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Designing and Constructing a Cassava Slicing Machine for Household Use

Virat Wangkuanklang
Faculty of Engineering and Technology, Rajamangala University of Technology Isan, Thailand.

Weerakul Meeklangsaen
Faculty of Engineering and Technology, Rajamangala University of Technology Isan, Thailand.

Jantana Suntudprom
Faculty of Engineering and Technology, Rajamangala University of Technology Isan, Thailand.

Purin Akkarakultron
Faculty of Agricultural Technology, Rajamangala University of Technology Thanyaburi, Thailand.

Khongdet Phasinam
Faculty of Food and Agricultural Technology, Pibulsongkram Rajabhat University, Thailand.
phasinam@psru.ac.th

Dowroong Watcharinrat*
Division of Educational Administration, Department of Education, Faculty of Education, Kasetsart University, Thailand.
*Corresponding author email: dowroong.w@ku.th

Abstract

The present research aimed to design and construct a household slicing machine with which smallholder farmers could cut cassava roots into fine pieces for use as an animal feed mixture. The efficiency of the machine was assessed by slicing cassava roots that were 2–9 cm in size across three rotational speeds: 50, 60, and 70 rpm. It was found that the rotational speed of 60 rpm led to 85.68% whole slices and 13.89% broken slices. In addition, the average measurements of the whole slices were 49 mm in width, 87 mm in length, and 3.7 mm in thickness. Finally, the capacity of the machine reached 198 kg/h with the slicing efficiency of 87.6%.

Index Terms - Cassava chips, Cassava slices, Household use, Slicing machine, Smallholder farmers

INTRODUCTION

Although the total volume of agricultural exports from Thailand in 2020 fell from that of 2019 by 2.21%, the export value of certain produces, especially fresh and processed cassava roots, such as cassava slices, cassava pellets, and raw and modified cassava starch, is on the rise [1]. This is a result of the continual demand for cassava products from Thailand of the main target market, largely comprising trade partners in Asian countries [1], attributable to their benefits not only as an animal feed ingredient but also as a raw material in industrial processes.

Consequently, cassava products constitute the sixth most important agricultural export of the country with the total value in 2020 standing at as high as THB 82,312 million and the wholesale price in 2021 equaling THB 7.53 per kg [1], [2]. In July 2021 alone, cassava slice exports reached 0.497 MT or THB 3,815 million, or a 21.22% increase from the corresponding figure in June the same year [2].

Due to cassava slices and pellets being the most common forms of animal feed ingredients and in response to the increased demand for Thai cassava products, attempts have been made to create a slicing machine to facilitate farmers. For instance, a study was conducted to evaluate the efficiency of a small slicing machine in cutting cassava

roots to be mixed with cattle feed [3]. The experimental equipment was made up of a pre-cleaning unit, a reciprocating blade slicer, and an abrasive cleaner [3]. The findings indicated the unremoved peel of 19.2% and the chopping efficiency of 85.35% [4].

Another research involved the design, construction, and evaluation of a small, lightweight, and portable yet durable cassava slicer [4]. The slicer comprised a motor, an axle shaft, a dimmer to regulate the rpm of the blade drive shaft, and a slicing unit, further consisting of a slicer made from stainless, cast iron or mild steel, a slicer holder, and a transmission shaft [4]. According to the findings, the rotational speed of 575 rpm and the stainless slicer material resulted in the highest percentage of whole slices, while the rational speed of 550 rpm and the mild steel slicer led to the highest percentage of broken slices [4].

In another study, a slicer was developed comprised of an abrasive pre-cleaning unit and a rotary blade to simultaneously slice and cut cassava roots into pieces [5]. It was found that the rotational speed of 50 rpm could yield clean slices containing no soil or sand residues with the percentage of unclean products of only 14.44% [5]. Additionally, the capacity of the slicer was recorded at 1,457.4 kg/h with the slicing efficiency hitting 85.2% and the percentages of whole and broken slices being 85.2% and 11.23%, respectively [5].

