Development and Knowledge Transfer of Bio-Fertilizer Pelletizing Machine Innovation for Communities in Sakon Nakhon Province

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Abstract : The purpose of this research is to study the effect of operating conditions on granular fertilizer production using the bio-fertilizer mixing pelletizing machinery, developing strategies for evaluating device's performance and knowledge transfer. The bio-fertilizer pelletizing machines can be used to develop the production of bio-fertilizer pellets. The machine dimensions are 60 centimeters wide, 100 centimeters long and 140 centimeters high. The machine is tested in two parts. First part is when mixing fertilizer is tested, and the second part is the testing of fertilizer pellets. The compound fertilizer consists of bio-fertilizer, rice bran, water and a biological fermentation. The efficiency of test compressed granular fertilizer ranges from 17.33 to 20.67%. The machine is successful in producing fertilizer pellets at 95.70% and can produces a maximum of 20 kg granular fertilizer at a time. The rotation speeds used for the production of fertilizer granules is at 450 rpm. From the field transfer of bio-fertilizer mixing and pelletizing technology, farmers are satisfied with the outcome. The results from assessing the farmer's satisfaction showed an average of 3.64 out of 5. The results of engineering economic analysis showed that the average cost of work is 1.63 baht per kilogram. The break-even point is after working 21 hours a year and with a payback period of 7 days.

Keywords: Bio fertilizer, Fertilizer mixer, Fertilizer pellets, Innovation.

1. Introduction

Bio-fertilizers consisted of microorganisms aim to improve biological and physical characteristic of soil. Biochemical and organic degradation of objects, as well as the release of nutrients from organic or inorganic objects is also possible for high performance bio-fertilizer. Bio-fertilizers can also help increase efficiency in combination with the use of chemical fertilizers, resulting in farmers reduction in the consumption of chemical fertilizers. However, when using dust-based bio-fertilizers in plantations, there is a fragmentation of bio-fertilizers that are harmful to the user. Another main problem and a great barrier to the use of bio-fertilizers is the cost of transportation when using these type of fertilizer. [1] Therefore, when considering the effectiveness, bio-fertilizer is considered to create a higher market value if it is pelletized. Bio-fertilizer comprised of various ingredients of fertilizers such as plant debris, manure, bio-fermented water which can be added to the soil and produced by farmer themselves. [2] Currently, there are 3 types of fertilizer pellets. Threaded pellet machines are designed to push the fertilizer to the destination with a perforated sheet of the desired size. The characteristics of this machine included 2-5 vertical roller cores adhering to the upper part and compressing the material through a circular rotating steel plate, which rotates vertically. The last type is a horizontal roller compressor, which works similar to vertical roller, but the roller compression touches the sidewall. [3] After that, researchers transferred technological knowledge of the Bio-fertilizer mixer and pelleting machine Inpang Community Enterprise Center, Kut Bak District, Sakon Nakhon Province. This place is a center for agricultural products processing enterprises, a center for learning about products from Mak Klao water, Thai herb from Mak Kao fruit, and other Thai herb that are grown by using conventional powder biological fertilizer. This conventional type of fertilizer consumes large amount of storage space and they are hazardous to human respiratory system as well. These problems can be eliminated by allowing researches to teach communities on how to use the Bio-fertilizer mixer and pelleting machine. After each lesson research passed on a survey to participant to evaluate students' satisfaction level of the Bio-fertilizer machine.

2. Objectives

2.1 Design and build a Bio-fertilizer mixer and pelleting machine using the principle of horizontal roller compressors. This principle was used in order to reduce production costs and reduce the process of transporting the mixed fertilizer into the pelletizing process.

2.2 To evaluate the performance of the Bio-fertilizer mixer and pelleting machine.

2.3 To transfer technology of the bio-fertilizer mixer and pelleting machine to communities at Inpang Community Enterprise Center, Kut Bak District, Sakon Nakhon Province. These activities are part of an appropriate model that can be used in other communities.

2.4 To be able to evaluate the Bio-fertilizer mixing and pelleting machine based on user satisfaction.

3. Experiment setup

3.1 Designing and creating bio-fertilizers and granules is divided into 3 parts as follows: [4]

3.1.1 The machine structure. To make it suitable for household use, which can be moved easily, it is designed to have a structure 60 cm in width, 100 cm in length and a height of 140 cm as shown in Figure 1. It is strong and has a base to support the weight of the working unit or assembly equipment.

