

Relationship of Reflection Coefficient (S_{11}) and °Brix Level Measurement of Malaysian Local Oranges Skin

Rafidah Rosman
Mohamad Ngasri Dimon
You Kok Yeow
Jamilah Karim

Abstract— This paper presents study towards Malaysian local oranges peel to predict °Brix i.e. sweetness level using a monopole sensor for its relationship on reflection coefficient (S_{11}), °Brix and moisture content (%m.c). Analysis was carried out in order to support hypothesis that oranges skin or peel can determined its flesh sweetness non-destructively. The effect on reflection coefficient (S_{11}) and its relation with °Brix are measured towards 30 sample of Malaysian local oranges that freshly plucked from local oranges farm. The unique design of a holder for local oranges that is made of nylon is enclosed in this project contributed to its invention. The experiment test bed was set up based on standard dimension of small monopole sensor available in the market.

Keywords-oranges; S_{11} ; monopole sensor, °Brix, moisture content, oranges

I. INTRODUCTION

The purpose of this research is to observe the simulation effect on reflection coefficient, Γ when an electromagnetic (EM) wave is emitted from the coaxial line port through a microwave monopole antenna. The nylon bowl (permittivity, $\epsilon_r = 3.1$) is designed as a holder for Malaysian tropical fruit such as local oranges. The material of the holder shall be having its permittivity closes to air permittivity to minimise the EM wave reflection.

Typical Malaysian local orange basically has a range of diameter between 5cm-7cm[1] and its peel thickness around 0.7 -1.3mm. The crop is planted in certain cities in Malaysia. It is known that this fruit is one of local produce that contributed for the high market value among the agricultural produce in Malaysia. Many research and investigation has been done towards varieties of fruits with many forms of methods, tools and equipment. Numerous methods have been developed among researchers in various years to investigate the internal and external fruit quality either destructively or non-destructively [2-7]. Some of the methods using Near Infra-Red Spectroscopy (NIRS), image processing, acoustic, capacitive sensing and microwave sensing techniques.

The Near Infra-Red Spectroscopy (NIRS) were reported to be one of the well-known methods to determine the sweetness level non-destructively. In fact, sweetness level can be also measured destructively by referring to its soluble solid content (SSC)[8]. However, by comparing both methods, the NIRS method has its drawback where it has

low individual correlations of dielectric properties with SSC and some drawbacks did reported in few researches [9].

Thus, in this paper, an idea on using microwave technique specifically using antenna monopole to classify sweetness level of Malaysian local oranges non-destructively is investigated. The idea was to examine the characteristics of oranges peel or skin, its relative permittivity in particular that can be related to its stages of maturity or sweetness.

II. BASIC PRINCIPLES

Dielectric properties of a biological material determine the interaction of the material with electromagnetic fields [10]. The relative permittivity, ϵ_r of a material is expressed in complex form as

$$\epsilon_r = \epsilon_r' - j\epsilon_r'' \quad (1)$$

where ϵ_r' and ϵ_r'' are the dielectric constant and loss factor, respectively. The dielectric constant, ϵ_r' is associated with the ability of a material to store energy in the electric field in the material. The loss factor, ϵ_r'' is mainly contributed by loss mechanisms and ionic conduction in the material. In connection with quality sensing in agricultural produce quality investigation i.e. fruit's quality determination, the dielectric properties of sample at certain frequencies were examined to observe these properties might be useful in distinguishing degree sweetness. Fundamentally, the reflection coefficient, Γ is related to relative permittivity, ϵ_r by the formula expressed as:

$$\Gamma = \frac{1 - \sqrt{\epsilon_r}}{1 + \sqrt{\epsilon_r}} \quad (2)$$

III. MATERIALS AND METHODS

The description in this section was separated into two division which is reflection coefficient measurement of air and local oranges using monopole sensor.

A. Reflection Coefficient (S_{11}) of Air Determination

The air measurement was carried out by connecting the sensor to CABANR54 reflectometer through a coaxial cable as in Fig.1. First, a full one-port calibration technique was implemented to the reflectometer using a commercial

Agilent 85052D 3.5 mm kits. The reflectometer was controlled by using personal PC.

