Development of a Miniaturized Papaya Sweetness Classification Device Based on Infrared Characteristic via Reflectance Method

Siti fadziela Bt Zulkfly
Bachelor of Electrical Engineering (Hons)
Faculty of Electrical Engineering
Universiti Teknologi MARA
40450 Shah Alam, Selangor
sitifadziela@yahoo.com

Abstract — **This paper is discusses on the development of a miniaturized device and experimental evaluation of the infrared reflectance to measure the sweetness of papaya. This device used to indicate the sweetness of papaya. Soluble solids content indicative of sweetness was used for papaya as the quality factor for correlation with near infrared reflectance technique. The voltage measured was taken from the center position which is 50% from the length of the papaya and the sugar level content is obtained in % Brix. Ripe papaya can be classified as a sweet papaya. The miniature handheld NIR sensor usually easier to bring anywhere for example can be used in orchard. This device also low cost because the component used inside the sensor are much cheaper compare than big device that used many component and also difficult to bring anywhere.**

Keyword: Near Infrared (NIR) reflectance, Percentage Brix

I. INTRODUCTION

NIR instruments have undergone radical change and more versatile in terms of the infrared region in which measurement can be made and more portable. The low cost of instrument have also started to appear in the market. However, before this technology can be successfully transferred to the fruit industry it needs further research. Further research is required into interaction of NIRS radiation from different regions of the near infrared with intact fruit to purpose of optimizing instrument depend on the type of fruit and parameters to be measured [1].

Previous research has demonstrated the potential of near infrared (NIRS) spectroscopy for assessing soluble solid content, firmness and other physiological properties content of fruit including plum [2, 1], cherries [4], watermelon [6], papaya [5, 14], mango [1] and apple [11].

A. Backgroud studies

A different technique of measurement has been introduced for obtaining the near infrared spectra. In reflectance mode the light source and detector are mounted under a specific angle for example 45 degree. This angle is to avoid specular reflection. In transmittance mode the light source is positioned opposite to the detector, while in interactance mode, the light source and detector are positioned parallel to each other in such a way light due to specular reflection cannot directly enter the detector [3].

This near infrared reflectance spectroscopy technique use reflected spectrum of a sample lit with halogen light by optical equipment. The spectrum that used in the technique is between 800nm and 1700nm to estimate the soluble solid content [4]. The development of nondestructive analytical method would enable to control the quality of individual fruits. Near-IR spectroscopy (NIRS) was used to assess total soluble solid content (SSC).

B. Problem Statement

Nowadays, to detect the quality of the product is not based on the random pick by human. The maturity of fruits usually not only depend the color of skin, but it depend on total soluble solid content in fruits. Miniaturized papaya sweetness device will be designed to detect the sweetness of papaya. By having a miniaturized device, it will easier for the worker to detect the sweetness of papaya in the orchard. This device will use NIR reflectance technique to assess the sweetness of fruit. This experiment only consider on papaya because the color of the papaya not indicates that it sweet or ripe. In this project the handheld sensor will design to make it easier to bring anywhere.

C. Objective

The main objective of the project is to develop of a miniaturized papaya sweetness device based on infrared characteristic via reflectance method.

D. *Scope of study*

The data was collected using reflectance method and refractometer. Reflectance method used receiver sensor and transmitter sensor. The data collected were analyzed and estimated using fuzzy logic in MATLAB application to determine correlation between near infrared (NIR) technique and sugar level in term of Brix.

E. *Section of organization*

This paper is organized as follow: Section II describes the literature review; Section III describes the Methodology used in this research; Section IV discusses about result and discussion; and Section V is the conclusion.

II. LITERATURE REVIEW

Different techniques of measurement have been introduced for obtaining the near infrared spectra. Reflectance of measurement has been described by various researchers [6, 2, 5, 1, 3, 13]. Recently several studies have reported using near-infrared (NIR) spectroscopy techniques in the spectral region between 700nm and 1100nm to measure sugar content of fruits. It provides a nondestructive analytical method with swift, accurate, and fast measurement [1]. NIR enhanced spectrometer was used to collect reflectance readings over a wavelength range of 700nm-1100nm in 2 nm increments, yielding 200 values per spectrum. For each variety, the reflectance measurements were done in one day. The light passed through a bundle of optical fibers to the fruit, and the reflected light was transferred to a photo diode array (PDA) detector through another bundle of fiber optics. A holder was designed to support the fruits and direct the light at a 45 degree angle to the fruits (to avoid specular reflectance), and maintain a distance of 1cm between the probe and the fruits [5].

