduction

Fig. 1 shows split-gill mushroom, also known as Schizophyllum commune, which is popular and widely distributed in many Asian countries such as Thailand, Laos, Myanmar, and Northeast India [1]. It grows on dead or fallen broadleaf trees. Its characteristic features are pale yellow to brown gills with dense white hairs and no stem [2].

Fig. 1 Split-gill mushroom

In addition, this mushroom is a medicinal herb [3] with nutritional values, especially in terms of its high carbohydrate and protein content and low-fat content [4]. It is also high in schizophyllan, a compound with many biological functions [5] such as immunomodulatory, anti-inflammatory, antioxidant, anti-cancer, anti-viral, and anti-fungal, including prebiotic activities [6-9].

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The production of split-gill mushroom spawn blocks starts from the mixing of raw materials. Water is then added to the mixture to about 65% moisture content. The suitability of moisture content can be checked by holding and squeezing the sawdust substrate by hand. If the substrate remains globular when you open your hand, the moisture level is ideal. But if the substrate falls apart when opening your hand, the substrate is still too dry and some more water is needed to be added. About 600 g of the substrate is then packed into each bag with a folded bottom.

The bag is lifted off and pressed against the ground lightly to make the mushroom substrate denser or press down with the hands. A bottleneck is put on the opening at the top of each bag. The opening of the bag is pulled downward and tied with a rubber band at the bottleneck to maintain its shape for further mushroom inoculation. A wooden stick is used to make a hole about 5 cm deep. The hole is then covered with cotton and paper and fastened with rubber, or you can use a cap instead of paper to prevent the cotton from getting wet while steaming. According to the production standards, the split-gill mushroom spawn blocks have an average weight of 590-610 g, with an average height of 9.5-10.5 cm, and an average density of 0.30-0.34 g/cm^3 [10].

Several studies have been conducted on the production of mushroom spawn blocks. For example, Modestus et al. [11] a briquette machine was designed using a screw-type extruder to convert the processed water hyacinth plant and wastepaper into a solid briquette for domestic consumption. The designed machine has a production efficiency of 84% and also produced smoke-free WH briquettes with high resistance to mechanical action, better handling, and efficient fuel characteristics for household use. The briquettes are developed by utilizing the remaining bag logs of white oyster mushrooms (waste) to become charcoal briquettes as the alternative energy [12]. Briquettes were made from a blend of corncobs and the bark of an oil palm trunk using a manual press. The significance of this study lies in the provision of a piece of baseline information to encourage local bio-energy development and serve as a guide for stakeholders in Nigeria with a potential interest in investing in briquette technology [13].

Preparation of biomass briquettes using durian peel char and spent mushroom compost char by using the screw press machine is utilized to form the briquette. The combined chars are fed into the extruder. The cylindrical briquette has an inner diameter of 5 cm and a height of 9 cm [14]. Briquetting machine with vertical ring die. The briquetting machine was driven by an electric motor, so the spindle speed of the briquetting machine was controlled by adjusting the motor speed with a frequency converter [15].

Therefore, to solve such problems, the researchers developed a semi-automatic mushroom spawn mixing and pressing machine covering the operations from mixing the mushroom substrate in the mixing tank, filling the mushroom substrate into bags, and pressing to obtain the mushroom spawn blocks. The mushroom spawn blocks obtained from the semi-automatic mushroom spawn mixing and pressing machine did not contain the split-gill mushroom spawn. A Mushroom inoculation step was required. The technology of the semi-automatic mushroom spawn block mixing and the pressing machine was subsequently transferred to the Split-Gill Mushroom Farming Community Enterprise in Tha Kham Sub-district, Hat Yai District, Songkhla Province.

2. Research Methodology

2.1. Machine design and construction

Fig. 2 shows the diagram of the semi-automatic split-gill mushroom spawn mixing and pressing machine developed in this study [16]. This machine was made of angle steel as the main material and had a dimension of 925 × 1125 × 1500 mm. Inside the machine frame (1), there was a motor and a gear reducer for driving the mixing tank and the press cylinder. The raw materials of mushroom substrate were put and mixed in the mixing tank (6). The substrate was discharged into a bag placed

over the cylindrical outlet (7) under the mixing tank. For the pressing unit, there was a long crankshaft (3) moving up and down simultaneously on each side, installed in front of the machine. This crankshaft was supported by a short rod (4). The height of the mushroom spawn block could be adjusted (5). The control box (14) for the motor was mounted on the side of the machine frame (1).

