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Low cost spectrometer for estimation of dry matter in fresh cassava tuber

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Abstract

The objective of this article was to develop a low-cost spectrometer for estimating dry matter in fresh cassava tubers and to create an equation for predicting the dry matter content. The NIR sensor gave the wavelengths of 610, 680, 730, 760, 810, and 860 nm. The cassava tubers were measured for reflectance mode. Methods for creating equations and analyzing the dry matter of cassava were applied using multiple linear regression (MLR) and different pre-treatment techniques. The near-infrared (NIR) sensor recorded the reflected values, and the results of prediction were displayed on an LCD screen. The effective model developed using 4 wavelengths (i.e. 610, 680, 730, and 860 nm) from raw spectra yielded highest r^2 of 0.78. The 4-wavelength model was preferred due to having fewer variables. Knowing the dry matter allowed for the estimation of starch content in fresh cassava without damaging the tubers, thus increasing the value of cassava.

Keywords: Cassava tubers, Dry matter, NIR-sensor

1. Introduction

The quality of cassava is something to consider. Agriculture should be encouraged to harvest during the time when cassava starch is at its peak. From the results of the survey, in the 2023/24 season, there was a total production of approximately 30 million tons of cassava. But information from the document reviewing the cassava production conditions in the 2023/24 production season [1] found that in every region of the country Cassava purchased from farmers has an average starch content not exceeding 21%, but from academic data it is found that cassava can produce starch up to 40% [2], so it can be seen that about 19% of the starch was lost due to inefficient harvesting because starch values were not considered before harvest. At present, it is found that there is no support and encouragement for agriculture to measure the amount of flour before harvesting. Due to difficulty Flour measuring devices available today are large. Cannot be carried into the field. Based on previous research, Sánchez et al. [3] created an equation to predict carotenoids, cyanide, and dry pulp in fresh cassava roots for use in species improvement. using a wavelength range of 400–2500 nm, while Maraphum et al. [4]; Posom and Maraphum [5], and Malai et al. [6] used a NIR spectrometer for evaluating starch and dry pulp in cassava roots without destroying the plant. Shows non-destructive measurement of flour and dry matter. The error value (SEP) is <2%. However, the scanning method still involves grinding and chopping the cassava roots thoroughly before scanning to collect spectra. which still destroys the sample before scanning the main goal is to use this method to replace laboratory measurement methods. The results of the experiment found that the r^2 value was higher than 0.90. However, the NIR machine still had a high price that was not worth using for the benefit of farmers. The research team therefore saw the need to develop technology for measuring flour. Small portable so it can be easily carried into the field to measure the amount of starch to use as information for planning the harvest as well as developing a system to display a map of the amount of starch in the plot.

The benefits of measuring starch and dry matter in cassava roots in portable plots Can be beneficial for the private sector including farmers to be able to plan planting. Maintenance including the harvest this can be used to map the accumulated flour and dry matter yields in the plot. (Distribution mapping of starch and dry matter content) to plan production improvements such as do you know the zones where you should add more fertilizer? provide more water, etc., and can also be used to store as a year-to-year database for use in planning next year's planting. Such benefits also increase the quality of cassava. Which, when the quality increases greatly, agriculture will gain more profit from cultivation. As a result, farmers have more income. Moreover, it also helps promoters of cassava cultivation to evaluate prices before purchasing a plot that is fair to both growers and buyers. This advantage will invite farmers to grow more cassava, which will help strengthen the cassava-related industry in line with government policy and the mission of the university. In terms of being a refuge for the community.

Therefore, this research aims to 1) develop a low-cost, near-infrared technique to measure the dry matter content of cassava roots. 2) develop a model for predicting the dry matter content of fresh cassava roots using a multiple linear regression equation.

2. Materials and methods

2.1 Low cost spectrometer

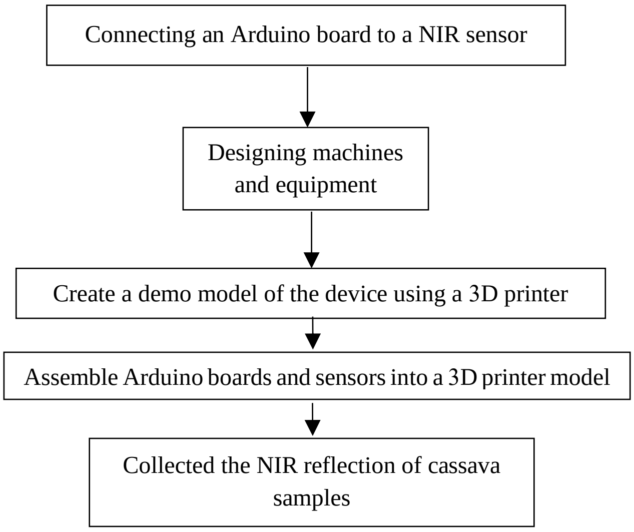
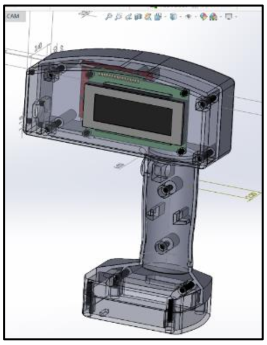
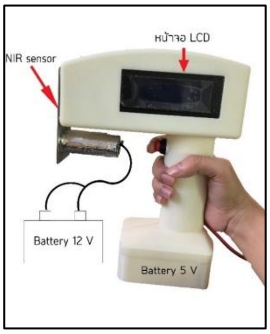


