วารสารสมาคมวิศวกรรมเกษตรแห่งประเทศไทย **บทความวิจัย**
ปีที่ 24 ฉบับที่ 1 (2561) 23-30
ISSN 1685-408X
Available online at www.tci-thaijo.org/index.php/TSAEJ

The Development of the Expanding Rollers, Sapodilla Sizing Machine Model 2.

Tannachart Wantang[1*]

[1]Department of Production Engineering and Management, Faculty of Agricultural Technology and Industrial Technology, Phetchabun Rajabhat University, Phetchabun, 67000

*Corresponding author: Tel: +66-56-717-164, Fax: +66-56-717-164, Email: tannachart.w@pcru.ac.th

Abstract

This research is to study the development of the expanding rollers, sapodilla sizing machine model 2. This has been done by studying the optimal factors of developing the expanding rollers, sapodilla sizing machine, examining the machine's competency and evaluating the satisfaction with sapodilla orchards after trying out. The 3^2 factors factorial designed and the analysis of experimental variance was applied to studying the optimal factors of developing this machine in order to study influential variables which affect the accuracy of sapodilla sizing which could be grouped into 4 sizes; 1, 2, 3, and 4 (small, medium, large, and extra-large). This research also studied the speed factor of spindle at 100, 200, and 300 rpm and the angle of inclination factor of spindle at 5 degree, 10 degree, and 15 degree. The study found that all factors statistically significant affected the accuracy of sapodilla sizing. The spindle speeds at 200 rpm and the spindle's angle of inclination at 5 degrees was the most proper for sizing. We took these factors to develop the machine. After examine the quality of the machine it is found that the mean of productivity was 473 kg h^{-1} which was more than the manual sorting about 2.60 times and less than 2.49 times for old version because minimizing the machine size. The error rate was 5.17% which the accuracy was gained from the previous model was 1.48%. The electricity consumption rate was 5.88 bath h^{-1}. The economic analysis indicated that the payback period was 1.13 years. The satisfaction evaluation, 43 sapodilla orchards of evaluate this machine at 4.27 which was in good level.

Keywords: Sapodilla, Sizing machine, Optimal factor

1 Introduction

The sapodilla cultivated area in Thailand is around 16,878 hectares. The major planted areas are Rachaburi (6,092 hectares), Sukhothai (5,535 hectares), Nakhon Ratchasima (2,728 hectares), Phetchaburi (828 hectares) and scattered around the country. The productivity from all provinces is around 13,409 tons y^{-1} (Department of Agriculture Extension, 2016). The total value of the entire country are approximately 230 million Bahts. Especially in Sukhothai could earn 51 million baths (Prapet et al, 2015) The species of sapodilla which are cultivated in Thailand are divided into 2 main species, Thai sapodilla and Foreign sapodilla. Thai sapodilla or Seda sapodilla is local species, it is sweet but small fruit. The another species is imported from aboard such as Makok, Khaihan, Kasuay sapodilla, etc. In the recent, the Makok and Kaihan sapodilla is the most popular with distribution because they are easy to grow and provide a lot of productivity. The sapodilla is an attractive upright, slow-growing, long-lived evergreen tree. The fruit is round to egg-shape, 2 - 4 inches in diameter. The flavor is sweet and pleasant, ranging from a pear flavor to crunchy brown sugar. The end of October to the beginning of February is the best period for harvesting the sapodilla because of the large productivity. The mean of productivity in this period is around 50-100 kg/tree. The fruit could be harvested in the morning and afternoon period. It takes time 3-5 hours d^{-1}. Sapodilla sizing should be done gently because of thin skin and it could be affected on 5% of distribution process (Suthumchai, 2003). Therefore, gentle sizing is should be considered. But lacking of labor is the barriers of this process. Sapodilla without sizing is cost around 6 - 8 baths kg^{-1} comparing with sapodilla with sizing the cost is going to be higher. The code size 3 are cost around

10 - 12 baths kg^{-1} and code size 1 is cost around 30 - 50 baths kg^{-1} Therefore, the innovation for sapodilla sizing is needed.