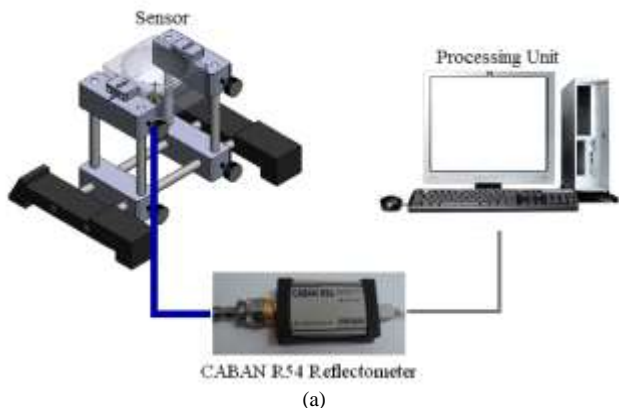


Figure 1. (a) Experiment setup. (b) Monopole sensor with nylon holder.

B. Reflection Coefficient (S_{11}) and °Brix Level Measurement of Orange Sample

The sample was measured from the second day the oranges were plucked out from the farm. Thirty (30) samples were gathered for this experiment. All oranges were kept in a controlled temperature of 24°C throughout the experiment and measurement. The weight of each samples were obtained for each day. The samples are then placed into the nylon holder so that the tip of monopole will touch the outer skin of local oranges as in Fig. 2(a) and the results of reflection coefficient were observed. Once the S_{11} is obtained, the sample was peeled and juice was extracted from each sample. Soluble solid content (SSC) that shows its °Brix was obtained thus indicate its glucose level. Once this is done, the remaining of oranges flesh including of its skin was put into a drying oven for moisture content (mc%) measurement. A 24-hour of 70°C drying oven was set for moisture content (%m.c) measurement. Apart from total moisture content, we were also looking at reduced moisture content (% reduced m.c) where it indicates the weight of water content in a sample reduced from day to a day and its relationship is obtained. The measurement was carried out from day 2 the samples obtained from local farm until day 14 as approximately consumable local oranges.



Figure 2. (a) Nylon holder filled with oranges sample (b) Measurement of reflection coefficient using monopole sensor and CABAN R54 Reflectometer

IV. RESULTS AND DISCUSSION

A. Reflection Coefficient (S_{11}) of Air Determination

The measurement was observed in two situations. The first situation is when no oranges is placed into the nylon holder and S_{11} of air is measured. The second situation is when a local orange is placed into the nylon bowl that will be discussed in later section. In both conditions, the S_{11} and resonance frequency were observed and analysed. The S_{11} of air was compared between simulation and measurement.

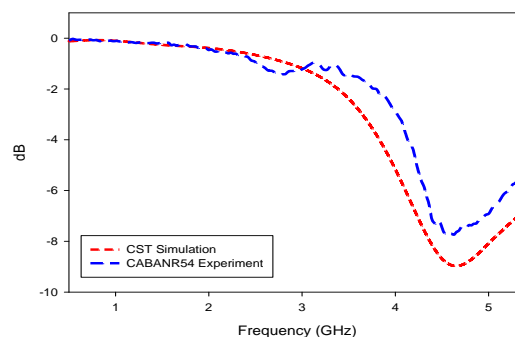


Figure 3. CABANR54 Measurement of S_{11} (dB) on air

From Fig.3, the simulation and measurement shows almost similar results where S_{11} falls at between -8 and -9dB at resonant frequency of 4.65 GHz.

B. Reflection Coefficient (S_{11}) and °Brix Level Measurement of Orange Sample

Figure 4(a),(b),(c) and (d) below shows the relationship between °Brix and its total moisture content (%m.c), °Brix and its reduced mc (°reduced m.c), °Brix and its S_{11} (dB) at resonance and °Brix and its S_{11} (dB) at 1.84 GHz respectively.

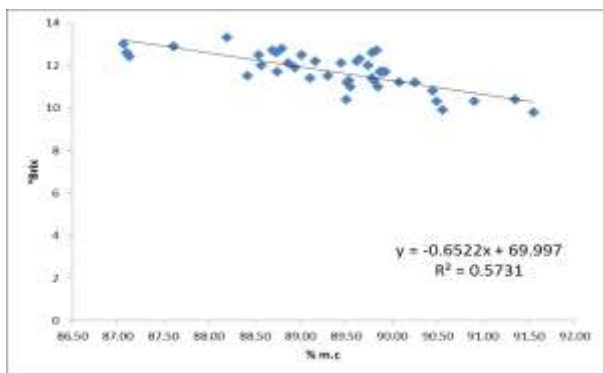


Figure 4 (a)