Fig. 3 shows the exploded diagram of the semi-automatic split-gill mushroom spawn mixing and pressing machine developed in this study. It consisted of a machine frame (1) and a motor (8) and belts (8a and 8b) inside this frame. The belt (8b) drove the reduction gear (10) to transmit power to the bevel gear (12). The bevel gear transmitted power to the crankshaft (13) with a gear ratio of 1:23 and the radius of the crankshaft dish was 10 cm. The power was then transmitted to the crankshaft made of a long steel rod (3) and to the support rod made of a short steel rod (4). The height of the spawn block could be adjusted using an adjustable screw (5) which was installed in front of the machine. Another belt (8a) drove the reduction gear (9) to transmit power to the mixing tank (6).

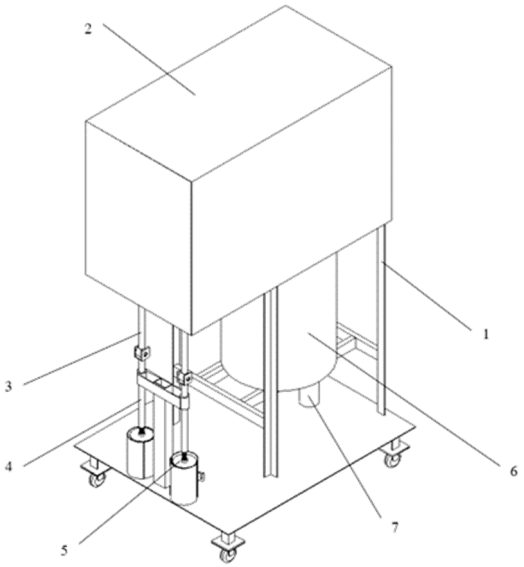


Fig. 2 Drawing of Semi-automatic split-gill mushroom spawn mixing and pressing machine

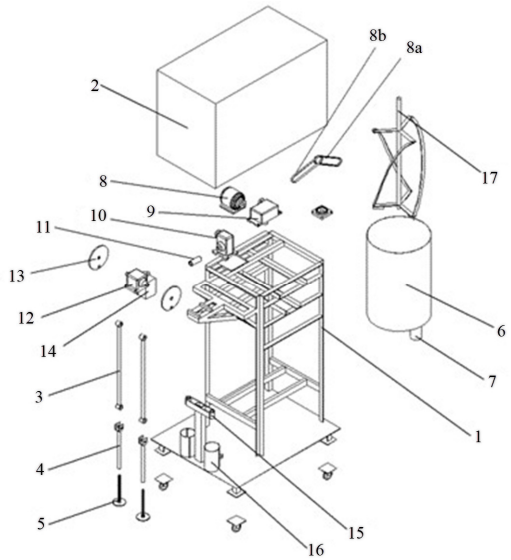


Fig. 3 Exploded diagram of semi-automatic split-gill mushroom spawn mixing and pressing machine

Fig. 4 shows the exploded diagram of the power unit of the semi-automatic split-gill mushroom spawn mixing and pressing machine developed in this study. The power unit was driven by a motor (8), which drives 2 belts. The first belt (8a) drove the reduction gear (9) with a gear ratio of 1:60 and transmitted power to the coupling (9a) for the impellers. The second belt (8b) drove the reduction gear (10) with a gear ratio of 1:60 and transmitted power to the shaft (11) driving the bevel gear (12) with a gear ratio of 1:1.

