Indonesian Journal of Electrical Engineering and Computer Science
Vol. 10, No. 3, June 2018, pp. 853~858
ISSN: 2502-4752, DOI: 10.11591/ijeecs.v10.i3.pp853-858

Correlation between Reflection Coefficient, Dielectric Properties and Brix Level of Malaysian Oranges at Microwave Frequencies

Rafidah Rosman[1], Mohamad Ngasri Dimon[2], You Kok Yeow[3]
[1]Faculty of Electrical Engineering, Universiti Teknologi MARA (UiTM), Malaysia
[2,3]Faculty of Electrical Engineering, Universiti Teknologi Malaysia, Malaysia

Article Info

Article history:

Received Jan 22, 2018
Revised Mar 9, 2018
Accepted Mar 28, 2018

Keywords:

Brix level
Dielectric properties
Malaysian oranges
Reflection coefficient

ABSTRACT

This paper presents sweetness degree (°Brix) prediction of the Malaysian oranges using microwave technique. Experimental measurement using monopole sensor and reflectometer was done in order to correlate the relationship between measured reflection coefficient, S_{11} of the orange and its sweetness level. Up to fifty orange samples were freshly plucked from local grower's farm and tested. The unique design of the monopole sensor's holder is made of nylon. The experiment test bed was set up based on the standard dimension of monopole sensor available in the market. The operating frequency is focusing on 2.2 GHz as it shows significant sensitivity for determining Malaysian local oranges sweetness level.

Corresponding Author:

Rafidah Rosman,
Faculty of Electrical Engineering,
Universiti Teknologi MARA (UiTM), Malaysia.

1. INTRODUCTION

The Malaysian orange fruit is one of local produce that contributed for the high market value among the agricultural produce in Malaysia. Typical Malaysian local orange basically has a range of diameter between 5cm to 7cm [1] and its peel thickness around 0.7 mm to 1.3 mm. Many research and investigation has been done towards varieties of fruits using various scientific methods. Numerous methods have been developed among researchers in recent years to investigate the internal and external fruit quality either destructively or non-destructively.

There are two methods of determining sweetness of fruit, which are the direct method and the indirect method. Direct method determine the sweetness by conventional wet chemistry methods [2], which is the sweetness level of the fruit is measured destructively based on its soluble solid content (SSC) in the fruit. The direct method is the most accurate method to determine the fruit sweetness, but it is time consuming. In contrast, indirect method requires the measurement of the physical property of the fruit using fabricated instrument or meter. The change in physical properties that can be directly correlated with a change in the actual sugars (soluble solids) content of the fruit obtained from conventional direct method [2]. Recently, the indirect methods become more popular than the direct method due to rapid test, high sensitivity and user friendly features [3], [4].

The Near Infra-Red Spectroscopy (NIRS) is the most common indirect method to determine the sweetness level non-destructively [2], [5]-[7]. The measurement parameter using optical techniques is the refractive index, n, which value is determined based on the change of linearly polarized light. The refractive index, n, for sucrose solutions of various percentage by mass has been measured and tables of n versus degrees Brix (°Bx) published. The parameter °Bx is used to meaure the sugar content in certain solution. One °Bx represents 1 gram of sucrose in 100 grams of solution.

In this paper, a microwave monopole was used as a sensory device to classify the sweetness level of the Malaysian oranges. The interaction between agri-foods samples using microwave can be described by the relative complex permittivity, εr (= εr′ - j εr″) where the real part, εr′ is the dielectric constant and imaginary part, εr″ is the dielectric loss factor [8],[9]. The εr′ influences the electric field distribution and the phase of waves traveling through the sample under test. In contrast, the εr″ influences the energy absorption or attenuation of the sample.

The change of εr for the orange peel in particular that can be related to its stages of maturity or sweetness. As mentioned above, the NIRS techniques normally refer to the change in refractive index, n parameter of the sample. However, the relationship between n and εr is given as n2 = εr [10]. This mean that, in principle, microwave technique has twice the power of sensitivity in determining the SSC as compared to NIRS techniques.

2. PRINCIPLE OF MEASUREMENT

Normally, the current flow at the monopole end is assumed to be zero in order to simplify the analytical analysis. In fact, the currents at the end of the monopole are not equal to zero due to a charge distributed on the end-cap. The accumulated charges on the monopole end will produce a small current flow to the end cap, which will affect the local electromagnetic fields (reflection of the electromagnetic fields), especially for monopole with thicker radius [11]. The distributed charge at the cap-end surface will produce a fringing fields around the cap-end area as shown in Figure 1 (a).