The researcher studies the way to develop the expanding rollers, sapodilla sizing machine which uses the principle of using double spindle in a way that tilt. Sapodilla flows along the pipes and falls over in the larger space and flow into the baskets belong its size. (Wantang, 2017), Cylindrical wheel spindles sapodilla sizing machine spins the fruit and makes it fall depending on its size but the experiment found that this machine is not gentle for sapodilla sizing. (Thepsatri Rajabhat University, 2012), Betel nut spiral spindle sizing with different sizes of holes that can group three sizes of betel nuts (Meein, 2014), Sugar apple sizing which uses principle of counterbalance, the sugar apple with higher weight than pendulum is going to roll out of the tray. This machine could group 5 sizes (Pramart et al, 2014), Cylinder with strainer job'tears sizing with the various sizes of hole can grouped many sizes (Phaichin et al, 2013), Weight sizing machine select the fruit by using weight for grouping the fruit (Inyasri et al, 2011), Strainer garlic sizing can size the garlic with the different sizes of holes of the strainer (Langapin et al, 2013), Running water system through the track is used for sizing two sizes of the jujube fruit (Vichaiya, 2011), Lemon will be captured by a webcam and Lemon images will be processed with MATLAB. lemons can be selected, counted and separated depending on their sizes and conditions (Phooyapaet et al, 2007), Double cylinder orange sizing with different sizes of holes can group the size of the orange while the machine is spinning (Likhitchewan, 2005), Guava and mangosteen sizing machine with the sizing plate spins to pick the small size of the fruit first and then selects the medium and big size later. (Jarimopas and Rachanukroh, 2002) (Jarimopas et al, 2001) and the mentioned sizing machines uses the principle of physical appearances of the fruits such as appearance, weight, mean, space, and gravity (Peleg, 1985)

From concern literature, each machine has both advantages and disadvantages. The objective of this study is developing the expanding rollers, sapodilla sizing machine model 2 which this machine exactly size of the sapodilla properly but this machine still has the point that need to be developed such as the large size of the machine and its weight. Those can cause the difficulty for the removal of the machine and it should be developed the supporter for decreasing the damage of sapodilla. The production rate of 1,176 kg h^{-1} and error rate of the machine is 6.65% (Wantang, 2017) The guideline on developing the machine is by studying the suitable factors of developing the double spindle, sapodilla sizing machine; minimizing the machine size, finding out the productivity rate and accurate percentage in sizing, comparing with human labor, decreasing electricity consumption, more convenience, higher quality, decreasing payback period. Then try out the machine with sapodilla orchards.

2 Materials and methods

2.1 Components

The machine designed by NX 8.5 programs which improves on the previous model. The new model concerns about the size, high competency, and accurate sizing of the machine. Then find out the suitable factors: speed of spindle, tilt of spindle, productivity rate, electricity consumption rate, human labor and previous model productivity rate, accuracy percent.

The main components (Figure 1) are the following.

1) Sapodilla truck is made of 19 mm iron. (41 cm x 51 cm x 8.5 cm.) The side wall is painted with acrylic thick 1 cm. and it has flowing space for sapodilla (8.5 cm) inside the truck.

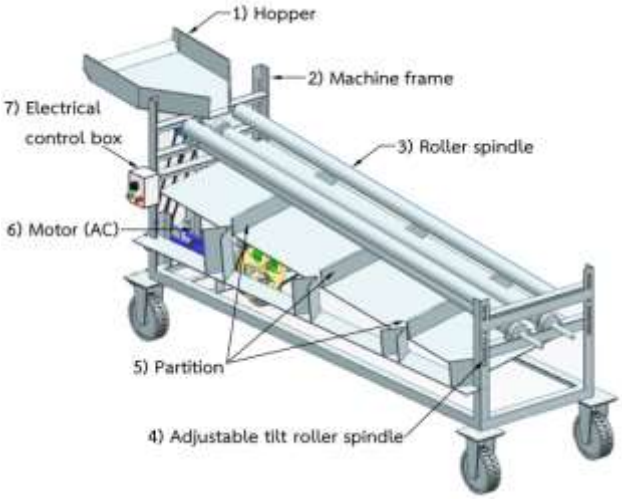

Figure 1 Assembly drawing and details of a sapodilla sizing machine using expanding rollers, Model 2.

2) Chassis supports the weight and connects the other components. (180 cm x 520 cm x 70 cm) which are equipped with wheels for mobility.

3) Double spindle sizing sapodilla is made from stainless steel SUS 304. (Ø 6.4 cm length 180 cm) The principle of using double spindle in a way that tilts which can make sapodilla flows along the pipes and falls over in the larger space and flow into the baskets belongs to its size. This machine could code size 4 sizes are 1, 2, 3 and 4. (National Agricultural Commodity and Food Standards, 2011) (Table 1) which the spindle on the left side rotates counter-clockwise and another side rotates clockwise. Spindle speed can be adjusted using the control box to adjust the speed and spindle angles that can be adjusted by using scale in front of the machine.

