The effect of blade type and speed to the bananas plant chopping machine

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Abstract. This research was aimed to find the best of blade and speed condition for the bananas plant chopping machine. The study consisted of three levels of blade types: straight edge blade, forward curved edge blade, and backward curved edge blade, with three levels of revolution speed of 100, 500, and 1000 rpm. The working capacity and specific power consumption were used as indicators. The results revealed that the 4 blades of straight edge blade and 4 blades forward curved edge blade with 1000 rpm gave the highest working capacity while power consumption remained insignificant.

1. Introduction

In Thailand, farmers usually/mainly grow bananas for a commercial purpose and as household food. However, a very important part of bananas is fruit bunch. After the fruit bunch was cut, the farmers usually leave the banana plant to rot in the field. In fact, the banana plant can be used as animal food. H J Over et al [1] recommend that it can be used as animal feed. The Department of Livestock Development of Thailand [2] also advises that bananas and plantains are suitable for livestock feeding as supplementary feed and can help the farmer to decrease the feed expenses. To use the banana plant as animal’s food, it must be chopped to small pieces. Normally, the small scale farmers use a kitchen knife to slice a banana trunk, which is a laborious and time-consuming task. To solve these problems, both farmers and the government sector were trying to develop a machine such as Anaek Somkrok [3] which tested the shape of blade and recommended that the radius cut blade more suitable than squirrel cut blade. Prasit Prapawong, et al [4] were designing and testing the grinder for banana stalk using knife-edges. They faced the problem that they must divide along banana tree in half then chop it part by part causing a low working rate. Danuwat Thangdee [5] studied the size of banana plant and recommended that at the 80th percentile of diameter of banana was 200 mm. Thus, to chop the whole banana plant without dividing it into two sections, the chopping knife should at least be 200 mm length. After that Danuwat Thangdee [6] studied the straight edge knife for banana plant chopping machine and found that the 1000 rpm with 4 blades gave the highest working capacity.

Then, to ease chopping and increase the working rate this research aims to find out the blade type and speed of blade for fixing the bananas plant chopping machine.
2. Materials and method

2.1. Types of blades
First of all, the researcher would like to use the blade that is produced by local smith that is normally found in the local market as it is familiar to farmers both in usage and maintenance. In the local market, the blade found is as shown in figure 1. First is the straight edge blade. Second is the forward curve edge blade, and third is the backward curve edge blade. The three types of these blades will be studied.

(a) straight edge blade   (b) forward curved edge blade      (c) backward curved edge blade

Figure 1. The blade types.

2.2. Chopping disc
After examining the blade type, the number of blade and speed will be studied. To approach these factors the three chopping discs were designed as figure 2. There are two slots, three slots, and four slots to be fixed with 2, 3, and 4 of blades respectively.

(a) for 2 blades         (b) for 3 blades      (c) for 4 blades

Figure 2. Chopping disc.

2.3. The test rig
The test rig as figure 3 was fabricated. It consisted of the main part which is the chopping machine mainframe, chopping disc for established blades, pushing weight for pushing banana plant to chopping disc with a steady state speed, and a 3 phase 5 hp electric motor as a power source.

The testing rig was set up as figure 4 and after a test rig pre-test, the researcher found that on low speed controlled by an inverter, the blade usually got stuck to the banana tree instead of cutting it. This is due to lack of motor torque even if the user applied boot torque function. Consequently, the electric consumption tends to be high. Then the speed factor was changed by pulley size ratio. For power consumption, the three phase KW-H meter (K.Y. group 3×15(45) A) was used. The researcher also found the problem that the meter cannot measure the current due to its low current and short time lapse on each replication. Then, the digital clamp meter (FLUKE 324) was used.
The testing was done as follows:
1) Weighed the banana plant (kg.), and measured length of banana plant (m.).
2) Assembled the test rig as fig. 3 by using the two blades chopping disc and set revolution speed to 100 rpm by changing the driving and driven pulley ratio.
3) Recorded the idle power consume (A.) by clamp meter FLUKE 324.
4) Put the banana plant on the rail and fixed the steel rope to the pushing weight.
5) Released the pushing weight to push banana plant to the chopping plate then recorded power consumed (A.) and chopping time (s.).
6) Tested as 1) – 5) five replications.
7) Calculated working capacity as equation (1), and specific power consumption as equation (2).