Similar findings were reported in a study designing and constructing an electrically operated cassava slicing machine that could achieve the minimum capacity of 10 kg/min and uniformity in slicing cassava roots 253 mm in length and 60 mm in diameter on average [6]. The findings revealed that at the rotational speed of 154 rpm, the slicer developed could yield 5.3 kg of slices 10 mm in length and 60 mm in diameter in 1 min with the machine efficiency reaching 95.6% [6].

Finally, the prototype of a motorized cassava root slicing machine was developed [7]. The efficiency of the slicer at the rotational speed of 100 rpm was reported at 67.8–72.2% with the output ranging between 13.09 and 27.02 kg/h [7]. In comparison, at the rotational speed of 50 rpm the efficiency of the slicing machine fell a little to 60–75.2% with a slightly lower output of 11.37–21.41 kg/h [7].

Despite the continual effort to develop a cassava slicing machine, it is still vital to design and construct a cassava slicer that is both economical and appropriate for household use to respond to different circumstances in terms of financial resources, know-how, and cultivation and production requirements. Therefore, the objective of this study was to design, construct, and evaluate a cassava slicing machine for household use to ensure that the outcome would bring maximal benefits to farmers, especially smallholder farmers.

MATERIALS AND METHODOLOGY

I. Designing and Constructing a Cassava Slicing Machine

The cassava slicing machine had the following specifications: 90 cm in height and 60 cm in width, as shown in Figure 1a. It was equipped with a power transmission unit, a pulley set connected to a 220 V, 2 horsepower electric motor enabling continual operation of the blades, and a gear reducer set to a 1:20 ratio, as displayed in Figure 1b. The blades to transport cassava roots to the slicer comprised a steel plate 15 cm in width, 39 cm in length, and 2 mm in thickness with a 7 cm XXXX to hold the cassava roots during slicing, as depicted in Figure 1c. The slicer consisted of four stainless knives 15 cm in length, 3.1 cm in width, and 3 mm in thickness, as illustrated in Figure 1d. The different components were individually constructed before being assembled into the final cassava slicing machine.

II. Operation of the Cassava Slicing Machine

After receiving electric current via the inverter, the motor transmitted power to the gear reducer. Once achieving the predetermined ratio, the gear reducer activated the pulley set, which further spun the blades connected to the drive shafts to sweep the cassava roots into the slicing unit. The operation of the cassava slicing machine is illustrated in Figure 2.

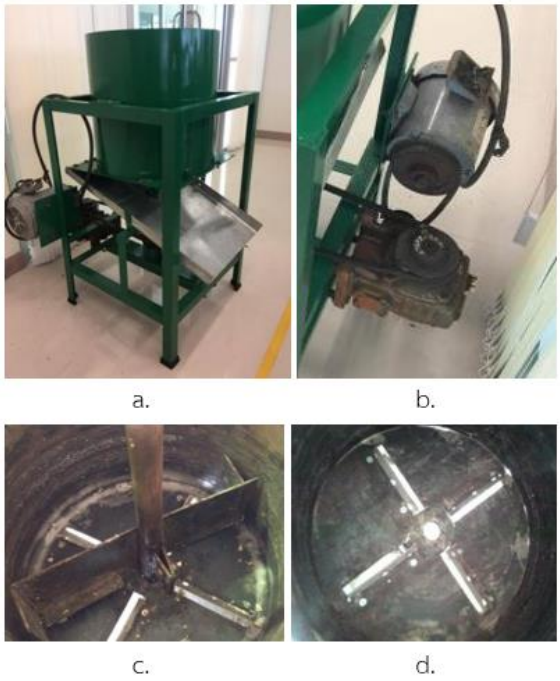

FIGURE 1

CASSAVA SLICING MACHINE; A. CONFIGURATION OF THE CASSAVA SLICING MACHINE; B. POWER TRANSMISSION UNIT; C. BLADE SET; D. SLICER SET