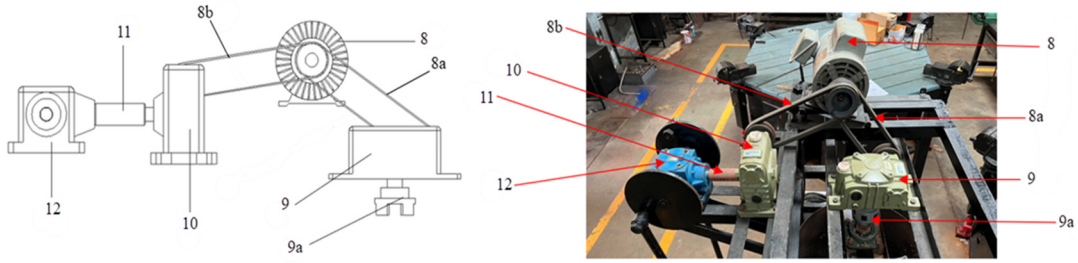


Fig. 4 Power unit of semi-automatic split-gill mushroom spawn mixing and pressing machine

Fig. 5 shows the pressing unit of the semi-automatic split-gill mushroom spawn mixing and pressing machine developed in this study. The pressing unit consisted of a bevel gear (12), in which both arms of the bevel gear were connected to the crankshaft (13) with a gear ratio of 1:23 and the radius of the crankshaft dish was 10 cm. This section was connected to the crankshaft made of a long steel rod (3) and to the support rod made of a short steel rod (4). The height of the spawn block could be adjusted using an adjustable screw (5) which was installed in front of the machine.

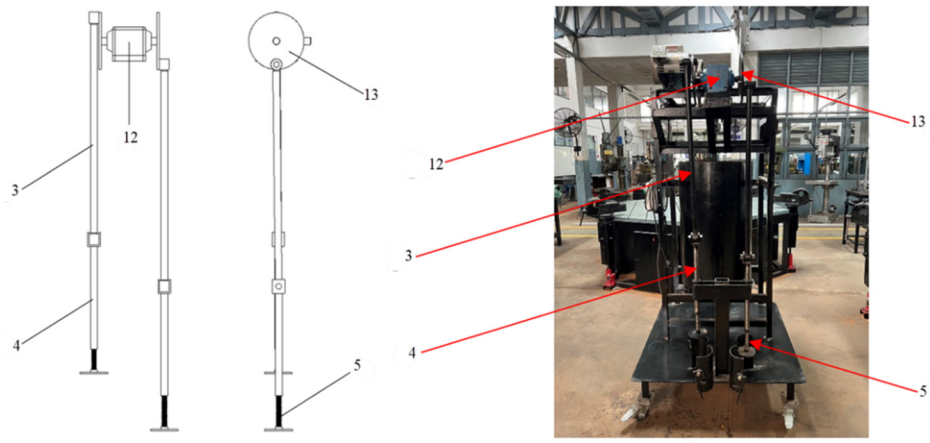


Fig. 5 Pressing unit of semi-automatic split-gill mushroom spawn mixing and pressing machine

Fig. 6 shows the mixing unit of the semi-automatic split-gill mushroom spawn mixing and pressing machine developed in this study. The unit consisted of a reduction gear (9) with a gear ratio of 1:60 connected to a coupling (9a). The coupling was connected to the impellers (17) inside the mixing tank (6). After mixing, the substrate was discharged into a bag placed over the cylindrical outlet (7) under the mixing tank.

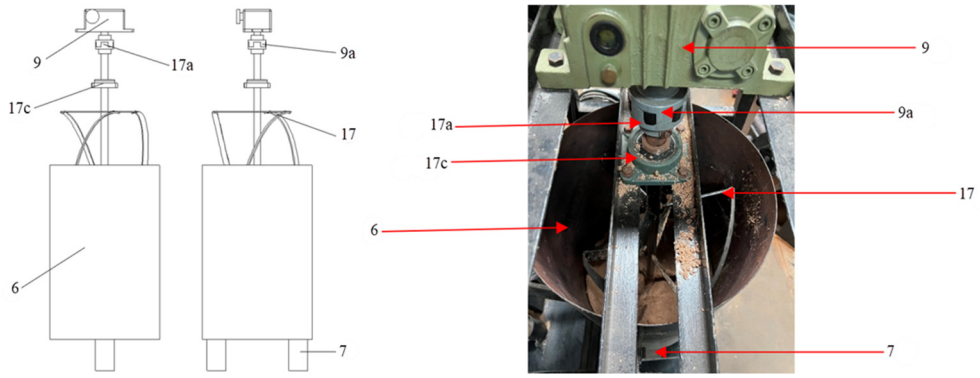


Fig. 6 Mixing unit of semi-automatic split-gill mushroom spawn mixing and pressing machine

2.2. *Machine performance test*

The performance test of the split-gill mushroom spawn block mixing and the pressing machine was performed by comparing the weight, height, and density of the mushroom spawn blocks obtained from the conventional machine, manual pressing, and the developed machine. The details are as follows:

(1) Conventional mushroom spawn pressing machine is a standard machine for producing mushroom spawn blocks.