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\text{Working capacity (kg/h)} = \frac{\text{weight of banana plant (kg) } \times 3600 \times \text{chopping time (s)}}{\text{chopping time (s)}} 
\]

\[
\text{Specific power consumption (kW-h/kg)} = \frac{(380 \times \text{power consume (A) } \times 3600)/(\text{chopping time (s) } \times 1000))}{\text{working capacity } \left(\frac{\text{kg}}{\text{h}}\right)} 
\]

8) Tested as 1) – 7) by setting revolution speed to 500 and 1000 rpm.
9) Tested as 1) – 8) by changing chopping plates for three and four chopping blades, and change the blade types respectively.
10) Analyzed results by statistical analysis program (SPSS 17.0).

3. Results and discussion
This research revealed that the high revolution speed is the high working capacity, as the higher number of blades, the more working capacity. Table 1 showed the working capacity of the straight edge blade type and the number of blade to revolution speed. It showed that the slow speed of 100 rpm gave a lowest working capacity, but when the number of blade and the speed is increased, it showed significantly high working capacity, while the specific power consumption was not quite different (table 2). Then in this case to fabricate the machine, the 4-blades with 1000 rpm are recommended.
Table 1. Working capacity of the straight edge blade.

| Rotational speed (rpm) | Working capacity (kg/h)* |
|------------------------|--------------------------|
|                       | S 2 blades | S 3 blades | S 4 blades |
| 100                    | 287.92^a,a | 1036.92^a,b | 2710.02^a,c |
| 500                    | 2516.80^b,a | 3128.88^b,a | 7879.38^b,b |
| 1000                   | 3736.34^c,a | 7850.88^c,b | 10955.80^c,c |

S = straight edge blade
*The different first letters within each column and the different second letters within each row are significantly different (P \( \leq 0.05 \)) based on DMRT.

Table 2. Specific power consumption of the straight edge blade.

| Rotational speed (rpm) | Specific power consumption (kw-h/kg)* |
|------------------------|---------------------------------------|
|                       | S 2 blades | S 3 blades | S 4 blades |
| 100                    | 0.130^a,a | 0.030^a,a | 0.066^a,a |
| 500                    | 0.034^a,a | 0.056^b,b | 0.048^a,a |
| 1000                   | 0.076^a,a | 0.076^c,a | 0.086^b,a |

S = straight edge blade
*The different first letters within each column and the different second letters within each row are significantly different (P \( \leq 0.05 \)) based on DMRT.

According to table 3, working capacity of the forward curved edge blade showed a significant increase both on revolution speed and number of blade, while specific power consumption was slightly not different (table 4). Thus, if the farmer decided to use the forward curved edge blade, the 4-blades with 1000 rpm is recommending.

Table 3. Working capacity of the forward curved edge blade.

| Rotational speed (rpm) | Working capacity (kg/h)* |
|------------------------|--------------------------|
|                       | F 2 blades | F 3 blades | F 4 blades |
| 100                    | 880.65^a,a | 1844.98^a,b | 2004.44^a,b |
| 500                    | 4290.88^b,a | 6914.06^b,ab | 8021.44^b,b |
| 1000                   | 7011.44^c,a | 9144.10^c,a | 10808.46^b,b |

F = forward curved edge blade
*The different first letters within each column and the different second letters within each row are significantly different (P \( \leq 0.05 \)) based on DMRT.

Table 4. Specific power consumption of the forward curved edge blade.

| Rotational speed (rpm) | Specific power consumption (kw-h/kg)* |
|------------------------|---------------------------------------|
|                       | F 2 blades | F 3 blades | F 4 blades |
| 100                    | 0.067^a,a | 0.140^a,a | 0.136^a,a |
| 500                    | 0.173^a,a | 0.178^a,b | 0.024^b,b |
| 1000                   | 0.054^a,a | 0.254^b,b | 0.130^a,a |

F = forward curved edge blade
*The different first letters within each column and the different second letters within each row are significantly different (P \( \leq 0.05 \)) based on DMRT.