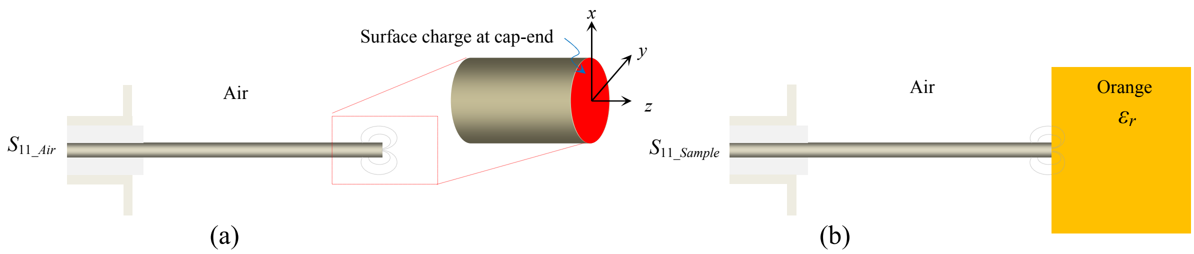


Figure 1. (a) Surface charge around the finite end of the monopole, (b) The finite end of the monopole terminated by orange sample

In this study, the orange sample is placed and contacted at the end of the monopole driven from coaxial line as shown in Figure 1 (b). Microwave incident signals have been generated and transmitted through the coaxial line to the end of the monopole. If an orange sample is terminated at the end surface, the fringing fields will be interrupted and changed. Thus, when the amount of brix changes in the orange, the monopole sensor will measure a change in reflection coefficient, $|S_{11}|$ (from the change in ε_r) that can be directly correlated with a change in brix level of the orange, which was obtained from commercial refractometer previously.

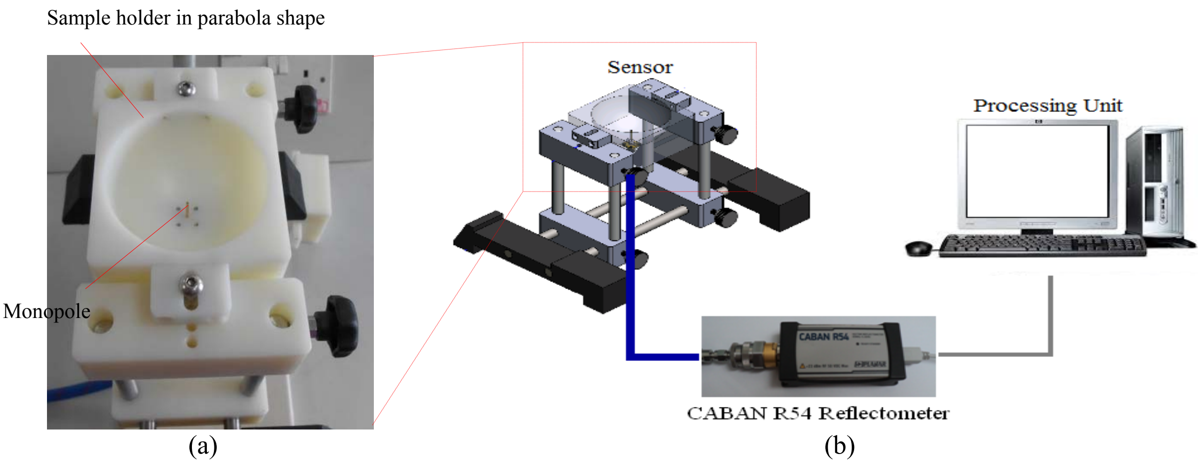
3. EXPERIMENTAL SET-UP

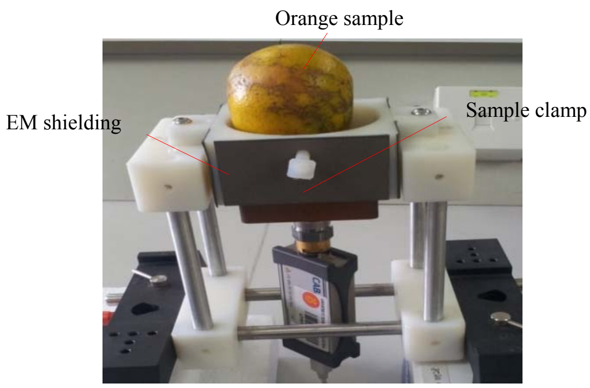
3.1. Reflection Coefficient Measurement

An orange sample holder was machined using nylon material which has curved surface with the cross-sectional shape of a parabola. The monopole was driven from the center position of the holder as shown in Figure 2 (a). The orange sample was placed into the holder, so that the tip of the monopole will touch the outer skin of the orange as shown in Figure 2 (c). The linear magnitude reflection coeffcient, $|S_{11}|$ of the orange sample was measured by connecting the monopole to CABAN R54 reflectometer as in Figure 2 (b). Before measurement has been done, a full one-port calibration technique was implemented to the reflectometer using a commercial Keysight 85052D calibration kit. The reflectometer was controlled and monitored using personal computer. The measurement was carried out from day 2 of the orange samples (unripe) obtained from local farm until day 14 (mature).