3.1.2 Inside the mixing tank is equipped with a 6 X 80 cm mixing blade. There is a fertilizer vent with a lid-opening of 10 X 20 cm at the bottom of the mixing tank which was used to release the fertilizer into the pellet unit, as shown in Figure 2.

Figure 1 Structural design characteristics of the bio-fertilizer mixer and pelletizer

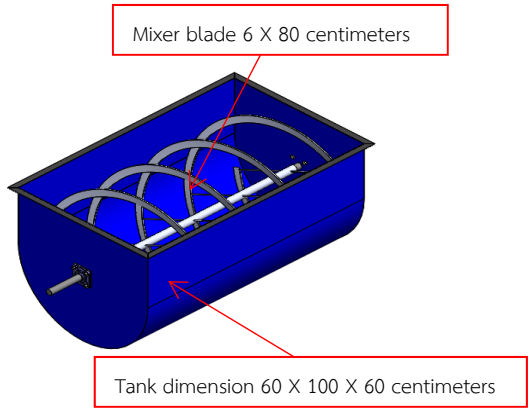

Figure 2 Design characteristics of mixing tanks and bio-fertilizer mixing outlet

3.1.3 Fertilizer pellet kit design as horizontal roller. The diameter of the pellet is 5 mm with 1,400 holes with the main components of the fertilizer pellet head unit. The spiral conveyor of the raw material roller is light in weight, as shown in Figure 3.

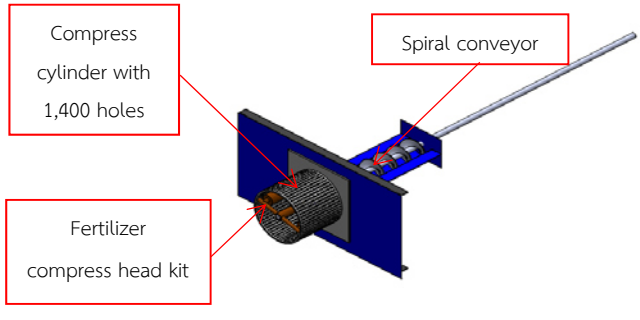

Figure 3 Design characteristics of the fertilizer conveyor unit

3.1.4 Adopted the design of various components of bio-fertilizer mixer and pellet consisting of machine structure, mixing tank, mixing blade, fertilizer transmission, extruded cylinder, and fertilizer pellet roller. The engine

is a 3-horsepower motor which is transmitted via the belts to mixing and fertilizer pellets. The mixed materials are characterized by a circular stirring leaf with a radius of around 58 cm and a radius of 80 cm, as shown in Figure 4.

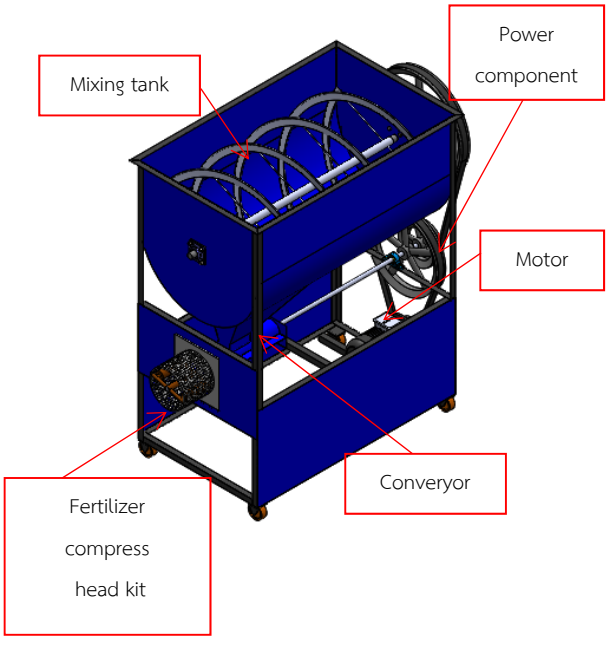

Figure 4 Design characteristics of the bio-fertilizer mixer and pellet.

3.1.5 The team of researchers created and assembled the components accordingly and spray paint to obtain the bio-fertilizer machine. After that, the team conducts a performance test collaborating with community enterprises, as shown in Figure 5.

Figure 5 Characteristics of the fertilizer mixer and pellet machine assembly of various parts.