Table 1 Sizes of the indicated class.

Code size	Unit weight (Unit g^{-1})	Number of units (approximately kg^{-1})
1	>105	≤9
2	>90 - 105	9 - 11
3	>75 - 90	11 - 13
4	>60 - 75	13 - 16

4) Spindle tilt angle adapters adjusts to the suitable angle for the spindle and spindle space adapters for accurate sizing.

5) Panel sizing machine makes the sapodillas flow into 25 kg basket belong to its size. (51 cm x 180 cm) The panel is divided into 4 channels. The channel could be adjusted to accurate size. In areas where the sapodilla skin is exposed are covered with rubber to prevent damaging.

6) Motor power acts as rotational power for double spindle in sapodilla sizing. In the beginning stage, we examine proper factors of spindle speed by using inverter motor speed controller size 4 kW – 6.7 kVA – 5 hp, frequency 50/60 Hz with 3-phase motor power 220 V. From the experiment, proper factors will be taken to set the constant speed for sizing with AC 220 V (1 hp) motor power. (Figure 2)

7) Controller boxes controls the electrical system. The controller box consists of circuit breaker, switch, 220 V motor power switch, and indicator LED.

Figure 2 Reverse gear assembly drawing and details of a sapodilla sorting machine.

Figure 3 The sapodilla sizing machine using expanding rollers, Model 2.

2.2 The examination for finding out the proper factors for double spindle sapodilla sizing.

After finishing the machine assembling (Figure 3), we study the proper factors of double spindle sapodilla sizing machine by using the three factors factorial design in order to study about the main and other minor effects on variable responses that are the accuracy sapodilla sizing for 4 sizes, small, medium, large, and extra-large (Figure 5) There are 2 control factors which are the speed of spindle: 100, 200 and 300 rpm and the tilt of spindle 5°, 10° and 15° (Table 2) As speed and tilt are the important factors that affect the sizing competency, so the experiment has been repeated for 3 times together with the analysis from Minitab program found that the power of test in more than 0.95 (Power of test ; 1-β). The variance analysis is analyzed by using Minitab R17 program and it has found that the control variables are the selected sizes of sapodillas: number 1, 2, 3 and 4 (Figure 4) or small medium large and extra-large, 50 fruits for each size that makes 200 fruits altogether. The sapodillas that we can get are unripe and damage fruits. The variable is the percentage of accuracy of 4 sizes of the sizing with recording the accuracy size of the sapodillas from the sizing machine.

Figure 4 Size of sapodilla.

Table 2 Typical data for the experiment.

Factor	Level		
	Low	Intermediate	High
The speed of spindle (rpm)	100	200	300
The tilt of spindle (°)	5	10	15

2.3 The test of the production rates and the competency of the machine comparing with the original model.

2.3.1 The test for the production rate of the machine

After study about the suitable factors for building the double spindle sapodilla sizing machine, speed and tilt, they are determined for the production rates of the machine with only one person for one machine. The test of the production rates has been repeated for 3 times, the variables are the production rates per hour, the electricity consumption measured with Amp Meter (15 Amp) and they are calculated as the household electricity consumption 3.94 baht per unit for the other basic household electronic appliances.

2.3.2 The test compares the competency between original machine model and human labor.

The test of comparing the competency between original sizing machine models and 1 human labor to size the fruits continuously for 1 hour. The test has been repeated for 3 times, and it found that the percentage of accuracy sizing is the variable measure that can be calculated by using the following equation. (Chayaprasert, 2012)

$$\text{Success} = \frac{S}{100} \times 100 \quad (1)$$

2.4 The satisfaction evaluation of sapodilla orchards.

The satisfaction evaluation consists of 4 items: machine design, safety, convenience, and productivity. Score data uses rating scale, analyze data uses Likert scale, and select sample group uses purposive selection. The sample group is 43 sapodilla orchards in Nongkwai sub-district, Lomsak district, Phetchabun province.