Each reflectance spectrum used in multivariable analysis was an average of the three spectra obtains for each fruit. This spectrum was used as a reference to calculate the relative reflectance of individual fruit. NIR diffuse reflectance measurements were performed using an Oriel spectrophotometer system [4]. NIR spectra of intact fruit were measured using a Perten DA-7000 diode-array vis + near infrared spectrophotometer (Perten Instruments North America, Inc). The spectrophotometer scanned at 5nm, across a range encompassing the entire visible (400nm-780nm). The NIR system was arranged in reflectance mode for receiving signal from the peel and flesh of fruit [6].

III. METHODOLOGY

The process for measuring and classifying the sweetness of papaya using NIR Reflectance technique involves two type of tests which are non destructive and destructive. For the experiment purposes, samples were divided into unripe and ripe which are green and yellow. A total of 80 Malaysian papayas used for the experiment were randomly selected and purchased from Tesco supermarket and fruit stalls in Shah Alam.

The experiment with data from the circumference, weight and length of papaya were collected as the sample characteristic of papaya and then the voltage was measured. Different sizes in papaya obtain different result in voltage reading and sweetness. The circumference was measured from the center position of each papaya, while the length was measured from the front to the back of papaya without including papaya trunk by using the thread.

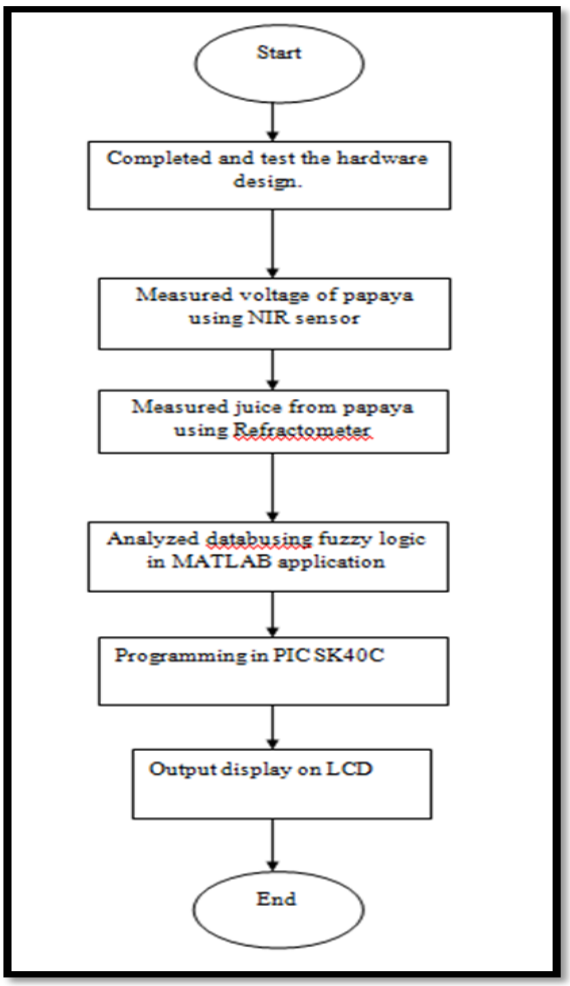


Fig. 3 Flow chart of methodology

Experiment Setup

There are two sensors used for this experiment which are infrared transmitter sensor and infrared receiver sensor. This experiment did not use halogen light and the light source because it used a transmitter sensor instead. Infrared transmitter is a device that emits a beam light in the infrared range. The infrared transmitter sensor was used because it will transmit the light to papaya's skin and the infrared receiver sensor will receive the signal.

In reflectance mode, the transmitter sensor is placed next to the receiver sensor. So, the papaya will be placed opposite to the detector. The distance between papaya and detector are fixed for the purpose of avoiding error in reading. The infrared transmitter and receiver sensor are surrounded with black cover in order to avoid any ambient light come in and effect the reading. The position of the infrared sensors and the papaya are shown as in figure 1.