FIGURE 2
OPERATION OF THE CASSAVA SLICING MACHINE

III. Testing and Evaluating the Cassava Slicing Machine

The cassava roots under investigation included a mixture of small (2–4 cm), medium (5–6 cm), and large (7–9) ones that were equal in weight. The rotational speed was varied across three levels: 50, 60, and 70 rpm. Each batch of cassava roots was cut at each rotational speed before being passed through a sieve with 1.2X1.2 cm nets to separate whole slices from broken ones. Finally, the percentages of the two types of slices were determined using (1) and (2) below.

$$Whole\ Slices\ (\%) = W_f / W_a \times 100 \quad (1)$$

$$Broken\ Slices\ (\%) = W_b / W_a \times 100 \quad (2)$$

Where W_f = the weight of whole cassava slices
W_b = the weight of broken cassava slices
W_a = the total weight of the cassava roots

To determine the efficiency of the cassava slicing machine, the weight of whole cassava slices obtained from machine operation was divided by that derived from human operation according to (3).

$$E_{ff} = W_{f\,(machine)} / W_{f\,(human)} \times 100 \quad (3)$$

Where E_{ff} = Efficiency of the cassava slicing machine
$W_{f\ (machine)}$ = the weight of whole cassava slices obtained from machine operation
$W_{f\ (human)}$ = the weight of whole cassava slices derived from human operation

To determine the capacity of the cassava slicing machine, the weight of whole cassava slices was divided by the number of hours of machine operation according to (4).

$$Capacity\ of\ the\ Machine = W_{chipping} / T \times 100 \quad (4)$$

Where $W_{chipping}$ = the total weight of cassava slices obtained from machine operation, (kg)
T = the number of hours of machine operation, (h)

FINDINGS

I. Relationship between Rotational Speeds and the Percentage of Whole Slices

A comparison of the small-, medium-, and large-sized cassava roots sliced at the rotational speeds of 50, 60, and 70 rpm indicated that the percentage of whole cassava slices increased with rotational speeds before dropping. To illustrate, the highest percentage of whole cassava slices was recorded for the large-sized roots at 85.68% with the rotational speed of 60 rpm but declined when the rotational speed reached 70 rpm. Additionally, the lowest percentage of whole cassava slices was found for the small-sized roots at 74.08% with the rotational speed of 70 rpm. The findings are displayed in Table I.

II. Relationship between Rotational Speeds and the Percentage of Broken Slices

From a comparison the small-, medium-, and large-sized cassava roots sliced at the rotational speeds of 50, 60, and 70 rpm, the percentage of broken cassava slices dropped as a result of the increase in rotational speeds before going up. For instance, the lowest percentage of broken cassava slices was obtained for the large-sized roots with the rotational speed of 60 rpm but rose with the rotational speed of 70 rpm. Similarly, the highest percentage of broken cassava slices was associated with the small-sized roots at 23.25% when the rotational speed grew to 70 rpm. The results are illustrated in Table I.

III. Relationship between Rotational Speeds and the Capacity of the Cassava Slicing Machine

In terms of the relationship between rotational speeds and the capacity of the cassava slicing machine, a similar tendency was observed. That is, for the cassava roots of all sizes an increase in rotational speeds contributed to a greater capacity but the output began to drop after the threshold of 60 rpm. In addition, the highest capacity was achieved for the large-sized roots at 116.69 kg/h with the rotational speed of 60 rpm. The findings are presented in Table I.