3 Results and discussion

3.1 The result of the examination for finding out the proper factors for double spindle sapodilla sizing.

From experiment (Table 3) found that every factor has P- Value = 0 which is less than significant level at 0.05 (reliability 95%). So the spindle speed (A) statistically significant affects accurate sapodilla sizing and spindle tilt angle (B) statistically significant affects accurate sapodilla sizing. For the overall effects factors found P-Value = 0 which is less than 0.05, both factors respond to each other. These can affect the sizing accuracy. From the data onto valued coefficients R^2 adj equal to 89.74% that means the regression can explain the changing of variable response more than 80% (Table 4)

The data is examined the accuracy according to 3 principles hypothesis of Montgomery (Montgomery, 2001) which are the test of normal distribution (Figure 5), straight line distribution. Later Fitted Value found (Figure 5), unformed distribution that shows constant variance and the error during the test (Figure 5)

The distribution of the remained factors is independent, having random distribution which proves the 3 principle of the hypothesis. In the area of the suitable factors analysis from Interaction Plot (Figure 6) shows using speed at 200 rpm. and tilt angles at 5° can provide the best accuracy sapodilla sizing.

Then the most suitable factors will be brought to determine the suitable speed and tilt angles for developing the machine and the further production rate.

Table 3 The result of experiment.

The speed of spindle (rpm)	The tilt of spindle (°)	Accuracy of the size sorting (%)	Average
100	5	87.5	88.67
		88.5	
		90.0	
	10	88.0	84.17
		82.5	
		82.0	
	15	77.5	84.50
		85.0	
		84.5	
200	5	93.5	94.83
		94.5	
		96.5	
	10	87.5	88.17
		89.0	
		88.0	
	15	76.0	75.67
		79.5	
		71.5	
300	5	88.5	89.50
		90.0	
		90.0	
	10	88.5	86.50
		86.0	
		85.0	
	15	69.0	68.50
		66.0	
		70.5	

Table 4 Analysis of variance for the experiment.

Source	DF	Adj SS	Adj MS	F-Value	P-Value
A	2	103.20	51.593	8.18	0.003
B	2	1116.10	558.037	88.50	0.000
A*B	4	264.40	66.093	10.48	0.000
Error	18	113.50	6.306		
Total	26	1597.10			
S = 2.51109		R-sq = 92.89%		R-sq (adj) = 89.74%	

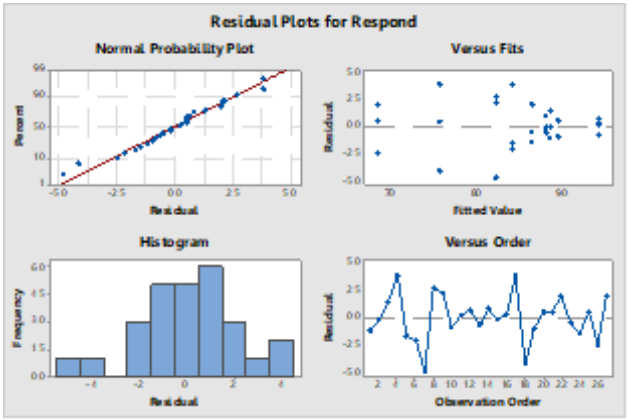

Figure 5 Residual Plots for Respond.

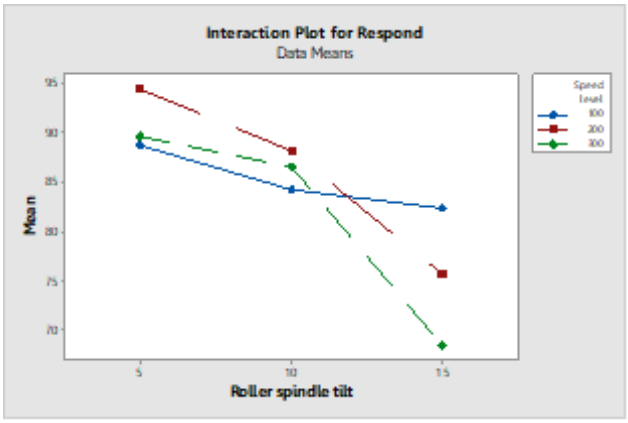

Figure 6 Main effects plot and interaction plot.

3.2 The result of the experiment for comparing the productivity between machine and human labor.

The study found that the mean of machine productivity is 473 kg h^{-1} which is higher than the mean of human labor productivity 183 kg h^{-1} and less than the previous model which is around 100 kg h^{-1}. From this data, we found that machine productivity rate is higher than human labor productivity rate of 2.60 times and less than previous model about 2.49 times because minimizing the machine size is more convenient for using. The productivity rate per day is 1,892 kg h^{-1} which is only 4 hours of the afternoon. The machine has accuracy rate of 94.83% (Table 5) when compare with human labor has the accuracy rate of 100%. Compare with the previous model, this machine has better accuracy rate than the old one 1.48%. The study found that while the machine working, it consumes 6.78 A. or 1.49 kW which costs the electrical consumption rate is 5.88 bath h^{-1}. It costs as the same price as the Air conditioner with 12000 BTU, Rice cooker capacity 4 liters etc.