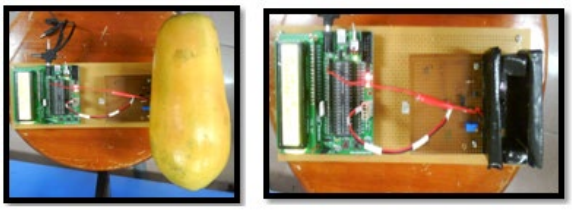


Figure 5

Infrared sensor was surrounded by a box for the purpose of covering the infrared sensor from ambient light when the voltage was measured. The papaya was placed on top of the box throughout the experiment. The infrared sensor detected the papaya and the voltage will display on LCD. The mean of voltage was taken from 3 positions which are 25%, 50% and 75%

$$\text{Mean} = \frac{25\% + 50\% + 75\%}{3}$$

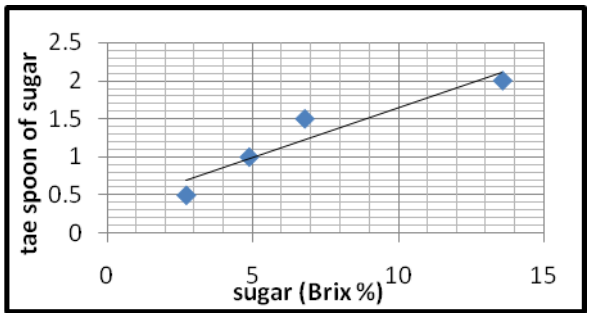


Figure 6: Laboratory Refractometer

The refractometer is a scientific instrument that is used to obtain the exact sugar level in term of %Brix. Refractometer is equipment that used a same concept as implementing the infrared sensors and halogen light because its operation is based on the index of refraction. The index of refraction is calculated from Snell's law and can be calculated from the composition of the material using the Gladstone-Dale relation. In this process, the type of refractometer that used is laboratory or Abbe-Refractometer types. This equipment is available at Faculty of Chemical Engineering.

In the experiment, the measurement of papaya sweetness with the refractometer is in the liquid form. The juice from the papaya was extracted and measured using refractometer. The percentage Brix observed from the refractometer is collected and correlation between Brix and the voltage obtained from NIR reflectance method was analyzed with fuzzy logic in Matlab application.

Another parallel experiment is adding sugar to plain water to identify the amount of sugar was supposed to be for the value of each %Brix. The amount of plain water used is 10ml. The combination of sugar and water was measured using refractometer. The result compared to the result in Brix from papaya's juice.



Graph1: Sugar vs %Brix for 10ml of water

From the experiment it is found that the amount of sugar in sweet papaya from 10.5% to 12.12% is approximately equal to the 2 tae spoon of the sugar.

Schematic Circuit

Figure 3 show the schematic circuit for the development device. The signal point was taken between potentiometer and receiver sensor and will connected to the RA0 at PIC SK40C.

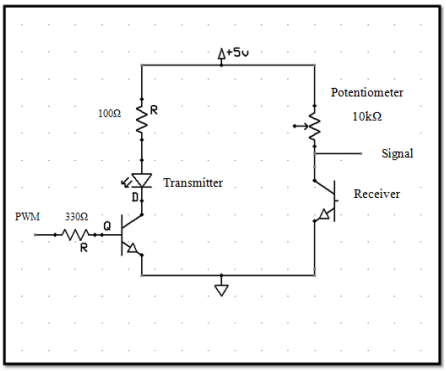


Figure 7

IV. RESULT AND DISCUSSION

FUZZY LOGIC DEVELOPMENT

In this project, the fuzzy logic was developed using two inputs and one output. The input variables are renamed as voltage and circumference. The output variable is renamed as output (%Brix). The range of input will depend on the data that have been collected from papaya. The fuzzy operator AND is used to obtain a result of the evaluation.

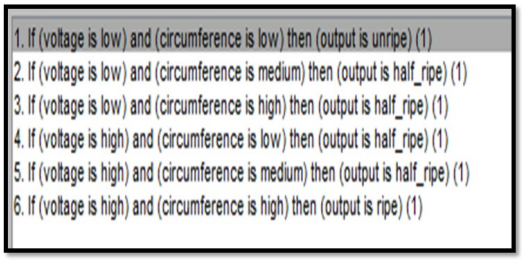


Figure 8: Fuzzy rules

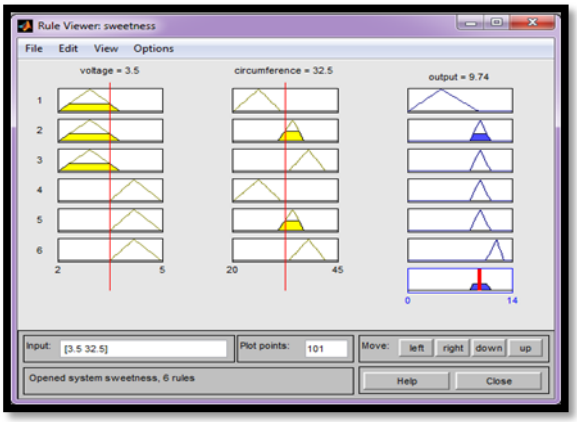


Figure 9: The fuzzy output in rule viewer for classifying the sweetness of papaya

For example, if the voltage is 2.84 and circumference is 31.1 cm, then the output after defuzzification is 5.5 which are included in the range of unripe papaya (4.78% - 8.76%). To validate the developed FIS that was used to classify the sweetness papayas, the output from the FIS was compared with the result obtained from the refractometer. The expected result is also based on the human evaluation of color, sugar content in papaya (%Brix) and sweetness level.

