The Amount of Cassava Tuber Remained on Underground Stem after Chopped with Various Cross-Section and Diameter of Cylinder Blades

K Suwanapa¹ and S Wongpichet¹
¹Department of Agricultural Engineering, Faculty of Engineering, Khon Kaen University, Khon Kaen, Thailand.

Corresponding author: kiatsuda2557@gmail.com

Abstract. This study aims to test and compare the amount of cassava tubers which remained with underground stem after chopped with cylinder blades which had different cross-section and sizes (3x3 Treatments) by using “Kasetsart 50 cassava variety” with the age of 8 months old that planted in sandy loam in Kalasin Province. There are 30 cassava stalks per treatment were used as the sample. The implement of the test was Factorial in Completely Randomized Design. The results found that increasing of diameter of the cylinder blade from 6 – 8 cm caused the increasing amount of cassava tuber remained with underground stem, however, average tuber loss was just in range of 2.56-3.36% wt. (p-value = 0.003), but the increasing did not affect the amount of force used in cassava chopper. As for changing the cross section of cylinder blade (Square, Round and Hexagon), it caused changes in the amount of cassava tuber remained with underground stem after chopping, but there was no exact direction (p-value = 0.036). However, changing of cross section would cause changes of cassava chopper force (p-value = 0.001) that its directions were related to the length of perimeter of each cross-section.

1. Introduction
Cassava is an important economic crop in Thailand because it is used as raw material in many industries such as cassava chips and pellets which are used as raw material for animal feed production, ethanol and alcohol, starch and processed tapioca flour used as raw material for food and beverage production and other industries, etc. In 2018, Thailand has 8.4 million rai of cassava plantations and 29.98 million tons of cassava production (Fresh Cassava Tuber) that 20-25% of production has been used domestically, and the remains are exported to Asian countries especially to China [1].

In general, the current method of harvesting cassava consists of 3 steps which are 1) pulling cassava out of the ground, 2) separating cassava tuber from trunk by chopping and 3) gathering and moving fresh cassava tuber on the truck which parks at the cultivation plot.

As for activities in the first and third step, research & development of agricultural machinery has already been used [2-6], but the activities in the second step are still in basic level research [7-11], and therefore farmers still apply traditional practices by using knife to chop the joint between cassava tuber and underground stem in order to separate fresh tuber from underground stem. Normally, cassava chopper is operated about 3-8 times/ stalk depending on the number and position of the cassava tuber that is inconsistent in shapes even though it is planted in the same cultivation plot.
The concept of cassava chopper machine development was brought from the requirement to chop and separate cassava tuber from underground stem by chopping only once with cylinder blade which has diameter that is equal or larger than diameter of underground stem.

Since underground stem has uncertain shape and cross-section whereas the cross-section of cylinder blade is in the form of geometric shape that has certain value. For this reason, cassava chopper with cylinder blade cannot cut all tuber parts from underground stem.

Thus, in this study, the objective was to compare the amount of cassava tuber which still remained with underground stem after chopping by cassava chopper with cylinder blades which have various cross-section and diameter in order to find the most suitable cross-section and diameter for further development of cassava chopper machine

2. Research Methodology

2.1. The sample of cassava used in the test
The samples of cassava used in the test were randomly chosen as block (1 block/ Treatment) from the middle area of cultivation plot. Each block was width 3 rows and length 7 m. as shown in figure 1. Furthermore, each block consisted of cassava stalk more or equal to 30 stalks / block.

![Figure 1: Block sample diagram (left) and the samples of cassava used in the test (right).](image1)

2.2. Cassava Chopper Testing unit
Cassava chopper testing unit (figure 2) composes of 2 key components which are gripping mechanism that hold trunk to upturn cassava tuber and cylinder blade used for chopping cassava tuber from underground stem when the trigger is pushed by worker.

![Figure 2: The sketch of cassava chopper testing unit.](image2)
1) Gripping Cylinder: Cylinder has 15 cm in height and 7 cm in diameter. Diameters installed with spring pad inside to hold the trunk that is inserted into the cylinder and rubber sheet on the edge of the top of gripping cylinder to support the blade.

2) Cylinder Blade: Cylinder has 25 cm in height with the knife edge at the apex. The cylinder blades used in the test have 3x3 types composed of 3 cross-section types (figure 3), and each type had diameter size of 6, 7 and 8 cm, respectively.

3) Chopping Force Scales is the scales for measuring of Chopping Force.