3.2 Bio-fertilizer mixing and pelletizing machine

3.2.1 Fertilizer is added to the mixing tank and mixed by the sheer force rotation of the blades. The solid compound is compressed into the fertilizer compress head kit to transform it into pellets. The bio-fertilizer mixture flows through the conveyor spiral unit and into the extruder of the fertilizer pellet unit containing a roller rotated around the drilled compressor. The wire attached outside the compressor rotates the fertilizer to produce uniform size pellet. The cut pellet will fall to the bottom of the machine. The obtained biofertilizer was then taken to dry in the sun. [5]

3.2.2 Material used to make the biofertilizer pellet includes plant-based material, manure, husk and bio-fermented water.

3.2.3 Equipment used in machine testing includes bio-fertilizer mixers, balance scale, fertilizer container, 1000 ml beaker, plastic bag or fertilizer bag and electrical connectors.

3.3 Calculation of belt wheel size and belt length

3.3.1 The calculation of the ratio and speed of the 3-horsepower electric motor, which had a speed of 1,475 rpm. The maximum torque of 14.48 Nm is used to calculate and determine the speed of the axle and the size of the various wheel belts. The calculation of the ratio (i) and the speed is used in the 1st.

$$i = \frac{D_2}{D_1} = \frac{n_1}{n_2} \quad (1)$$

Where, D_1 = Diameter of belt wheel (m)

D_2 = Diameter of drive belt wheel (m)

n_1 = Cycle speed of the belt wheel (rpm)

n_2 = Drive wheel speed (rpm)

3.3.2 The calculation of shaft size is based on the shaft design code of the American Society Mechanical Engineers (ASME). The method is based on the theory of maximum shear stress, which is a static design method. However, most shafts are under cyclical stress therefore it is recommended that shaft is made from ductile metal (St.42) according to ISO / R 775-1969. This material also being lower than the other type of metal. The material for making the shaft need to be ductile because a lot of torque is generated during the screwed shaft. Equation 2 was used to calculate the size of the shaft (d).

$$d^3 = \frac{16}{\pi \tau_d}[(C_t \cdot T)^2 + (C_m \cdot M)^2] \quad (2)$$

Where, C_m = Bending fatigue factor (rotational shaft appearance) Slow increase force, 1.5

C_t = Fatigue factor due to twisting (slowly increased shaft, force increase, value equal to 1.0)

T = Torque caused by shaft (Nm)

M = Momentum bending caused by shaft (Nm)

T_d = Design shear stress (if the shaft does not have a wedge groove equal to 55 Nm per square millimeter)

3.4 Evaluation of performance of bio-fertilizer mixer and pellets.

This study determines the amount and duration it takes to turn raw material into pellet from machine mixer.

3.4.1 Finding the efficacy of bio-fertilizers and granules. [6]

$$\text{Efficacy of biofertilizers} = \frac{Amount\ of\ biomass\ output\ (kg)}{Time\ consume\ during\ experiment\ (h)} \quad (3)$$

3.4.2 Finding percentage of moisture. [6]

$$W = \frac{m - d}{m} \times 100 \quad (4)$$

Where, W = Percentage of moisture (standard-wetness)

m = Weight before heated (gram)

d = Weight after heated (gram)

3.5 Economic feasibility study [7]

3.5.1 Average cost analysis and assessment of the overall cost of using the machine which consist of the farmers acquiring the mixers and using it to make bio-fertilizers instead of doing manual labor. The total cost consists of fixed cost and variable cost. However, the analysis does not charge a fixed cost on insurance costs, taxes, greenhouses, transportation fees for various locations, and etc. For variable costs, the cost included the amount of mixing and pellets of bio-fertilizers, i.e. workers' wages to work with machines, electricity, maintenance, repair costs, and etc.

3.5.2 Pay-Back Period analysis is a calculation of the machine's payback period on how long will it take for the investor to actually obtain a profit from acquiring the machine. The return should be in the amount equal to the amount invested within the period of time as shown in equation 5. [8]

$$PBP = \left(\frac{P}{R}\right) \quad (5)$$

Where, PBP = Payback period (year)

P = Price of the machine (baht)

R = Net profit (baht per year)

3.5.3 Break - Even Point analysis calculates the time it takes to operate the machine per year by comparing the cost of mixing and making pellet fertilizers. It is based on the cost of labor force equaled to the cost of operating mixer and the biofertilizer calculated from the Equation 6.

$$BEP = \frac{F_c}{B - VC} \quad (6)$$

Where, BEP = Break-even point (hour per year)

Fc = Fix cost (baht)

B = Employment Rate (Baht per hours)

VC = Variable cost (Baht per hour)

3.6 Sustainable knowledge transfer process to the communities The research team introduced a bio-fertilizer mixing and pellet machine designed and built to convey bio-fertilization technology and the use of bio-fertilizers and granules at Ingbang Community Enterprises, Kut-bak District, Sakon Nakhon Province. It is a community enterprise and learning resource center for the processing of Thai mak and herbal water. The raw material used in processing bio-fertilizer are fruit of trees from the mountain and the medicinal plants cultivated by the villagers. The problem of procuring fertilizers used in cultivation is that they are dust-based biofertilizer. This type of fertilizer can be wasted in storage spaces and also dust dissipates during use. The research team has applied the knowledge of bio-composting and the use of bio-compost mixers and pellets to convey the technology to ensure sustainability in the community, as shown in Figure 6.