Voltage	Circumference	Output	Fuzzy	Expected
2.84	31.1	5.5	Unripe	Unripe
2.78	30.5	4.78	Unripe	Unripe
2.55	27.2	4.74	Unripe	Unripe
3.15	31.5	9.06	Unripe	Unripe
3.36	30.5	4.78	Unripe	Unripe
3.04	30.5	4.78	Unripe	Unripe
3.3	28	4.74	Unripe	Unripe
2.88	31.8	9.75	Half ripe	Unripe
3.46	31.6	9.74	Half-ripe	Unripe
2.94	29.8	4.77	Unripe	Unripe
3.26	31.6	9.74	Half ripe	Unripe
3.18	30.60	4.79	Unripe	Unripe
3.03	28.9	4.74	Unripe	Unripe
3.85	29.4	9.74	Half ripe	Unripe

Table 1: Output for unripe papaya

(10/14) x 100% = 71.43% degree of membership

Voltage	Circumference	Output	Fuzzy	Expected
4.1	35.20	10.5	Half ripe	Half ripe
4.01	36.10	10.8	Half ripe	Half ripe
3.83	35.40	10.6	Half ripe	Half ripe
4.09	36.30	10.9	Half ripe	Half ripe
4.7	35.80	10.7	Half ripe	Half ripe
4.85	35.20	10.3	Half ripe	Half ripe
3.37	34.80	9.74	Half ripe	Half ripe
2.9	33.90	9.74	Half ripe	Half ripe
3.6	36.90	10.20	Half ripe	Half ripe
3.7	36.90	10.7	Ripe	Half ripe
4.3	36.70	11.00	Ripe	Half ripe
4.64	33.90	10.20	Half ripe	Half ripe
3.63	33.90	9.72	Half ripe	Half ripe
2.32	34.40	9.54	Half ripe	Half ripe
4.06	37.00	11.6	Ripe	Half ripe

Table 2: Output for half ripe papaya

(13/15) x 100% = 86.67% degree of membership

Voltage	Circumference	Output	Fuzzy	Expected
3.9	36.40	11.00	Ripe	Ripe
3.5	37.8	9.54	Ripe	Ripe
3.71	41.20	11.1	Ripe	Ripe
3.59	38.5	10.4	Half ripe	Ripe
3.66	35.1	10.7	Ripe	Ripe
3.62	36	10.6	Ripe	Ripe
4.59	39.8	11.70	Ripe	Ripe
4.01	37.2	11.70	Ripe	Ripe
4.35	36	10.8	Ripe	Ripe
4.13	34.5	10.2	Half ripe	Ripe
3.86	35.9	10.7	Ripe	Ripe
3.73	34.4	10.4	Half ripe	Ripe
3.81	42.2	7	Unripe	Ripe
4.59	36.10	10.8	Ripe	Ripe
4.66	37.6	11.7	Ripe	Ripe

Table 3: Output for ripe papaya

(11/15) x 100% = 73.33% degree of membership

15 data of voltage and circumference in the range of unripe, half ripe and ripe were picked randomly to measure the output in fuzzy inference system (FIS). Then the output produced in fuzzy rules will be compared to output in the membership function whether it is in the range or out of range. If all the output 100% in the range, there has something wrong during apply them in fuzzy rule and also must adjust at range of input to get 80% degree of membership.

The intersection between medium and low graph and intersection between medium and high for both voltage and circumference of papaya was adjusted. Then we get 71.43% for unripe, 86.67% for half ripe and 73.33% for ripe. Fuzzy rule are defined to classify sweetness of each papaya. Algorithms from fuzzy rule were applied in PIC SK40C to display the result.

V. CONCLUSION

From the experiment, the objective of determining the level of sweetness based on reflectance method was achieved. A method of reflectance was evaluated as a non-destructive technique for identifying the sweetness level in the papaya. Ripe papaya also classified as a sweet papaya because the sugar content in the papaya is high. Soluble solids content indicative of sweetness.