4) A Trigger is a pedal for transmitting the force to the Cylinder Blade.

2.3. The Experimental Plan and Testing Index Value

In this research, Factorial in Completely Randomized Design was implemented in the test, and testing factors composed of 3 types of cross-section blades (Round, Square and Hexagon) and 3 levels of diameter size of the blades (6, 7 and 8 cm). Testing Index Value was consisted of:

1) The amount of cassava tuber which remained with underground stem (%) after cassava chopping

\[ W_{tu} = \left( \frac{W_{tu}}{WT_{total}} \right) \times 100 \]  \hspace{1cm} (1)

2) The amount of underground stem which remained with cassava tuber (%) after cassava chopping

\[ WU_n = \left( \frac{WU_n}{WU_{total}} \right) \times 100 \]  \hspace{1cm} (2)

3) Chopping force (N) to separate cassava tuber from underground stem

\[ F = (E \times 9.81) \]  \hspace{1cm} (3)

When

\[ W_{tu} = \text{The weight of cassava tuber which remained with underground stem after cassava chopping, kg./stalk} \]

\[ WT_{total} = \text{The weight of cassava tuber after chopping, kg./stalk} \]

\[ WU_n = \text{The weight of underground stem which remained with cassava tuber after chopping, kg./stalk} \]

\[ E = \text{All chopping force measured from 6 sets of weighing machine, kg./stalk} \]

4) Physical properties of cassava used in the test were composed of max. Dia. of trunk at surface level of soil, the amount of underground stem, the weight of cassava tuber and the number of sides which cassava tuber spread around underground stem.
3. Research results

3.1. Physical Properties of Cassava used in the Test

From the study results of physical properties of cassava used in the test by using samples of cassava in the subject 2.1, it was found that:

The maximum diameter of underground stem and the average diameter of new cassava trunk were 2.10 and 1.92 cm. respectively. The number of cassava tuber per stalk was 4.88 tubers. The average weight per stalk was 1.24 kg., and the average number of sides which cassava tuber spread around underground stem was 3 sides as shown in table 1.

Table 1. Physical properties of cassava used in the test.

| Physical Qualifications                  | avg. | sd  |
|-----------------------------------------|------|-----|
| Max. Dia. of cassava trunk at surface level of soil, cm | 92.1 | 44.0 |
| Max. Dia. of underground stem, cm       | 10.2 | 76.0 |
| Number of cassava tubers, tubers/stalk  | 88.4 | 48.2 |
| Weight of cassava tuber, kg./stalk      | 24.1 | 81.2 |
| Number of sides which cassava tuber spread around underground stem ,sides | 00.3 | 99.0 |

* The number of cassavas (n) which used in the test were 311 stalks. All cassava are Kasetsart 50 variety with the age of 8 months old that cultivated in sandy loam area in Kalasin province. The average distance between planting rows was 89 cm., and the distance between cassava stalks was 63 cm.

3.2 Testing results of comparison between percentage of cassava tuber loss and percentage of underground stem which could not be chopped with various cross-section and blade sizes

The results of comparison test of cassava tuber loss after chopping when tested with 3 cross-section types of blades which were round, square and hexagonal cylinder blades and 3 levels of diameter size of the blades which were 6, 7 and 8 cm. are described as follows.

From the study results, it was discovered that increasing blade size resulting in an increase of internal area of the blade used for underground stem chopping, and also affected to significant increase in the percentage of the cassava tuber loss as shown in table 2. However, changing of cross-section of blades (Round, Square and Hexagon) resulting in increasing percentage of cassava tuber loss (table 3) that was in random direction. According to the study of physical qualifications of the cassava used in the test, it was found that the size of diameter of underground stem and the spread of cassava tuber around underground stem had uncertain cross-section and spreading that cannot be concluded. For this reason, it resulted in changing of blades that affected to the loss of cassava tuber percentage which was also inconsistent in figure 3.

Table 2. Internal area of the blades with various cross-section.

| Cross-section Type | Internal Area of the Blades (cm$^2$) for Blade Size |
|--------------------|-----------------------------------------------|
|                    | 6 cm. | 7 cm. | 8 cm. |
| Round              | 30.28 | 50.38 | 30.50 |
| Square             | 00.36 | 00.49 | 00.64 |
| Hexagon            | 40.23 | 80.31 | 60.41 |
Figure 4: The loss of cassava tuber after chopping with round blade (A) and square blade (B).