3.2. Relative Complex Permittivity Measurement

The relative complex permittivity ($\varepsilon_r = \varepsilon_r' - j\ \varepsilon_r''$) of orange samples was measured using Keysight 85070E dielectric probe at room temperature as shown in Figure 2 (a). Probe calibration is performed before dielectric measurement has been done. The probe calibration consists of air, short-circuits and deionized water. After the $|S_{11}|$ was measured, the corresponding orange sample was peeled and its juice was extracted. During the ε_r measurement, the orange juice is made to in contact with the aperture of the dielectric probe.





(c)

Figure 2. (a) Monopole sensor with sample holder, (b) Experimental-setup. (c) $|S_{11}|$ measurement of the orange sample

3.3. pH Measurements

The pH values for the the oranges were measured by burying HI 98127 waterproof pH tester into the orange juice and record the measured value of pH from the display LCD tester as shown in Figure 3.

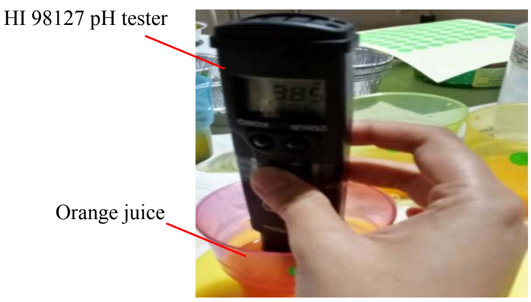


Figure 3. HI 98127 pH sensor immersed into orange juice

3.4. Degree Brix Measurement

The value for Brix measurement was done by extracting juices from the oranges and the displayed Brix value from ATAGO PAL-1 pocket refractometer was recorded as shown in Figure 4.

Figure 4. Brix level measurement of orange juice using ATAGO PAL-1 pocket refractometer

3.5. Moisture Content Measurement

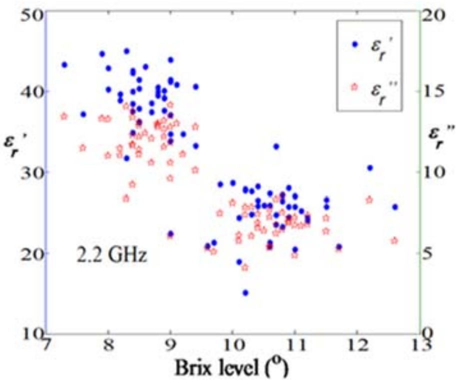
The moisture content, *m.c.* of all the orange sample used were obtained by the wet basic oven-drying method. First, weigh the corresponding destructive oranges (including orange skin) in the initial condition at room temperature using digital balance, the initial mass, m_w of the orange sample was recorded. The orange samples were dried in a forced-convection oven at 70˚C for 24 hours to reduce the moisture containing in the orange samples. After oven drying, the mass, m_d of the all orange sample was re-weighed and recorded, respectively, as soon as it have cooled to room temperature. Finally, the amount of *m.c.* (in %) inside the orange samples were calculated as:

$$m.c. = \left(\frac{m_w - m_d}{m_w} \right) \times 100\% \quad (1)$$

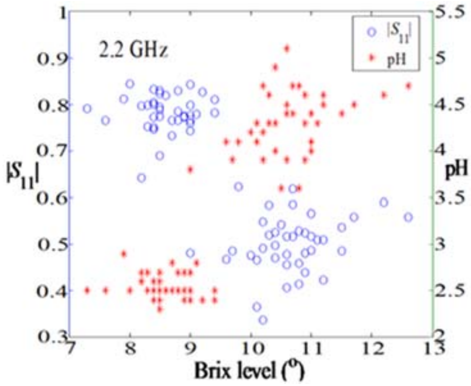
where m_w and m_d is a mass (in gram) before drying and after drying, respectively. The value of m_d was obtained 24 hours in oven until the reading of mass are constant.

