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Development of portable starch content measuring device for fresh cassava tubers using gravimetric method

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Abstract

This project aims to create a portable instrument for measuring cassava starch content in fresh cassava tubers by using specific gravity method. Use approximately 100 g of cassava root and can determine without damaging the whole cassava plant. To bring information to plan the harvest and indicate the location of the plant. The cassava " Kasetsart 50 (KU50) " varieties were studied, twenty tubers were obtained from Department of Agronomy, Faculty of Agriculture Khon Kaen University, aged 12 months and 25 cassava tubers from Nong Kung Sub-district, Khon Kaen aged 8 months. To measure the weight of cassava tuber obtained from load cell an equation from the load cell's electrical signal has been created, in order bring the weight to find the specific gravity and take the specific gravity to predict the starch content in casava tubers, automatically working by writing a command. Load cell's electrical signal was strongly correlated with weight, with R^2 of 0.99 and the results of the comparison of the starch content by the standard starch meter and the developed portable starch meter were significantly correlated with R^2 of 0.99 presenting information to the web app with location coordinates.

Keywords: Cassava tuber, Specific gravity, Starch content

1. Introduction

Cassava is a significant crop in the country's economy, valued at around 23,000 million baht [1]. Approximately 80% of cassava production is processed into human and animal food products, including cassava flour, noodles, and pellets [2]. Currently, much of the cassava flour processing results in substantial resource loss to ensure profitability in factory production or at cassava buying stations. Therefore, the price of cassava is determined based on its weight and the quantity of flour it produces [3]. Currently, there is no inspection of the flour percentage before harvesting, leading to issues such as farmers harvesting cassava but being unable to sell it because of low flour percentage. Alternatively, if sold, it fetches very low prices due to the low flour percentage being the pricing criterion.

Regarding quality inspection before harvesting, data analysis for the 2563/64 season revealed that out of the total 28 million tons of harvested fresh cassava heads [4], the average starch percentage was found to be not more than 21%. However, scientific data suggests that cassava can produce up to 40% starch [5]. Good care and harvesting at the right time can significantly reduce starch losses during production, which could be as high as 19%. One of the reasons for this is the lack of consideration for starch percentage before harvesting and the absence of incentives for farmers to consider starch values due to the unavailability of convenient and rapid starch measuring tools in the field.

Previous research by Maraphum et al. [6] investigated the relationship between specific gravity (SG) and starch and dry matter percentages using small-sized samples (approximately 100 grams) from four different cassava varieties. The results showed a strong correlation between specific gravity and starch and dry matter percentages, with R values of 0.90 and 0.91. These findings were used to develop a starch and dry matter measuring device installed with GPS equipment for position tracking and a data processing system to display starch values on a map through a web application. The smaller size of this measuring tool allows for easy portability into the fields. Thus, the development of a low-cost, portable measuring tool that can be taken into cassava fields could determine the optimal harvesting time and help ensure harvested cassava has a high starch percentage.

The main objective of this project is to design and create a small-sized starch measuring device for fresh cassava heads using a gravimetric method that can be carried into the cassava fields for measurement. This aims to compare the starch percentage measured by the current gravimetric starch measuring device and the newly developed device and to present the cassava starch quantity data to a web application, along with specifying the coordinates. The scope of the study is to investigate methods of determining the starch percentage in fresh cassava heads using a gravimetric method.

2. Materials and methods

2.1 Sample

The samples used in the experiment were cassava varieties from the Department of Agronomy, Faculty of Agriculture, Khon Kaen University, aged 8 and 12 months. They were collected from the cassava plantation in Nong Kung Subdistrict, Nam Phong District, Khon Kaen Province. The 12-month-old cassava was harvested in quantities of 20 heads, while the 8-month-old cassava was harvested in quantities of 25 plants. Each plant weighed between 4 - 5 kg.

2.2 Device development

In the study to improve and develop a starch measuring device for fresh cassava heads using a gravimetric method, a prototype was designed by creating drawings using SolidWorks engineering design software. The main components included a weight scale set, machine frame, drive set, water container, control set, and display set. Next, the prototype measuring tool was constructed using aluminum profiles, brackets for aluminum profiles, and acrylic sheets to enclose the aluminum frame. Load cells were installed on the aluminum frame, and wires were connected to the ESP8266 Board through the HX711 module.