Table 3. The percentage of cassava tuber loss after chopped with various cross-section and sizes of blades.

| Type of Cross-section | Cassava Tuber Loss (%) after chopped with Blade Size |
|-----------------------|-----------------------------------------------------|
|                       | 6 cm. | 7 cm. | 8 cm. | Avg.   |
| Round                 | 03.2  | 96.2  | 09.4  | 03.3   |
| Square                | 56.2  | 96.2  | 40.2  | 64.2   |
| Hexagon               | 09.3  | 99.2  | 58.3  | 22.3   |
| Average               | 56.2  | 97.2  | 36.3  | -      |

According to table 3, it illustrates the comparison results of cassava tuber loss after chopping with various cross-section and sizes of blades. It was found that the loss of cassava tuber with the 8cm blade was higher than other blades with 6 and 7 cm sizes with an average value of 0.80 and 0.39% respectively.

From the analysis results of the comparison of percentage of cassava tuber loss with various cross-section and sizes of blades, it was discovered that cross-section and size of blades caused difference of cassava tuber loss after chopping at the statistical significant level 0.05 which was in accordance with the hypothesis set in table 4.

Table 4. The results of comparison of cassava tuber loss after chopping with various cross-section and sizes of blades.

| SOV                  | SS      | df. | MS     | F       | p-value |
|----------------------|---------|-----|--------|---------|---------|
| Cross-Section of blade | 13.74   | 2   | 6.87   | 3.368   | 036.0   |
| Blade Size           | 24.73   | 2   | 12.36  | 060.6   | 003.0   |
| Interaction          | 39.87   | 4   | 9.97   | 886.4   | 001.0   |
| Within               | 459.00  | 225 | 2.04   |         |         |
| Total                | 537.34  | 233 |        |         |         |

According to the study results of percentage of underground stem which remained with chopped cassava tubers after chopping with various cross-section and sizes of blades, it was found that the value was 0% because the blade can chop only in tuber area, so there were only cassava tuber parts that were chopped and attached to the underground stem after chopping as shown in Figure 7.

In addition, it was also found that the blade size which increased from 6 to 8 cm. resulted in the increase of underground stem which could not be chopped from 3.85 to 8.97%. The number of underground stems which could not be chopped with square blade was not more than that of round and hexagonal blades as illustrated in table 5.
significant level 0.05; however, cassava chopper with square blade would use more chopping force than round and hexagonal blades obviously shown in table 6 and 7.

Table 5 The numbers of cassava underground stem which could not be chopped with various cross-section and sizes of blades.

| Type of Cross-section | The Cassava which could not be chopped (%) after chopped with Blade Size |
|-----------------------|---------------------------------------------------------------------|
|                       | 6 cm. | 7 cm. | 8 cm. | Avg.  |
| Round                 | 0.00  | 11.54 | 0.00  | 85.3  |
| Square                | 3.85  | 3.85  | 26.92 | 54.11 |
| Hexagon               | 7.69  | 3.85  | 0.00  | 85.3  |
| Average               | 85.3  | 41.6  | 97.8  | -     |

3.3 The results of comparison of chopping force at various cross-section and sizes of blades
According to the study results of comparison of chopping force at various cross-section and sizes of blades, it was found that using of round blade resulted in decreasing of chopping force when the blade size was increased from 6-8 cm. that the average chopping force was 1,368.49 N., and the chopping force would be increased if the blade size was increased when square and hexagonal cross-section blades were used for underground stem chopping as shown in table 6.

In addition, the statistical analysis of comparison results of chopping force at various blade sizes suggested that increasing of blade size had no difference in chopping force at the statistically significant level 0.05; however, cassava chopper with square blade would use more chopping force than round and hexagonal blades obviously shown in table 6 and 7.

Table 6 Cassava chopping force at various cross-section and sizes of blades.

| Type of Cross-section | Chopping Force (N) when chopped with Blade Size |
|-----------------------|------------------------------------------------|
|                       | 6 cm. | 7 cm. | 8 cm. | Avg.  |
| Round                 | 1,490.14 | 1,390.08 | 1,226.25 | 1,368.50 |
| Square                | 1,357.70 | 1,381.25 | 1,580.39 | 1,440.11 |
| Hexagonal             | 1,239.00 | 1,276.28 | 1,310.62 | 1,275.30 |
| Average               | 1,362.61 | 1,348.88 | 1,372.42 | -     |

According to the study results of comparison of chopping force at various cross-section and sizes of blades, it was found that the use of different cross-section of blades resulted in different chopping force at the significant level 0.05 because the changing of cross-section would cause changes of blade length for cassava chopper that resulted in increasing chopping force according to the increased blade length. Moreover, square cross-section blade had higher average blade length in every size so it would provide higher chopping force than other cross-section blades as shown in table 8.