For ripe papaya the value of voltage obtained is from 3.5V to 4.9V and circumference is from 33.5cm to 42.2cm at (10.54% - 12.12%) of Brix. The different value of voltage is caused by the factor such as color, size, weight and lighting effect.

The data that had been collected was analyzed using fuzzy logic in Matlab. From the project that had been completed, there is a lot of knowledge about fuzzy logic using MATLAB software. The fuzzy logic was developed to classify voltage unripe, voltage half ripe, and voltage ripe where it successful done in fuzzy logic. The result was obtained whether the papaya unripe, half ripe or ripe by comparing fuzzy output with result from refractometer. The output condition can be display automatically on LCD using MPLAB programming in PIC SK40C.

Research on peel thickness is necessary in the future to eliminate the error in reading especially when papaya is in unripe stage. It is because during unripe stage, papaya's peel is much thicker compare to papaya in ripe stage. This will affect the value of voltage.

REFERENCES

[1] P. Paz, Sanchez, M.T., Perez- Marin, D., Guerrero, J.E, Garrido-Varo, A, "Nondestructive Determination of Total Soluble Solid Content and Firmness in Plums Using near-Infrared Reflectance Spectroscopy," *journal of Agriculture and Food Chemistry,* vol. 56, pp. 2565-2570., 2008.

[2] D. Perez-marin et al, "Miniaturized handheld NIR sensor for the on-site non-destructive assessment of post-harvest quality and refrigerated storage behaviour in plums," Journal of Food Engineering , vol.99, pp.294-302.,2010

[3] B. M. Nicolai, Beullens, K., Bobelyn, E., Peirs,A.,Saeys,W., Theron,K.L.,Lammertyn,J, "Nondestructive measurement of fruit and vegetable quality by means of NIR spectroscopy," *A review, Postharvest Biology and Technology,* vol. 46, pp. 99-118, November 2007.

[4] R. Lu et al," PREDICTING FIRMNESS AND SUGAR CONTENT OF SWEET CHERRIES USING NEAR-INFRARED DIFFUSE REFLECTANCE SPECTROSCOPY," American Society of Agricultural Engineers,vol.44(5),pp.1265-1271,2001

[5] N. Abu-Khalaf, Bennedsen, B.S., "Plum-tasting using near infra-red (NIR) technology," *International Agrophysics,* vol. 16, pp. 83-89, 2002.

[6] Z. Schmilovitch, Mizrach, A., Hoffman , A., Egozi, H., Fuchs,Y., , "Determination of mango physiological indices by near-infrared spectrometry," *Postharvest Biology anf Technology* vol. 19, pp. 245-252, july 2000.

[7] Yong he, Yun Zhang, Annia G. Pereira, Antihus h. Gomez & Jun Wang et al., "Nondestructive Determination of Tomato fruit Quality Characteristics Using Vis/NIR Spectroscopy Technique"International Journal of Information Technology,vol.11,2005

[8] D. C. Slaughter, "Nondestructive Maturity Assessment Methods For Mango," *Biological and Agriculture Engineering University of California,Davis,* pp. 1-18, January 2009.

[9] F. J. Garcia-Ramos et al,"Non-destructive fruit firmness sensor:a review,"Spanish Journal of Agricultural Research, vol.3,pp.61-73.,2005

[10] Mohd Hafeez Bin Hashim "A Non-Invasive Method for Papaya Sweetness Determination usong NIR full-transmittance Technique" Faculty of Electrical Engineering

[11] H. Q. Tian, Ying, Y.B., Lu, H.S., Fu, X.P. , "Measurement of soluble solids content in watermelon by Vis/NIR diffuse transmittance technique," *Journal of Zhejiang University – Science B,* vol. 8, pp. 105-110, February 2007

[12] M. Zude et al., "Non-destructive tests on the prediction of apple fruit flesh firmness and soluble solids content on tree and in shelf life ," Journal of Engineering,vol.77,pp.254-260,2006

[13] D. C. Slaughter et al.," Nondestructive determination of totul and soluble solids in fresh prune using near infrared spectroscopy," Postharvest Biology and Technology,vol.28,pp.437-444,2003

[14] C. V. Greesill and D. S. Newman et al,"An investigation into the determination of the maturity of pawpaws (Carica papaya) from NIR transmission spectra,"J. Near Infrared Spectrosc,vol.7,pp.109-116,1999

[15] Fu et al," Application of NIR spectroscopy for firmness evaluation of peaches," *Journal of Zhejiang University – Science B,* vol. 9(7),pp.552-557.2008