(2) Manual pressing is the traditional method for producing mushroom spawn blocks using human labor. The data and experimental results were also collected from a group of farmers who participated in this study.

(3) Developed machine is the machine designed and constructed in this study. The data and experimental results were collected for a group of farmers who participated in this study for further practical use as shown in Fig. 7.

(4) Raw materials used as mushroom substrates are shown in Table 1.

(5) Raw materials used as mushroom substrates were mixed in the mixing tank for machine testing with a moisture content of 65-75%.

(6) A bag was then placed over the cylindrical outlet under the mixing tank.

(7) The mushroom substrate in the bag was pressed using the press cylinder in front of the machine.

(8) After pressing, the mushroom spawn block was removed from the machine and a cap was put on the opening at the top of the bag as shown in Fig. 8. The data such as weight, height, and time were recorded in the table.

Fig. 7 Semi-automatic split-gill mushroom spawn mixing and pressing machine

Table 1 Graph representations

No.	Category	Volume (kg.)
1	Sawdust	100.0
2	Fine rice bran	7.0
3	Sugar	1.0
4	Gypsum	1.0
5	Lime	1.0
6	Epsom salt	0.2
7	Water	45.0

(a) Putting a cap on the opening at the top of the bag

(b) Split-gill mushroom spawn block obtained

Fig. 8 Split-gill mushroom spawn block

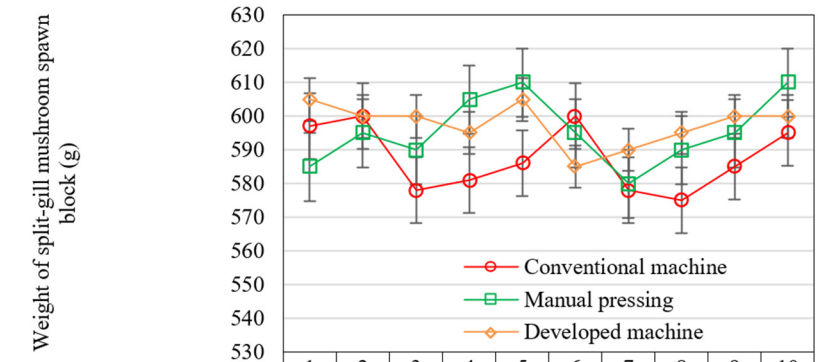
3. Results and Discussion

Performance test of semi-automatic mushroom spawn block mixing and the pressing machine was performed by filling mushroom substrate with an average weight of 570-600 g into the bag and then pressing. The mushroom spawn blocks were obtained from the conventional machine, manual pressing, and developed machine. The data of the mushroom spawn blocks obtained from manual pressing is shown in Table 2 and data of the mushroom spawn blocks obtained from semi-automatic mushroom spawn mixing and pressing is shown in Table 3.

3.1. Comparison of weight of mushroom spawn blocks

A comparison of the weight of split-gill mushroom spawn blocks obtained from the conventional machine, manual pressing, and semi-automatic split-gill mushroom spawn mixing and pressing machine is shown in Fig. 9. The average weight of split-gill mushroom spawn blocks obtained from the conventional machine, manual pressing, and semi-automatic split-gill mushroom spawn mixing and pressing machine was 588, 596, and 598 g, respectively. According to the production standards,

the weight of the split-gill mushroom spawn blocks ranges between 590-610 g [10], and the average weight of produced split-gill mushroom spawn blocks is within the standard range. When considering the weight of split-gill mushroom spawn blocks obtained from the conventional machine, it was found that the weight of split-gill mushroom spawn blocks was the lowest due to insufficient flow of raw materials. When observing the work of manual pressing, it was found that the weight was closest to the average due to the expertise of the work.