2.3 Equation development

Equations for weight measurement were derived from load cell electrical signal values. The 12-month-old cassava tubers was cut into various sizes ranging from 0 to 200 g, peeled, and weighed with a digital precision scale with a resolution of 4 decimal. Load cell electrical signals were then measured, and equations for weight measurement were derived. Subsequently, a stepper motor (Nema 17) and stepper motor driver (A3967) were installed, and plastic trays printed from a 3D printer were used as water containers. Code was written to control the stepper motor to move the water container up and down to immerse the cassava samples in water for specific gravity calculation. Further, code was written to calculate specific gravity (SG) as starch content (SC) using the relationship between starch content and specific gravity. The prediction equation was SC = 179.36SG + 170.3 [6]. Grove - GPS module was installed, and code was written to send data collected from the starch measuring device to a web application via WiFi, with an LED display to show the data. Finally, starch was measured using the starch measuring device by gravimetric method, with 8-month-old cassava samples. Each plant weighed between 4 - 5 kg, and 5 heads were selected. The central part of each head, weighing approximately 50 - 150 g, was peeled and measured for starch content using the small-sized starch measuring device. The results were recorded, analyzed to find the relationship equation between starch content measured by both models of devices, and then incorporated into the Arduino code.

3. Results and Discussion

Building a starch measuring device for fresh cassava heads using the gravimetric method involves several main components: machine frame, weight scale set, water container set, control set, and display set. The design was created using SolidWorks software, and then the construction proceeded according to the design, detailing each component of the main parts of the starch measuring device for fresh cassava heads using the gravimetric method. This is illustrated in Figure 1.

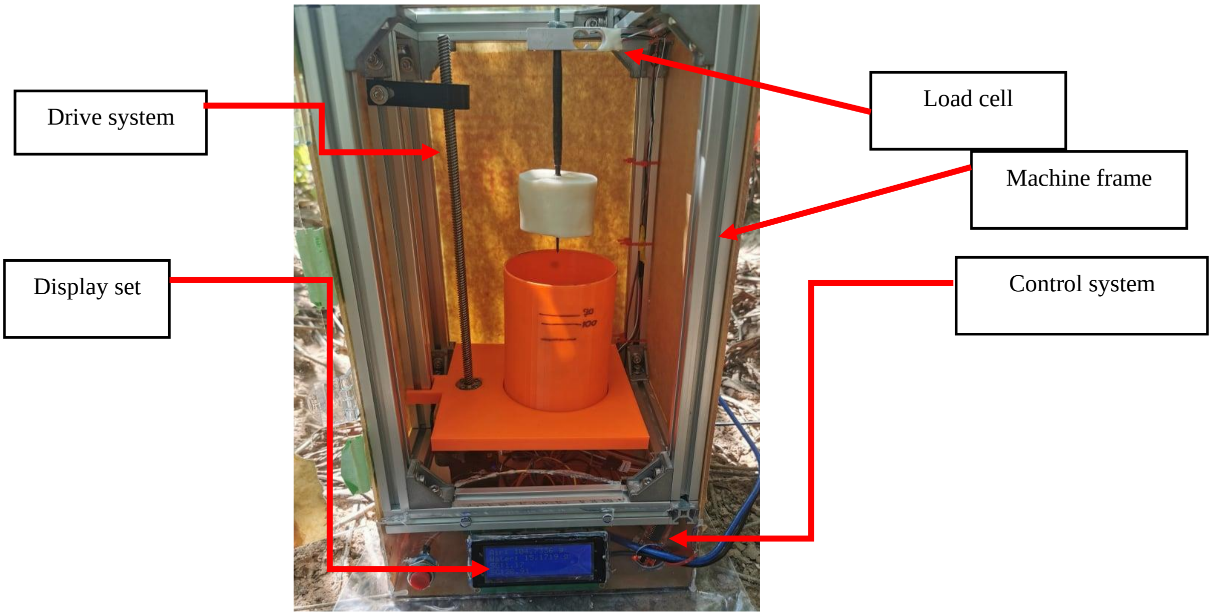

Figure 1 A small-scale starch measuring device for fresh cassava heads using the gravimetric method.

A starch measuring device using the gravimetric method involves weighing fresh cassava both in air and in water. The weight determination of the measuring tool comes from load cells constructed with Strain Gauges arranged in a Wheatstone Bridge circuit, capable of converting compression or tension forces into electrical signals. These load cells can be applied to create weighing scales.