Figure 1 Flow diagram of experiment



a)



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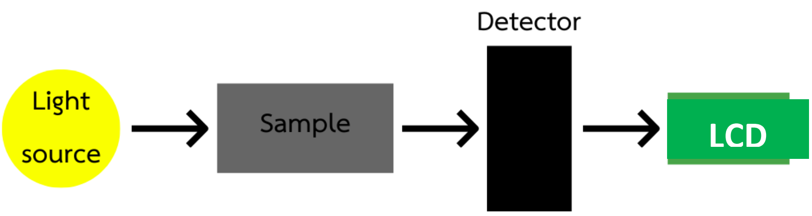


c)

Figure 2 a) 3D model of the device b) Product from the 3D printer and c) the working principle of the low-cost spectrometer

Figure 1 shows flow diagram of this research. The NIR spectrometer was designed and then its prototype was created using 3D printer machine. Afther, NIR spectrometer was built, it was used for data collected for cassava sample. Figure 2, the results show the construction of a low-cost spectrometer, which includes various components such as an Arduino board and a NIR sensor. The NIR sensor providing the wavelength of 610, 680, 730, 760, 810, and 860 nm, specifically the SparkFun RedBoard AS7263 model (Made in U.S.A.), a 12-volt light bulb, a 16×4 LCD screen, a 3D-printed model, a light bulb on/off switch, and 12-volt.

The spectrometer uses a 12-volt Halogen light bulb as the light source. The light from the bulb shines onto the cassava tuber, which absorbs some of the light. The light absorbed by the cassava tuber is relevant to the chemical reactions in the cassava. The light that the cassava tuber cannot absorb is reflected back to the NIR sensor. The NIR sensor analyzes the reflected values and displays the results on a 16x4 LCD screen.

2.2 Data collection

Twenty cassava tubers were used for the experiment. They were cleaned thoroughly to remove all soil residues and then divided into three parts, each 5 cm in length. Each part was designated as a separate sample. Each sample was scanned at four points around the unpeeled cassava pieces. The reflection values from the four positions in each sample were averaged to obtain a single value, which was used as the representative reflectance for each tuber.

2.3 Determination of Dry Matter

After scanning, each sample was chopped into small size then weighted. The chopped sample were placed into aluminum cans. The weight of the empty aluminum cans was first measured, followed by weighing the cans with the cassava before baking. Then, these cans are placed in a drying oven at 60 degrees Celsius for 72 hours, or until moisture was completely removed. After 72 hours or once the moisture has been removed, the cans are weighed again to determine the weight of both the cassava and the empty cans after baking. The results are recorded. The dry matter content was calculated as

$$\mathrm{DM} = \left(\frac{\mathrm{Wf}}{\mathrm{Wi}}\right) \times 100 \quad (1)$$

Where Wi and Wi was the initial and final weight of cassava sample, respectively.

2.4 Model development

The model development was performed using multiple linear regression (MLR). The relationship between reflectance value (collected from 6 wavelengths i.e. X_1 is wavelength at 610 nm (R), X_2 is wavelength at 680 nm (S), X_3 is wavelength at 730 nm (T), X_4 is wavelength at 760 nm (U), X_5 is wavelength at 810 nm (V), and X_6 is wavelength at 860 nm (W)) and its corresponding dry matter content value.

The performance of the MLR model was indicated by R^2, SEP, and bias as shown in Equation 2, 3 and 4 , respectively:

$$R^2 = \sqrt{1 - \frac{\sum(Y_i - Y_{pre})^2}{\sum(Y_i - \bar{Y})^2}} \quad (2)$$

$$\mathrm{SEP} = \sqrt{\frac{\sum((Y_i - Y_{pre}) - (\frac{\sum(Y_i - Y_{pre})}{N}))^2}{N-1}} \quad (3)$$

$$\mathrm{Bias} = \frac{\sum(Y_i - Y_{pre})}{N} \quad (4)$$

where R^2, SEC, Y_i, Y_{pre}, $\bar{Y}$, and N is coefficient of determination, standard error of calibration, measured value, predicted value, and number of samples, respectively.