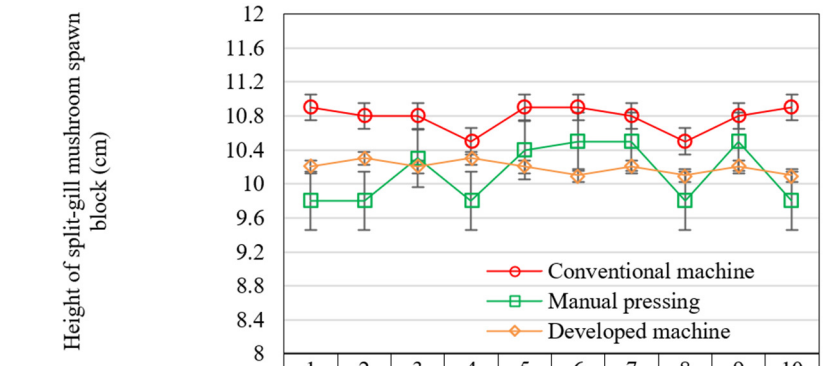


	1	2	3	4	5	6	7	8	9	10
Conventional machine	597	600	578	581	586	600	578	575	585	595
Manual pressing	585	595	590	605	610	595	580	590	595	610
Developed machine	605	600	600	595	605	585	590	595	600	600

Fig. 9 Comparison of weight of split-gill mushroom spawn blocks

3.2. *Comparison of height of mushroom spawn blocks*

The comparison of the height (cm) of mushroom spawn blocks obtained from the conventional machine, manual pressing, and semi-automatic split-gill mushroom spawn mixing and pressing machine is shown in Fig. 10. The average height of split-gill mushroom spawn blocks obtained from the conventional machine, manual pressing, and semi-automatic split-gill mushroom spawn mixing and pressing machine was 10.8, 10.1, and 10.2 cm, respectively. According to the production standards, the height of the split-gill mushroom spawn blocks ranges between 9.5-10.5 cm [10], and the average height of produced split-gill mushroom spawn blocks is within the standard range.



	1	2	3	4	5	6	7	8	9	10
Conventional machine	10.9	10.8	10.8	10.5	10.9	10.9	10.8	10.5	10.8	10.9
Manual pressing	9.8	9.8	10.3	9.8	10.4	10.5	10.5	9.8	10.5	9.8
Developed machine	10.2	10.3	10.2	10.3	10.2	10.1	10.2	10.1	10.2	10.1

Fig. 10 Comparison of height of split-gill mushroom spawn blocks

When considering the height of split-gill mushroom spawn blocks compressed by conventional machines, it was found that the height of the split-gill mushroom spawn blocks was the highest and exceeded the standard value of the mushroom mass because conventional machines could not adjust the distance of the compression shaft. When observing the operation of the semi-automatic split-gill mushroom spawn mixing and pressing machine, it was found that the weight value was closest to the average due to being able to adjust the distance of the compressed axis.

3.3. Comparison of density of mushroom spawn blocks

The comparison of the density (g/cm^3) of mushroom spawn blocks obtained from the conventional machine, manual pressing, and semi-automatic split-gill mushroom spawn mixing and pressing machine is shown in Fig. 11. An example of calculation for a mushroom spawn block with a diameter of 15 cm, a height of sawdust of 10.9 cm, and a weight of 597 g.

Volume can be calculated by

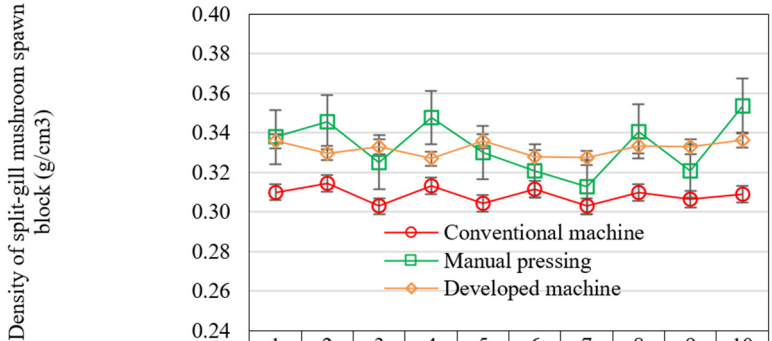
$$V = \pi r^2 h \tag{1}$$

when r is the radius of the circular cross-section, h is height. Substitute the known values in the above equation can be derived $V = \pi \times 7.52 \times 10.9 = 1.926.18$ cm^3.