Table 5 Result summary of comparison between the machine and manual.

Test	Production rate (kg hour^{-1})	Accuracy of the size sorting (%)
Sapodilla sorting machine	459	93.50
	480	94.50
	480	96.50
Average	473	94.83
Manual	185	100
	186	100
	178	100
Average	183	100

In eco

nomics analysis for the payback period, it found that the cost of sapodilla sizing the machine is 16,000 baht with 1,892 kg 4 h^{-1} working for the production rate. For one human labor 4 hours working per day provides 732 kg 4 h^{-1}. From the data, if you would like to get the same production rate of the machine by using human labor, you have to hire 2.58 persons. So the net profit of using the machine is 16,718.97 baht comparing the cost of the machine 16,000 baht, maintenance 1,500 baht y^{-1}, Lifetime is 10 years, residual value 2,000 baht with 1.13 payback period. (Table 6)

Table 6 The pay back period.

Title	Sapodilla sizing machine	Manual
Production rate	473 kg h^{-1}	183 kg h^{-1}
	1892 kg d^{-1}	732 kg d^{-1}
Wage (Baht d^{-1})	300	1,892/732=2.58
		2.58x300=775.41
Electricity charge	5.88 Bahtx4 hr	0
(Baht d^{-1})	= 23.52	
Expenditure	323.52	775.41
(Baht d^{-1})		
Difference cost	775.41 – 323.52 = 451.89 Baht d^{-1}	
Total product	70,000 kg y^{-1}	
Cost reduction	(70,000/1,892) x 451.89 = 16,718.97 Baht d^{-1}	
Straight – Line method	(16,000 Baht – 2,000 Baht)/10 year = 1,400 Baht y^{-1}	
Total cost	16,000 Baht + 1,400 Baht/year + 1,500 Baht y^{-1}= 18,900 Baht	
Payback period	18,900 / 16,718.97 = 1.13 year	

3.3 The result of satisfaction evaluation of sapodilla orchards.

The result of satisfaction evaluation of 43 sapodilla orchards in Nongkwai sub-district, Lomsak district, Phetchabun province consists of 4 items (Figure 6); design, safety, convenience, and production are 4.33, 4.22, 4.24 and 4.31 as ordering. It is in a good level for all items and the average satisfaction are 4.27 which are good level with 0.67 standard deviations. (Table 7)

Figure 8 Sapodilla orchards Nongkwai sub-district, Lomsak district, Phetchabun province.

Table 7 A satisfaction survey of the orchards to a sapodilla sizing machine, Model 2 in Phetchabun province of Thailand.

Overall satisfaction	Question	Satisfaction scale ($\bar{x}$)	(S.D)
Design	Machine frame	4.56	0.56
	Materials	4.26	0.69
	Sorting mechanism	4.37	0.66
	Motor transmission	4.12	0.59
	Satisfaction level	4.33	0.63
Safety	Electricity	4.16	0.69
	Power mechanic	4.19	0.63
	Transmissions	4.30	0.67
	Satisfaction level	4.22	0.66
Easy to use	Easy to control switch	4.44	0.63
	Easy to fill sapodilla	4.30	0.74
	Easy to maintenance	4.12	0.73
	Easy to moving	4.12	0.70
	Easy to use the basket	4.23	0.65
	Satisfaction level	4.23	0.69
Production rate	Enjoyable with accuracy	4.37	0.62
	Enjoyable with production rate	4.30	0.60
	Non damage, bruise and cracks	4.20	0.80
	Satisfaction level	4.31	0.69
	Overall satisfaction level	4.27	0.67

4 Conclusion

From the development, test, and competency evaluation of the double spindle sapodilla sizing machine model 2 with factorial design found that the speed and tilt angle affect the accuracy of the sapodilla sizing competency with different statistical significant level at 0.5

The suitable factors are speed at 200 rpm and tilt angles at 5° that can cause the best accuracy to the sizing machine. For analysis of variance found that proves the hypothesis;

The competency of the machine the production rates is 473 kg h^{-1} or 1,892 kg h^{-1} for 4 working hours in the afternoon which provides 2.60 times higher productivity than one human labor and about 2.49 times less than the previous first model because of minimizing the machine size.