4. RESULTS AND ANALYSIS

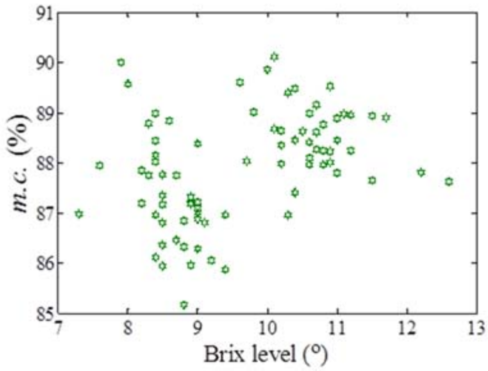
Brix level of orange change has caused the change of ε_r' value from 45 to 15 and ε_r'' is changing within 2 to 18, respectively as shown in Figure 5 (a). Obviously, microwave technique is very sensitive to be used in soluble solid content measurement. Normally, fruit juices have pH values ranging from 2.5 to 3.5. In fact, sugar has a pH value of almost 7. From Figure 5 (b), the value of pH increases with Brix level. This means that an acidic (sour taste) content is reduced and the sugar content increases in the oranges. The frequency for measuring $|S_{11}|$ is ranging from 85 MHz to 5.4 GHz. For this study, it is found out that at 2.2 GHz, significant data obtained pertaining to the reflection coefficient of the oranges' outer skin. $|S_{11}|$ decreases with increment of Brix level. It shows that the sugar level content does effect the outer skin of the oranges properties that eventually changes the value of $|S_{11}|$. Overall, Brix level changes between 7 and 13 for all orange samples from day 2 (unripe) to day 14 (mature). Clearly, the significant variation of ε_r' and ε_r'' in orange sample is most probable due to presence of soluble solid content (SSC), since the moisture content for overall orange sample are approximately same (~ 88 % *m.c*) as shown in Figure 5 (c).



(a)



(b)



(c)

Figure 5. (a) ε_r' and ε_r'' versus Brix level. (b) |S11| and pH versus Brix level. (c) Moisture content, *m.c.* of the orange sample versus Brix level

4. CONCLUSION

Internal attributes of oranges such as SSC can be determined by using nondestructive method which in this case, by using a monopole antenna driven by a reflectometer. Its correlation between destructive methods that are Brix, pH and moisture content is gathered and measured to justify that this microwave technique is able to predict sweetness level prior consuming it. The frequency measurement ranging from 85 MHz to 5.4 GHz is obtained but 2.2 GHz is chosen which gives substantial value that relates $|S_{11}|$, ε_r' and ε_r'' and destructive method. This concludes that microwave technique can be used to predict sweetness level of Malaysian oranges.

ACKNOWLEDGEMENTS

The authors would like to acknowledge Radar Laboratory of Universiti Teknologi Malaysia (UTM) Skudai for providing us with high-end equipment such as Vector Network Analyzer (VNA) and ENA Series of Network Analyzer for dielectric permittivity measurement. The acknowledgment also goes to KPT and RMI UiTM for funding the research with Fundamental Research Grant Scheme 600-RMI/FRGS 5/3 (102/2015).

REFERENCES

[1] R. K. K. Eng, "Food Security and Quality in Malaysia," *Jurutera*, Jan 2013.

[2] C. Jarén, *et al*., L. Magwaza, *et al*., "Sugar Determination in Grapes Using NIR Technology," *International Journal of Infrared and Millimeter Waves*, vol. 22, pp. 1521-1530, Oct 2001.

[3] K. Y. You, *et al*., "Precise Moisture Monitoring for Various Soil Using Handheld Microwave-Sensor Meter," *IEEE Sensors Journal,* vol. 7, pp. 2563-2570, 2013.

[4] H. S. Li and Z. Y. Lei, "Research on Infrared Special Facula View Measurement Method Based on Image Processing Technology," *TELKOMNIKA Indonesian Journal of Electrical Engineering*, vol. 10, pp. 1422-1429, Oct 2012.

[5] L. Magwaza, *et al*., "NIR Spectroscopy Applications for Internal and External Quality Analysis of Citrus Fruit—A Review," *Food and Bioprocess Technology*, vol. 5, pp. 425-444, Feb 2012.

[6] H. Wang, *et al*., "Fruit Quality Evaluation Using Spectroscopy Technology: A Review," *Sensors*, vol. 15, pp. 11889-11927, Feb 2015.
[7] Y. Zhang, et al., "Comparision of Several Preprocessing Algorithms Based on Near Infrared Spectroscopic Measurement of Glucose in Aqueous Glucose Solutions," *TELKOMNIKA Indonesian Journal of Electrical Engineering*, vol. 12, pp. 2683-2689, April 2014.
[8] S. O. Nelson, "Agricultural Applications of Dielectric Measurements," *IEEE Transactions on Electrical Insulation*, vol. 13, pp. 688-702, 1991.
[9] X. B. Bu and Z. L. Li, "Design and Compared of Two Types of Microwave Moisture Instruments," *TELKOMNIKA Indonesian Journal of Electrical Engineering*, vol. 11, pp. 4512-4516, August 2013.
[10] K. Y. You, *et al*., "Palm Oil Moisture Monitoring Based On Dielectric Properties at Microwave Frequencies," *International Journal of Microwave and Optical Technology,* vol. 9, pp. 294-302, 2014.
[11] K. Y. You, "RF Coaxial Slot Radiators: Modeling Measurements and Applications," Artech House, US., 2015.