IV. Actual Performance of the Cassava Slicing Machine

To evaluate the actual performance of the cassava slicing machine, cassava roots of varied sizes from 2 cm to 9 cm were continually fed into the slicing machine. It was found that the amount of time required to finish slicing for 10 kg of cassava roots was 3.02 min, which was equivalent to 198 kg/h. Also, to determine the quality of output whole cassava slices were randomly selected and their measurements were taken and averaged. According to the results, they were 49 mm in width, 87 mm in length, and 3.7 mm in thickness. Finally, 2 kg of cassava roots was tested to assess the slicing efficiency of the machine. The outcome was satisfactory as the efficiency rate reached 87.6%.

TABLE I
RELATIONSHIPS BETWEEN CASSAVA ROOT SIZES, ROTATIONAL SPEEDS, THE PERCENTAGES OF WHOLE AND BROKEN CASSAVA SLICES, AND THE CAPACITY OF THE CASSAVA SLICING MACHINE

Size of Cassava Roots (cm)	Rotational Speed (rpm)	Whole Cassava Slices (%)	Broken Cassava Slices (%)	Capacity of the Cassava Slicing Machine (kg/h)
Small (2–4)	50	78.86	19.90	81.04
	60	80.66	18.24	89.36
	70	74.08	23.25	86.73
Medium (5–6)	50	80.73	17.87	94.33
	60	85.34	14.35	111.58
	70	80.46	19.04	109.25
Large (7–9)	50	82.01	17.25	108.87
	60	85.68	13.89	116.69
	70	85.37	15.78	112.12

DISCUSSIONS

The results showed that the rotational speed of 60 rpm achieved the highest percentage of whole cassava slices (80.66–85.68%), followed by the rotational speed of 50 rpm (78.86–82.01%) and 70 rpm (74.08–85.37%). The lower percentage at the slower rotational speed may have resulted from the insufficient shearing force in the process, while the smaller percentage at the faster rotational speed may have been caused by the increased friction between cassava slices. In addition, at the rotational speed of 60 rpm the capacity of the cassava slicing machine was the highest for the large-sized roots at 116.69 kg/h. Finally, the slicing efficiency of the machine equaled 87.6% with the capacity hitting an equivalent of 198 kg/h and the average measurements of cassava slices equaling 49 mm in width, 87 mm in length, and 3.7 mm in thickness when a performance test was carried out on 10 kg of cassava roots of varied sizes.

The present findings provide corroborative evidence to those reported in the literature. For instance, one study developed and assessed the efficiency of a cassava slicing machine by varying the knife thickness across three levels: 2, 4, and 6 mm, and the rotational speeds across five levels: 300, 350, 400, 450, and 500 rpm [8]. The highest capacity of 18.5 kg/h and slicing efficiency of 98% were achieved with the knife thickness of 2 mm and the rotational speed of 350 rpm [8]. In other words, their slicer fared worse than the one presented in this research in terms of capacity but outperformed ours in terms of slicing efficiency.

Another research constructed an electrically operated cassava slicing machine and tested the machine by varying the rotational speed in a narrow range from 300 to 400 rpm [9]. In line with expectations, their findings revealed a direct relationship between rotational speeds and the percentage of whole cassava slices [9]. Also, machine operation was found to yield better output than manual operation with the cassava slices being only 10 mm in thickness, or only 50% of the measurement of those cut by humans [9]. Interestingly, the capacity and slicing efficiency of their machine were 209 kg/h and 86.7%, respectively [9], while ours led to 63–81.5% thinner cassava slices and a 0.9% higher capacity rate.

In another study, an electrically operated cassava peeling and slicing machine was invented as part of the system to dry, pelletize, and store cassava products [10]. Their machine was shown to be able to peel and slice 7 kg of cassava roots in 1 min with the efficiency of peeling being 66.2% and of slicing being 84% and the flesh loss being only 8.52%, demonstrating its great potential to save human labor, time, and time [10]. Their inferior machine capacity and efficiency compared to ours may have resulted from its dual function configuration that hindered its performance in such aspects.