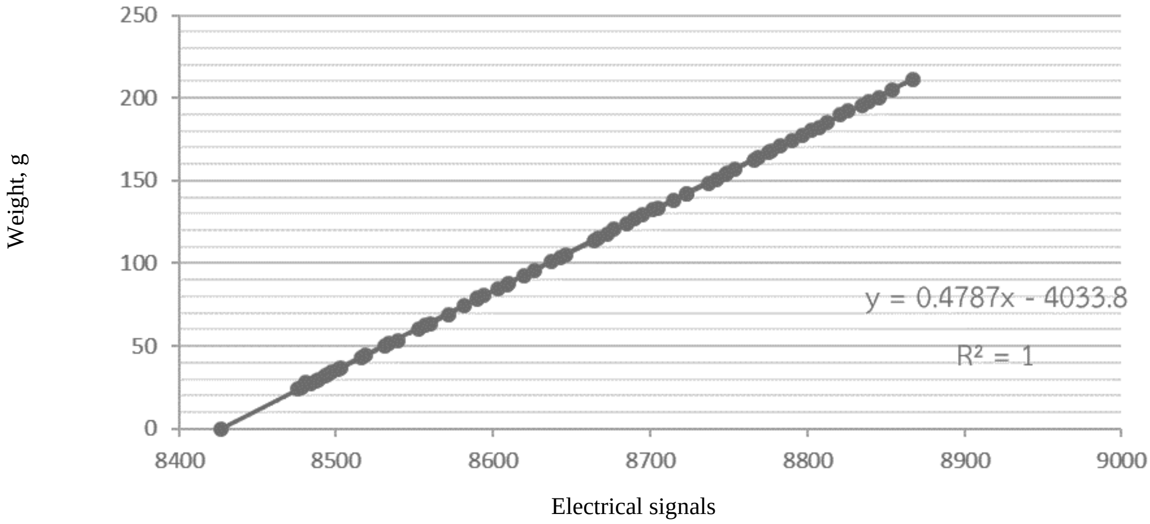

Figure 2 Creating the weight measurement equation from the electrical signals of the load cells.

From Figure 2, the process of predicting weight from the electrical signals of the load cells was conducted. Various sizes of cassava ranging from 0 to 200 grams were weighed using a digital weighing scale. Comparing the electrical signal values of the load cells, the equation obtained was y = 0.4787x - 4033.8, where y represents the weight of the cassava and x represents the electrical signal value of the load cell.

Table 1 Statistical analysis results of the equation for measuring weight from the electrical signals of the load cells

	df	SS	MS	F	Significance F
Regression	1	218631.7976	218631.798	1454482.564	3.8693E-141
Residual	64	9.62021505	0.15031586		
Total	65	218641.4178			
Regression Statistics					
		Multiple R	0.999978		
		R Square	0.999956		
		Adjusted R Square	0.99995531		
		Standard Error	0.38770589		
		Observations	66		

From Table 1, the statistical analysis results of the equation for predicting weight from the electrical signals of the load cells reveal that the coefficient of determination (R^2) is equal to 0.999956, and the statistical significance test (Significance F) is equal to 3.8693E-141, which is less than 0.05. Therefore, the null hypothesis (H0) is rejected. Consequently, it demonstrates that there is a statistically significant relationship between the weight and the electrical signals of the load cells.

Table 2 Results of weight measurement using the equation derived from load cells and weights measured from the standard measuring instrument.

	Digital Balances	Load cell	diff
Mean	105.973865	106.6717167	0.697852
Variance	3530.530848	3565.066239	
t Stat	-9.708252134		
P(T<=t) one-tail	4.23065E-09		
t Critical one-tail	1.729132812		
P(T<=t) two-tail	8.46131E-09		
t Critical two-tail	2.093024054		
Repeatability (SD)	0.068297313		

From Table 2, the results of weight measurement using the equation derived from load cells and the weights measured from the standard measuring instrument, with weights measured by a standard digital scale and predicted by load cells, with a sample size of 20, show that the t-statistic is equal to -9.708252134, which is less than $t_{0.05,19}$ (1.729132812). Therefore, based on the results of the hypothesis test, we accept H0, indicating that the weight of cassava obtained from load cells does not differ significantly from the standard scale, statistically.