Density can be calculated by

$$\rho = m/v \tag{2}$$

when ρ is the density of the material, m i is the mass of the material, v is the bulk density of the material. Substitute the known values in the above equation can be derived $\rho = 597/1926.18 = 0.31$ g/cm^3.



	1	2	3	4	5	6	7	8	9	10
Conventional machine	0.31	0.31	0.30	0.31	0.30	0.31	0.30	0.31	0.31	0.31
Manual pressing	0.34	0.35	0.33	0.35	0.33	0.32	0.31	0.34	0.32	0.35
Developed machine	0.34	0.33	0.33	0.33	0.34	0.33	0.33	0.33	0.33	0.34

Fig. 11 Comparison of density of split-gill mushroom spawn blocks

The average density of split-gill mushroom spawn blocks obtained from the conventional machine, manual pressing, and semi-automatic split-gill mushroom spawn mixing and pressing machine was 0.31, 0.33, and 0.33 g/cm^3, respectively. According to the production standards, the density of the split-gill mushroom spawn blocks ranges between 0.30-0.34 g/cm^3 [10], and the average density of produced split-gill mushroom spawn blocks is within the standard range.

3.4. Comparison of production capacity per hour

From Table 2, it was found that manual pressing resulted in the split-gill mushroom substrate blocks with an average weight of 596 g, and an average height of 10.12 cm and took about 1.48 min per block. The production capacity was 40.55 blocks or about 40 blocks per hour. From Table 3, it was found that the semi-automatic split-gill mushroom spawn mixing and pressing machine resulted in the split-gill mushroom substrate blocks with an average weight of 598 g, and an average height of 10.19 cm, and took about 1.07 min per block. The production capacity was 56.07 blocks per hour. However, as the semi-automatic machine could produce 2 blocks at a time, the production capacity was 112 blocks per hour as shown in Fig. 12. Considering manual pressing by 1 worker, excluding time spent in sawdust mixing, it can be seen that manual pressing could produce 40 mushroom spawn blocks per hour while the developed machine could produce 112 mushroom spawn blocks per hour, which is 2.8 times faster.

Table 2 Data of the mushroom spawn blocks obtained from manual pressing

No.	Weight of split-gill mushroom spawn block (g)	Time (min)	Height of split-gill mushroom spawn block (cm)
1	585	1.49.33	9.80
2	595	1.42.15	9.75
3	590	1.46.00	10.27
4	605	1.46.43	9.85
5	610	1.55.30	10.46
6	595	1.54.31	10.50
7	580	1.51.91	10.50
8	590	1.47.90	9.80
9	595	1.49.92	10.50
10	610	1.49.54	9.76
Average	596	1.48.00	10.12

Table 3 Data of the mushroom spawn blocks obtained from the semi-automatic split-gill mushroom spawn mixing and pressing machine

No.	Weight of split-gill mushroom spawn block (g)	Time (min)	Height of split-gill mushroom spawn block (cm)
1	605	1.12.27	10.2
2	600	1.00.75	10.3
3	600	1.03.26	10.2
4	595	1.05.17	10.3
5	605	1.09.85	10.2
6	585	1.07.48	10.1
7	590	1.06.50	10.2
8	595	1.08.68	10.1
9	600	1.10.93	10.2
10	600	1.09.07	10.1
Average	598	1.07.00	10.19