Table 7 The length of the perimeter at the cross-sectional and size of blades.

| Type of Cross-section | The Length of the Perimeter (cm.) for Blade Size |
|-----------------------|------------------------------------------------|
|                       | 6 cm. | 7 cm. | 8 cm. |
| Round                 | 80.18 | 00.22 | 10.25 |
| Square                | 00.24 | 00.28 | 00.32 |
| Hexagonal             | 00.18 | 00.18 | 00.24 |

Table 8. Chopping force at various cross-section and sizes of blades.

| SOV                     | SS      | df. | MS      | F       | p-value |
|-------------------------|---------|-----|---------|---------|---------|
| Cross-Section of blade  | 11,042.0| 2   | 5,521.0 | 7.578   | 0.001** |
| Blade Size              | 221.6   | 2   | 110.8   | 0.152   | 0.859m  |
| Interaction             | 18,163.2| 4   | 4,540.8 | 6.232   | 0.000** |
| Within                  | 163,931.9| 225 | 728.6   |         |         |
| Total                   | 193,358.8| 233 |         |         |         |
4. Conclusions

From the study results of the influence of cross-section and size of blade affected to the percentage of cassava tuber loss after cassava chopper, it was discovered that increasing of blade size would increase percentage of cassava tuber loss from 3.85 to 8.97%. The cassava chopper with Round and hexagon cross-section was increased from 6-8 cm. resulting in lower percentage of cassava loss than that of square cross-section of blades 7.69%. An average value of the increasing of blade not more than 2 cm. was not affected any difference of percentage of cassava tuber loss, and it was also discovered that the increasing of blade size was not affected chopping force, but changing of cross-section resulted in different chopping force. The use of square cross-section would apply more chopping force that other cross-sections.

References
[1] Thai Tapioca Development Institute 2019 Harvested Area and Production at: https://www.tapiocathai.org/L1.html, Accessed on 1 March 2019
[2] Muntamkarn W, Ratanasrimetha S and Suriwong M 2009 The development of cassava root lifted up by pulling stump harvester type. Postharvest Technology Innovation Center, Chiang Mai University, Thailand
[3] Saengpanta P, Chamsing A, Asawang S, Taikontong P, Chansraku W, Senanarong A, Sangiampong S and Wannarong K 2011 Research and development of cassava digging machine. The Meeting Report of the 12th Conference of the Agricultural Engineering Association of Thailand (Chon Buri: Thailand)
[4] Chansiri C and Wongpichet S 2011 Research and development of cassava digging and aggregating machines. Postharvest Technology Innovation Center, Chiang Mai University, Thailand
[5] Chansiri C and Wongpichet S 2011 The study and development of equipment for conveying cassava on trucks. Postharvest Technology Innovation Center, Chiang Mai University, Thailand
[6] Panbhumi A and Chansiri C 2013 The study of transporting cassava equipment installed on the truck at post harvesting. Agricultural Science Journal pp 442-5
[7] Langkapin J, Kalsirisilp R and Tantrabandit M 2012 Design and Fabrication of a Cassava Root Picking Machine. Thai Agriculture Res. J. 30
[8] Wongpichet S 2013 The study of physical properties of cassava rhizome and design the principle of cutting mechanism. Postharvest Technology Innovation Center, Chiang Mai University, Thailand.
[9] Junyusen P, Vatakit K, Somphong C and Arjharn W 2014 Development of a cassava harvester for cutting cassava tuber from rhizome. Agricultural Sci. pp 353-6
[10] Suvanapa K and Wongpichet S 2014 Technical possibility to use the cylinder blade for chopping cassava root from rhizome. Proceeding in The 16th TSAE National Conference and the 8th TSAE international Conference
[11] Arsawang S, Chansrakoo W, Chamsing A, Sangphanta P and Chawkongchak S 2016 Design and development of cassava root plucking out machine. Agricultural Sci. pp 463-6

Acknowledgement
I would like to present my gratitude to Kalasin University for supporting research fund and the Department of Agricultural Engineering, Faculty of Engineering, Khon Kaen University for supporting the facilities used in this research.