From Table 2, the repeatability of weight measurements obtained from load cell measurements, with a sample size of 20, and measured three times at approximately the same time, showed a standard deviation (SD) of 0.068297313.

To predict the weight from the load cell, weighing the weight of fresh cassava in air and in water, the specific gravity was calculated, and then the starch percentage was calculated from the relationship between the specific gravity and the dry matter content using a texture analyzer to weigh the weight and a dry oven to find the dry matter content of cassava. The quantity per sample was approximately 100 grams, in cassava aged 4 to 12 months. The developed prediction equation is SC = 179.36SG + 170.3, where SC is the starch percentage, SG is the specific gravity, and the starch percentage in fresh cassava heads of the agricultural cultivar 50 is consistent at a significant level of 0.05 [6].

For predicting the starch percentage, 24 cassava plants were used, and one plant was equivalent to one sample, to test the measurement of starch quantity using the GRNIX SM model and the small-scale specific gravity starch measuring device, which has been newly improved. The comparison of the starch percentage by the two measuring devices yields y = 1.0454x - 12.322, where y is the starch percentage measured by the GRNIX SM model and x is the percentage measured by the small-scale specific gravity measuring device.

Table 3 Results of starch percentage analysis by the specific gravity starch measuring device

	df	SS	MS	F	Significance F
Regression	1	58.34145	58.34145	122.6674	1.82E-10
Residual	22	10.46335	0.475607		
Total	23	68.8048			

Regression Statistics	
Multiple R	0.92083
R Square	0.847927
Adjusted R Square	0.841015
Standard Error	0.689642
Observations	24

From Table 3, the analysis results of starch percentage by the specific gravity starch measuring device indicate that the coefficient of determination (R^2) is equal to 0.847927, and the statistical significance test value (Significance F) is equal to 1.82E-10, which is less than 0.05. Therefore, we reject the null hypothesis H_0, indicating that there is a statistically significant relationship between the starch percentage measured by the GRNIX SM model and the small-scale specific gravity measuring device.

Based on the comparison results of the starch percentage measured by the starch measuring device using the specific gravity method of both models, adjustments were made to improve the accuracy of the small-scale device. The revised relationship is $SC = 1.0454SC_1 - 12.322$, where SC is the adjusted starch percentage, and SC_1 is the original percentage after adjustment, yielding the following results.

Table 4 Results of refining the prediction equation for starch of the small-scale specific gravity starch measuring device.

	Original percentage	Percentage of starch modified
Mean	25.2625	25.26311
Variance	3.855489	3.269308
t Stat	-0.00389	
P(T<=t) one-tail	0.498466	
t Critical one-tail	1.713872	
P(T<=t) two-tail	0.996932	
t Critical two-tail	2.068658	

From Table 4, the results of refining the prediction equation for starch of the small-scale specific gravity starch measuring device, predicting from measurements of 24 samples, show that the t-statistic value is -0.00389, which is less than $t_{0.05,23}$ (2.068658). Therefore, based on the results of the hypothesis testing, we accept H_0, indicating that the weight of the starch obtained from the load cells does not differ significantly from the standard scale statistically.

The presentation of data is further conveyed to the web application by transmitting the data measured by the small-scale specific gravity starch measuring device via Wi-Fi.