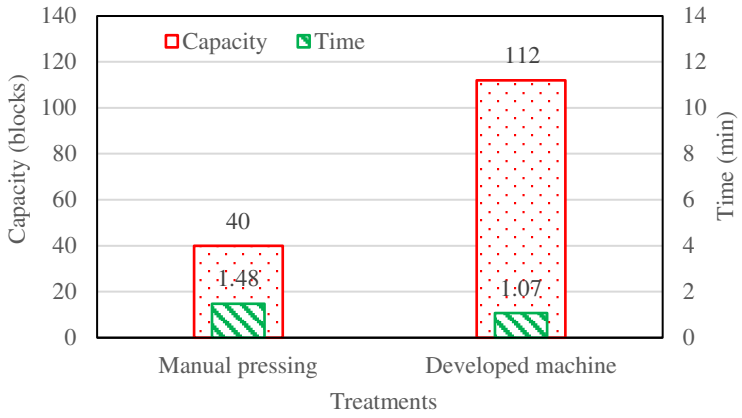


Fig. 12 Comparison of production capacity per hour

3.5. Economic analysis

In the production of mushroom spawn blocks, labor cost for manual pressing of mushroom spawn block is charged per block and the productivity is not enough to meet the demand. Therefore, in this study, a semi-automatic mushroom spawn block pressing machine was developed and constructed to reduce the time and steps in mushroom spawn block production. It was found that the developed mushroom spawn pressing machine reduced production time and increased the production capacity to 2.8 times faster compared to manual pressing. The details of the cost comparison between the production of mushroom spawn blocks by manual pressing and semi-automatic mushroom spawn pressing machine and the payback period when labor cost per block is 0.27 baht are as follows. This semi-automatic mushroom spawn block pressing machine uses a

single 0.5 hp motor to drive the entire mechanism of the machine which consumes a total of 1,650 W (7.5 A) of power, if the semi-automatic mushroom spawn block pressing machine operates 4 h a day, and 24 days a month. (Note: 1 unit of electricity meter equals 1,000 W.)

In the above calculation, one worker working 4 hours a day can produce 720 mushroom spawn blocks a day, so the wage is 194.4 baht per day. The semi-automatic mushroom spawn block pressing machine requires 1 worker to work 4 hours a day to control the machine and it can produce 2,720 mushroom spawn blocks per day. After deducting electricity costs, overhead costs, labor costs, and depreciation of the machine, the cost is 530.73 baht per day and the payback period of the semi-automatic mushroom spawn pressing machine is 1 month and 25 days.

3.6. Assessment of machine performance

The results of the survey with 60 mushroom spawn block producers in the community using a questionnaire to rate the performance of the developed machine (when 5 = most satisfied, 4 = very satisfied, 3 = moderately satisfied, 2 = less satisfied, and 1 = least satisfied) are shown in Table 4.

Table 4 Summary of a survey of performance of the developed machine with a group of mushroom spawn block producers

No.	Area	Average	Range
1	Continuous production of the mushroom spawn blocks	5.00	1
2	Density of the mushroom spawn blocks	4.30	7
3	Safety in the mushroom spawn block production	4.50	5
4	Production capacity of the machine	4.45	6
5	Control of the automatic mushroom spawn pressing machine	4.70	3
6	Ease of use of the machine	4.85	2
7	Power consumption of the automatic mushroom spawn pressing machine	4.56	4
Average		4.62	-

From Table 4, the continuous production of the mushroom spawn blocks showed the highest score with an average score of 5, followed by the ease of use of the automatic mushroom spawn block pressing machine with an average score of 4.85, control of automatic mushroom spawn press machine with an average score of 4.70, power consumption of automatic mushroom spawn pressing machine with an average score of 4.56, safety in mushroom spawn block production with an average score of 4.50, the production capacity of the machine with an average of 4.45 and the density of the mushroom spawn block with an average score of 4.30. Overall, the group of mushroom spawn block producers showed the highest level of satisfaction with the performance of the automatic mushroom spawn block pressing machine developed in this study.

4. Conclusions

This study developed the mixing s through the construction of a semi-automatic machine, the performance test was also performed. Based on the experimental results, the following conclusions are made:

(1) The developed machine produced the split-gill mushroom spawn blocks with an average weight of 598 g which is between 590-610 g of the production standard.

(2) The developed machine produced the split-gill mushroom spawn blocks with an average height of 598 cm which is between 9.5-10.5 cm of the production standard.

(3) The developed machine produced the split-gill mushroom spawn blocks with an average density of 0.33 g/cm3 which is between 0.30-0.34 g/cm3 of the production standard.

(4) As for production capacity, manual pressing produced 40 mushroom spawn blocks per hour while the developed machine produced 112 mushroom spawn blocks per hour, which is 2.8 times faster.

(5) The developed machine showed a payback period of 1 month and 25 days.

Acknowledgments

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Conflicts of Interest

The authors declare no conflict of interest.

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