The accuracy is 1.48% better than the previous model or the error rate is 5.17%.

The electricity consumption is 5.88 baht h^{-1} and the payback period is within 1.13 years.

The result of evaluation for 4 items; design, safety, convenience, and production is in a good level for all items. The development of this machine can be used for agriculture and it is the useful technology for the community

5 Acknowledgement

The authors also wish to thank the Research and Development Institute of Phetchabun Rajabhat University for research funds.

6 References

Chayaprasert, W., Poniyom, K., Kheawkham, A., Deetong. P. 2012. Development of a single-seat tobacco transplanter. Thai Society of Agricultural Engineering Journal 18(1), 1-7.

Department of agricultural extension. 2016. Reports production plant for the year 2015 (sapodilla). Available at: http://production.doae.go.th/report/report_main_land_02_A_new2.php?report_type=. Accessed on 4 October 2016.

Inyasri, C., Yammen, S., Chaiprasart, P. 2011. Weight estimation of mangoes on dynamic weighing system by using modified median filter. Agricultural Science Journal 42(3), 446-449.

Jarimopas, B., Rachanukroh, D. 2002. Guava sizing machine. Agricultural Science Journal 33(6), 49-53.

Jarimopas, B., Niamhom, S., Suwanprateep, T. 2001. Improvement of mangosteen fruit sizing machine. Agricultural Science Journal 19(2), 121-131.

Langapin, J., Parnsakhorn, S., Hongto, R., Chanchana, A., Phulltawee, A. 2013. Design and development of a garlic sizing machine. KHON KAEN Agricultural Journal 41(2), 191-198.

Likhitchewan, S. 2005. Sizing machine automation was cylinders stacked several layers. Thai Patent Act No. 18014.

Montgomery, D.C. 2001. Design and analysis of experiments. (5th ed). New York: John Wiley& Sons.

Meein, N. 2014. The development of betel nut size screening and cutting machine by value engineering techniques. Master dissertation. Bangkok, Thailand: Department of Industrial Education, Srinakharinwirot University.

National bureau of Agricultural commodity and food standards. 2011. Thai agricultural standard 19-2011 sapodilla. bangkok: Ministry of agriculture and cooperatives.

Phaichin, B., Yangyuen, S., Laohavanich, J. 2013. Factors Affecting the Separating of Job's Tears after Hulling and Cleaning by Rotary Screen. Agricultural Science Journal 42(3), 497-500.

Peleg, K. 1985. Produce handling packaging and distribution. Westport, Connecticut: AVI Publishing Company. Inc.

Phooyapaet, S., Kopraseadsud, A., Loy, A.F. 2007. Image Processing-Based Lemon Grading Machine. Bachelor dissertation. Bangkok, Thailand: Department of Electronic and Telecommunication Engineering, King Mongkut's University of Technology Thonburi.

Pramart, K., Jaruwat, P., Jitjumnong, B., Veriyanan, S., Pratcharoenwanich, R., Youyen, N. 2014. Research and development of the sugar apple mechanical sizer. Agricultural Science Journal 45(3), 433-436.

Prapet, A., Chaovalit, S., Duanmesuk, W., Suwannachome, O., Janseanto, C. 2015. Research and development of technology to produce commercial sapodilla in the North Thailand. Sukhothai: Sukhothai agricultural research and development center, Department of agricultural extension.

Suthumchai, W. 2003. Effect of harvesting stage and postharvest handling on quality of sapodilla. Master dissertation. Bangkok, Thailand. Department of Horticulture, Kasetsart University.

Treeamnuk, K., Pathaveerat, S., Terdwongworakul, A., Janthong, M. 2010. Test of zero damage java fruit sizer. Agricultural Science Journal 41(1), 585-588.

Thepsatri Rajabhat University. 2012. Sapodilla sizing machine. Available at: http:/ / youtube.com/ watch?v=cyxUize4QnY. Accessed on 27 February 2017.

Vichaiya, P. 2011. Design and fabricate of the sizing machine prototype for jujube. Agricultural Science Journal 42(3), 497-500.

Wantang, T. 2017. Design and fabrication of sapodilla sizing machine using expanding roller. Proceedings of the 55th Kasetsart University Annual Conference, 211-222. Kasetsart University. 31 Jan – 3 Feb 2017, Bangkok, Thailand.