(a) Transfer knowledge on bio-fertilizer, (b) Knowledge transfer on mixers and pellets machine and (c) Output from mixer and pellets machine

Figure 6 Shows the transfer of bio-fertilizer mixing and pelletizing technology

4. Methodology

4.1 The test for the optimum quantity of the bio-fertilizer and pellet mixing machine.

The ingredients to be processed are raw materials consisting of plants, black manure, rice husk and water in the ratio of 15:2. The ratio of the water mixture is tested by adding water in 1 liter to 5 liters in order to find the ratio of water that is suitable for compression. Once the fertilizer is mixed well, the lid on the bottom of the fertilizer mixer is open to observe what fertilizer granules look like. To determine the percentage of moisture, the coagulation of the fertilizer pellets was observed and an approximately 300 gram of fertilizer pellets were heated in an open at 100 ^{O}C for 24 hours and then weigh again. [9]

4.2 Testing of the functional capabilities of the bio-fertilizer pelletizing machine. [10]

Pelletizing machine's performance testing is available at a speed range of 450 – 550 rpm and the fertilizer is well mixed at a speed range of 75 - 105 rpm. The results of the experiment are shown in Table 1 . The optimum test for bio-fertilizer pellets at 17.33% is based on the water mixture per fertilizer content: 1 liter of water per 5 kg fertilizer. Based on the performance testing, the pelletizing machine is operational at a weight capacity which ranges from 7, 10, 15, 17, 19 and 22 kg., but at a weight capacity of 23 kg, the machine become inoperative. During the second testing, mixing speed at 95 rpm and compression speed of 500 rpm, the machine can operate at a capacity of 7, 10, 15, 17, 19 and 20 kg, the machine is inoperative at 21 kg. Based on the test results, it can be determined that the capacity value of the bio-fertilizer that the machine can operate depends on the rpm of the mixing unit, pellet kit, and horsepower of the electric motor.

4.3 assess the satisfaction level of the farmers who attended the training in bio-fertilizer technology.

Out of 40 farmers who listened to the explanation and demonstration on the process of mixing and bio fertilizer pellets twenty individuals are randomly chosen to evaluate the questionnaire.

5. Results and Discussions

From Table 1, the results of the suitable moisture test of the mixer and pelletizer revealed that fertilizer weight at 15 kilograms per 3 liters resulted in a moisture content of 17.33% after compression. And the fertilizer weight at 15 kg per 4 liters of water mixed with biofermented fertilizer gave moisture content of 20.67% after compression.

The effect on which the fertilizer mixer and pellet can work at optimum cycle speed is shown in Table 2. Results revealed that a mixing speed of 105 rpm and compression speed of 550 rpm generated 18.22 kg of bio-fertilizer with 17.33% moisture content. Another experiment using 95 rpm mixing speed and compression speed of 500 rpm resulted in a 20 kg bio-fertilizer with a moisture content of 17.33%. The same percentage of moisture content was measured when bio-fertilizer was produced at 75 rpm mixing speed and 450 rpm compression speed.

Based on Table 3, the results of the biofertilizer and pellet mixer test showed that at the mixing speed of 105 rpm and compression speed of 550 rpm approximately 18.22 kg of bio-fertilizer was produced per batch within 8.32 minutes and the total residual dust generated after production weights 1.78 kg. At compression speed of 500 rpm, the bio-fertilizer pellet obtained weight 18.64 kg per batch after operating for 8.45 minutes and contained 1.36 kg of dust residual. At mixing speed of 75 rpm and compression speed of 450 rpm, biofertilizer pellet weighted 19.14 kg per batch at operating time of 8.52 minutes with 0.86 kg residue. These results corresponded well with other researches on the grinding mechanism inside the mixing and pelletizing devices [11].

However, the impact of mixing speed in this research is relative small compared with other research due to the smaller impeller size used in this research [12].