3. Results and discussion

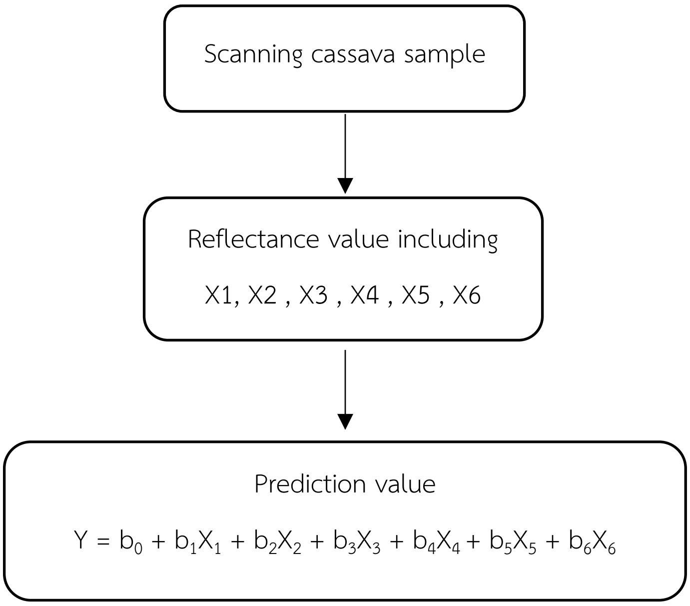
For the results of measuring fresh cassava tuber dry weight, when using a low-cost spectrometer scanner, it can immediately display the dry weight of fresh cassava tubers. This is achieved by generating an equation to predict the dry weight of fresh cassava tubers. The dry weight value displayed on the LCD screen can preliminarily assess the price of cassava. The Schematic of the results of measuring dry weight in fresh cassava tubers is shown in Figure 3.

From Table 1, statistical values for the shortwave range of 4 wavelengths show the results of Multiple Linear Regression (MLR) with data preprocessing using mathematical techniques (Pre-treatment) across 4 methods. It was found that the Raw spectra method has the highest coefficient of determination (r^2) of 0.78. The standard error of calibration (SEC) is 3.64, and the standard error of prediction (SEP) is 3.33. The coefficient of determination for the model (R^2) is 0.66. The average difference between measured and predicted values is -2.86.

Figure 4 depicts the prediction results for dry weight of cassava using 4 wavelengths. The dry weight values were adjusted using the Raw spectra method with a factor of 4, achieving an R^2 value of 0.78 and an SEC value of 3.64.

Table 1 Results of model development for predicting cassava dry weight using 4 wavelengths

Parameter	Pre-treatment	Calibration Set			Validation Set		
		F	R^2	SEC (%)	r^2	SEP (%)	Bias (%)
Dry matter content	**Raw spectra**	**4**	**0.66**	**3.64**	**0.78**	**3.33**	**-2.86**
	Centering	4	0.66	3.65	0.73	3.65	-2.29
	Normalize	4	0.50	4.37	0.29	6.72	-0.99
	SNV	4	0.46	4.55	0.40	5.53	-1.46



Y is the predicted value, X_n is the reflectance value, and b_n is the regression coefficient of the calibration model

Figure 3 Schematic of the results of measuring dry weight in fresh cassava tubers.

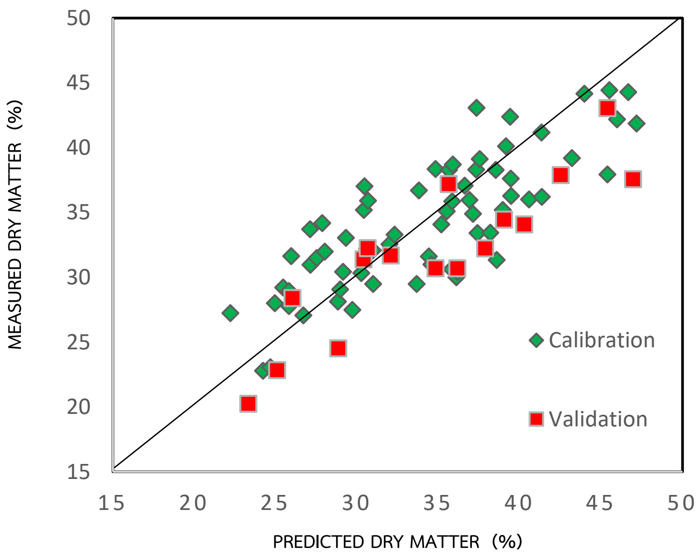


Figure 4 Prediction values between measured values and results from the spectrometer

4. Conclusions

From the development of prediction equations for dry weight analysis of cassava using Multiple Linear Regression (MLR) and preprocessing with mathematical techniques (Pre-treatment), the following conclusions were drawn: The Raw spectra method yielded the highest coefficient of determination (r^2) for the test dataset. Predicting dry weight using a shortwave range of 6 waves and a shortwave range of 4 waves showed that both ranges were equally accurate. However, the 4-wavelengths required fewer variables, resulting in lower errors compared to the 6-wave range.

The values for predicting the dry weight of cassava using the shortwave range of 6 waves are as follows:

$$Y = 42.76 + 1.20\ X_1 - 0.98\ X_2 + 0.18\ X_3 - 0.01\ X_4 - 0.06\ X_5 - 0.16\ X_6$$

The values for predicting the dry weight of cassava using the shortwave range of 4 waves are as follows:

$$Y = 42.53 + 1.14\ X_1 - 0.96\ X_2 + 0.12\ X_3 - 0.19\ X_6$$

where X_1, X_2, X_3, X_4, X_5, and X_6 are wavelength at 610, 680, 730, 760, 810, and 860 nm, respectively.

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