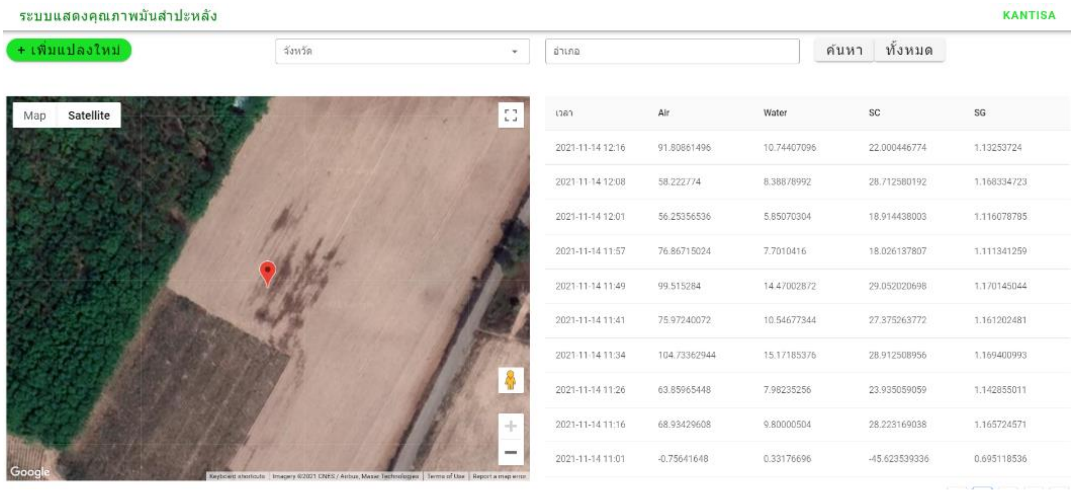

Figure 3 The page displays various data and the location of the plot.

Figure 3 shows various data and the location of the plot. When entering the system, you will find measurements obtained from the small-scale specific gravity starch measuring device. The data displayed includes the time of measurement, weight in air, weight in water, specific gravity, starch percentage, and coordinates of the measurement points transmitted as latitude and longitude, presented on a Google Maps interface.

4. Conclusions

From the study on the improvement and development of the starch measuring device in fresh cassava heads using the strain gauge method, using a quantity of cassava heads of approximately 100 grams, which does not destruct the cassava plant, and being able to identify the measured position coordinates, the study findings can be summarized as follows:

From the design and construction of the starch measuring device in fresh cassava heads using the strain gauge method, by using the weight measurement of cassava heads from the electrical signal of the load cell and then using the measured weight to find the specific gravity to determine the starch percentage, it can be concluded that weight prediction and starch percentage determination can be done quickly. The weight prediction equation from the electrical signal of the load cell is $y = 0.4787x - 4033.8$, where y is the weight of the cassava, and x is the electrical signal value of the load cell.

From the comparison of starch percentages by the starch measuring device using the strain gauge method, GRNIX model SM, and the small-scale strain gauge method, there is a statistically significant relationship, which is expressed by $y = 1.0454x - 12.322$, where y is the starch percentage measured by GRNIX model SM, and x is the starch percentage measured by the small-scale strain gauge method. Then, the prediction equation of starch by the small-scale starch measuring device was adjusted by the relationship $SC = 1.0454SC1 - 12.322$, where SC is the adjusted starch percentage, and SC1 is the original starch percentage. It can be concluded that accurate starch percentage determination can be achieved.

From presenting cassava starch quantity data to the web application along with position coordinates, it can be summarized that the small-scale strain gauge method can present data measured by the small-scale starch measuring device via Wi-Fi to the web application rapidly. However, the positioning is still subject to deviation, but the coordinates remain within the same plot area.

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6. References

[1] Chamsing A. Research and Development on Determination of Starch Content in Cassava Tuber. Final report. Bangkok: Department of Agriculture; 2013. https://www.doa.go.th/research/attachment.php?aid=2055.

[2] Surtono A, Aprilliana P, Supriyanto A, Pauzi GA, Junaidi, Suciyati SW, Warsit. Measuring of Cassava Starch Content by Using Strain Gauge. Journal of Physics: Conference Series. 2019;1338. DOI: 10.1088/1742-6596/1338/1/012019.

[3] Phanomsophon T, Jaisue N, Tawinteung N, Khurnpoon L, Sirisomboon P. Classification of N, P, and K concentrations in durian (Durio Zibethinus Murray CV. Mon Thong) leaves using near-infrared spectroscopy. Engineering and Applied Science Research 2022;49(1):127-132.

[4] Thai Tapioca Development Institute Foundation (TTDI). Results of the Survey and Review of Cassava Production Conditions for the 2565/66 Crop Season [Internet]. 2023 [cited 2023 Jun 3]. Available from: http://thaitapioca.org/2023/
[5] Thai Tapioca Development Institute Foundation (TTDI). Results of the Cassava Survey by the Cassava Production and Trade Survey Team [Internet]. 2023 [cited 2023 Jun 3]. Available from: https://tapiocathai.org/L1.html.
[6] Maraphum K, Saengprachatanarug K, Wongpichet S, Phuphaphud A, Posom J. Modified specific gravity method for estimation of starch content and dry matter in cassava. Heliyon. 2021;7(7). DOI:10.1016/j.heliyon.2021.e07450