According to Table 4, the results of the assessment for the level of farmer's satisfaction on the production of bio-fertilizers by the machine are summarized as follows: Farmers are satisfied with the bio-fertilizer mixer and pelletizing machine, with an average of 3.64 satisfaction levels. The average yield quality is at 3.86 satisfaction levels. The farmer's suggested that the mixing and pellet machine should be reconstructed into a small agricultural engine, as some of which have to be moved to work continuously in places where there is no electricity. After evaluation of the knowledge transfer process, it was realized that user gained considerably first-hand knowledge which can be apply directly to the bio-fertilizer production procedure. Additionally, the learning effectiveness is improved as more learning-by doing technique was applied.

Economic analysis and evaluation from the results of the bio-fertilizer mixing and pellet test designed and built using two workers, and an average power of 2.23 kW/hr. The capacity to mix and produce 404 kg per day of bio-fertilizer in proportion to the cost of building the machine for 30,000 baht showed that there was a break-even

point in the work period of 21 hours per year. When considering the working hours of the bio-fertilizer mixer and pellet maker at 864 hours per year, there is a 7-day payback period, the cost of mixing and pelletizing is 1.63 baht per kilogram. Payback period in this research is relative smaller than other researches which are conducted in different countries due to lower equipment prizes in Thailand. [13]

Table 1 Effect of heating on bio-fertilizer pellet product.

Trial	Fertilizer weight (kg)	water (L)	Fertilizer weight		Moisture (%)	Physical observation of Pelletized bio-fertilizer
			Before bake (g)	After bake (g)		
1	15	1	300	277	7.67	Dry, do not pelletize
2	15	2	300	265	11.67	Dry, do not pelletize
3	15	3	300	248	17.33	Compressed well into pellet
4	15	4	300	238	20.67	Compressed well into pellet
5	15	5	300	224	25.33	Liquid, do not pelletize

Table 2 Effect of agitation rate on bio-fertilizer pellet product.

Mixer speed (rpm)	Pelletizing speed (rpm)	Possible operating capacity (kg)	Not possible operating capacity (kg)	Moisture (%)
105	550	7,10,15,17,19,22	23	17.33
95	500	7,10,15,17,19,20	21	17.33
75	450	7,10,15,17,19,20	21	17.33

Table 3 Test results using bio-fertilizer mixer and pelletizing machine.

Mixer speed (rpm)	Pelletizing speed (rpm)	Fertilizer (kg)	Pelletized (kg)	Residual (kg)	Time (min)	Pelletizing ability (kg/hr.)	Loss (%)	Efficiency (%)
105	550	20	18.22	1.78	8.32	131.39	8.90	91.10
95	500	20	18.64	1.36	8.45	132.35	6.80	93.20
75	450	20	19.14	0.86	8.52	134.78	4.30	95.70

Table 4 The results of the assessment showed the level of satisfaction of farmers with bio-fertilizers and pellets.

Farmer's satisfaction with bio fertilizer mixer and pellet	Average	Indicator
1. Ease of use	3.56	Good
2. Safety in use	3.52	Good
3. Yield Quality	3.86	Good
4. Working time	3.54	Good
5. Cleaning ease	3.65	Good
6. Do not cause air pollution	3.72	Good
7. Ease of maintenance	3.62	Good
8. Suitability of size and shape	3.77	Good
9. Performance (kg/h)	3.57	Good
Overall average	**3.64**	**Good**

6. Conclusion

This research reported the functional capabilities of the bio-fertilizer mixer and pelletizing machine operating at mixing speed in the range of 75-105 rpm and compression speed at 450-550 rpm. By getting the maximum pellet fertilizer production of the machine at 95.70%, the experiment shows the capabilities of the bio-fertilizer mixer and pelletizing machinery. The machine's pellet fertilizer production efficiency is up to 95.70% at 75 rpm mixing speed and compression unit speed of 450 rpm. The fertilizer mix can be mixed together in an average of 5 minutes and takes an average of 8 minutes to test the amount of fertilizer that can be produced from a 20 kg. at a time.

The results show the physical properties of compressed bio-fertilizers at 5 mm in diameter, with an average length of 10 mm, a pleasant value for bio fertilizer pellets, between 17.33-20.67%. Engineering economics analysis provides payback periods and breakeven points of bio-fertilizer mixers and pelletizing machine. It was found that the break-even point was after operating for 21 hours per year. When considering the working hours of the bio-fertilizer mixer and pelletizing at 864 hours per year, there is a 7-day payback period, the cost of mixing and pelletizing was 1.63 baht per kilogram.

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