A last experiment involved the development of a pedalled, hand-driven cassava slicing machine [11]. The machine was reported to be able to cut cassava roots into slices 3 mm in thickness at the efficiency rate of 97% and the capacity of 86.88 kg/h, surpassing ours in terms of efficiency but falling behind in terms of capacity while performing comparably in terms of slice thickness.

CONCLUSION

This study was conducted with the aim of designing and constructing a cassava slicing machine and evaluating the machine in terms of the percentages of whole and broken cassava slices, capacity, and slicing efficiency. It was found that with the large-sized cassava roots and at the rotational speed of 60 rpm, the percentage of whole cassava slices was the highest at 85.68% and the capacity of the slicing machine was the greatest at 116.69 kg/h. Also, when tested with 10 kg of cassava roots of varied sizes, the slicing machine exhibited a satisfactory capacity of 198 kg/h with the cassava slice output having the measurements of 49 mm in width, 87 mm in length, and 3.7 mm in thickness on average. The findings suggest significant relationships between cassava root size, rotational speeds, the percentages of whole and broken cassava slices, and the capacity of a slicing machine.

RECOMMENDATIONS

- Further studies should be carried out on the design and construction of a blade that will most effectively sweep cassava roots into the slicing unit.
- The slicer of a cassava slicing machine should be enlarged to enhance its contact surface on cassava roots and thus increase the percentage of whole slices, reduce the percentage of broken slices, and better slicing efficiency as the present findings indicate close connections between these variables

REFERENCES

[1] The Office of Agricultural Economics, "Thailand foreign agricultural trade statistics 2020," Centre for Agricultural Information, the Office of Agricultural Economics, the Ministry of Agriculture and Cooperatives, 2020, accessed November 12, 2021, www.oae.go.th/assets/portals/1/files/jounal/2564/trade2563.pdf.

[2] The Office of Agricultural Economics, "Agribusiness sector," Journal of Agricultural Economics, 778, 2021, 14–45.

[3] Whangkuanklang, V., "A study on the use of a reciprocating blade slicer to make cassava slices," Unpublished Master's Thesis, Department of Mechanical Engineering, Khon Kaen University, Thailand, 2004..

[4] Sakwong, J. and Wichityutthapoom, R., "Evaluation of small cassava slicing machines," Unpublished Bachelor's Thesis, Department of Agricultural Machinery Engineering, Faculty of Engineering and Architecture, Rajamangala University of Technology Isan, Thailand, 2011.

[5] Whangkuanklang, V., "Cassava chipping machine," Proceedings of the 13th Thai Society of Agricultural Engineering Conference, Chiang Mai, Thailand, 2012, 148–155.

[6] Aji, I. S., James, E., Ejovwoke, A., and Mshelia, D. A., "Development of an electrically operated cassava slicing machine," Arid Zone Journal of Engineering, Technology and Environment, 9, 2013, 90–95.

[7] Ndukwua, M.C. and Onyenwigwe, D., "Development of a motorized parboiled cassava tuber shredding machine," Nigerian Journal of Technology, 32, 2013, 1–6.

[8] Ojomo, A. O., Ologunagba, F. O., Lawson, O. S., and Alagha, S. A., "Effect of machine variables on the performance of a locally built cassava chipping machine," Journal of Agricultural Engineering and Technology (JAET), 19, 2, 2011, 73–78.

[9] Awulu, J.O., Audu, J., and Jibril, Y.M., "Development of cassava (Manihot) chipping machine using electric motor cum manual operation," Journal of Harmonized Research in Engineering, 3, 2, 2015, 78–84.

[10] Aji, I. S., Emmanuel, M.U., Abdulrahman, S. A., and Franklyn, O. F., "Development of an electrically operated cassava peeling and slicing machine," Arid Zone Journal of Engineering, Technology and Environment, 12, 2016, 40–48.

[11] Moses, O., "Design and construction of a pedalled and hand-driven cassava chipping machine," Unpublished Bachelor's Thesis, Department Agricultural Engineering, Makerere University, Uganda, 2019.