Table 5 and table 6 showed the working capacity and specific power consumption of the backward curved edge blade. The data were along as previous two types of blade. Thus, considering the statistical analysis result as a letters superscript in each table, its leading to use 1000 rpm of revolution speed that gave a significantly high working capacity.
Table 5. Working capacity of the backward curved edge blade.

| Rotational speed (rpm) | Working capacity* |
|------------------------|-------------------|
|                        | B 2 blades | B 3 blades | B 4 blades |
| 100                    | 781.18a,b  | 1458.10a,b | 1831.04a,b |
| 500                    | 2652.52a,b | 3530.42b,b | 5819.86b,c |
| 1000                   | 4887.68a,b | 4843.84b,a | 6615.10a,c |

B = backward curved edge blade
*The different first letters within each column and the different second letters within each row are significantly different (P ≤ 0.05) based on DMRT.

Table 6. Specific power consumption of the backward curved edge blade.

| Rotational speed (rpm) | Specific power consumption (kW-h/kg)* |
|------------------------|--------------------------------------|
|                        | B 2 blades | B 3 blades | B 4 blades |
| 100                    | 0.040a,b   | 0.022a,a   | 0.052a,b   |
| 500                    | 0.038a,b   | 0.030a,a   | 0.048a,b   |
| 1000                   | 0.186a,b   | 0.144b,a   | 0.092b,a   |

B = backward curved edge blade
*The different first letters within each column and the different second letters within each row are significantly different (P ≤ 0.05) based on DMRT.

However, when comparing the working capacity to all types of blade as table 7 for the best condition. The result revealed that the appropriate conditions were 1000 rpm with straight edge 4-blades or forward curved edge 4-blades. The specific power consumptions (table 8) were not difference. While the backward curved edge blade gave a lowest working capacity.

Then researchers recommend that the farmer should assembly their machine with straight edge 4-blades or forward curved edge 4-blades, and set revolution speed to 1000 rpm.

Table 7. Working capacity of three type blades with three numbers of blades on difference rotating speed.

| Rotational speed (rpm) | Working capacity (kg/h)* |
|------------------------|--------------------------|
|                        | S 2 blades | S 3 blades | S 4 blades | F 2 blades | F 3 blades | F 4 blades | B 2 blades | B 3 blades | B 4 blades |
| 100                    | 287.92a  | 1036.92b | 2710.02c | 880.63a  | 1844.98b | 2094.44d | 781.18a  | 1458.10b | 1831.04a,b |
| 500                    | 2516.80a | 3128.88a | 7879.38d | 4290.88a | 6914.06d | 8021.44d | 2652.52a | 3530.42c | 5819.86b,c |
| 1000                   | 3736.34c | 7850.88c | 10955.80d | 7011.44c | 9144.10d | 10808.46d | 4887.68c | 4843.84b | 6615.10a,c |

S = straight edge blade, F = forward curved edge blade, B = backward curved edge blade
*The different letters within each row are significantly different (P ≤ 0.05) based on DMRT.

Table 8. Specific power consumption of three type blades with three number blades on difference rotating speed.

| Rotational speed (rpm) | Specific power consumption (kW-h/kg)* |
|------------------------|--------------------------------------|
|                        | S 2 blades | S 3 blades | S 4 blades | F 2 blades | F 3 blades | F 4 blades | B 2 blades | B 3 blades | B 4 blades |
| 100                    | 0.130b   | 0.030b    | 0.066b    | 0.068b   | 0.140b    | 0.136b    | 0.040b    | 0.022b    | 0.052b   |
| 500                    | 0.034b   | 0.056b    | 0.048b    | 0.172b   | 0.178b    | 0.024b    | 0.038b    | 0.030b    | 0.048b   |
| 1000                   | 0.076b   | 0.076b    | 0.086b    | 0.054b   | 0.254b    | 0.130b    | 0.186b    | 0.144b    | 0.092b   |

S = straight edge blade, F = forward curved edge blade, B = backward curved edge blade
*The different letters within each row are significantly different (P ≤ 0.05) based on DMRT.

4. Conclusion

According to the results and statistical analysis of blade types, regarding numbers of blades to revolution speed. The researcher would like to recommend using the 1000 rpm of revolution speed and either the straight edge 4-blades or forward curved edge 4-blades. This condition give high working capacity on reasonable power consumption.
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