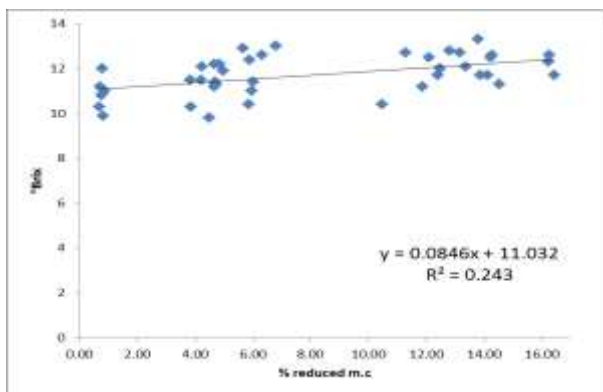


Figure 4 (b)

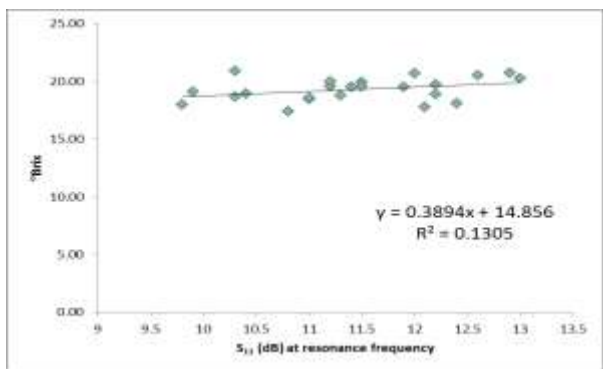


Figure 4 (c)

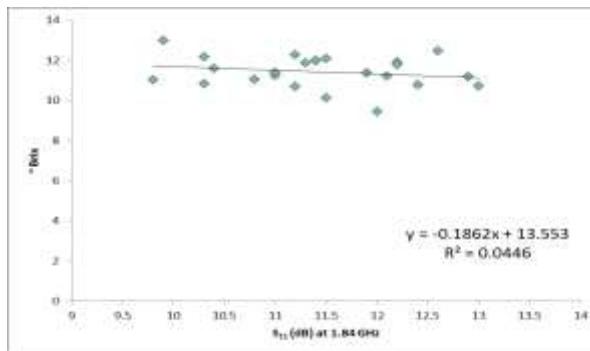


Figure 4 (d)

Linear regression model was obtained for various parameters shown below.

Regression on °Brix and %m.c:-
 $y = -0.6522x + 69.997$
 $R^2 = 0.5731$

Regression on °Brix and %reduced m.c:-
 $y = 0.0846x + 11.032$
 $R^2 = 0.243$

Regression on °Brix and S_{11} (in dB) at resonance:-
 $y = 0.3894x + 14.856$
 $R^2 = 0.1305$

Regression on °Brix and S_{11} (in dB) at 1.84 GHz:-
 $y = -0.1862x + 13.553$
 $R^2 = 0.0446$

V. CONCLUSION

Based on measuring fabrication system, it was ascertain that sweetness quality measurement was working properly where CST simulation and measurement using CABANR54 shows similar result.

The measuring system starting from day 2 until day 14 shall be able to quantify sweetness quality. This can be shown from the significant results of °Brix level versus moisture content (%m.c). The regression models on °Brix versus S_{11} at resonance and at 1.84 GHz were also obtained. Thus, the difference suggest that changes in S_{11} shows that the monopole sensor is able to quantify sweetness quality. However, works are continuing to unravel the significant frequency for this particular local oranges example by analyzing S_{11} at more frequency ranges.

REFERENCES

[1] R. K. K. Eng. (2013, January 2013) Food Security and Quality in Malaysia. *JURUTERA*.
 [2] N. Grimi, *et al.*, "Acoustic impulse response in apple tissues treated by pulsed electric field,"

- Biosystems Engineering*, vol. 105, pp. 266-272, 2010.
- [3] A. A. Ibrahim, "Development of A Non-Destructive Technique For Assessing Internal Quality of Sapodilla Fruit," Master of Science, Faculty of Engineering, UPM, 2001.
- [4] S. O. Nelson, "Dielectric properties of agricultural products-measurements and applications," *Electrical Insulation, IEEE Transactions on*, vol. 26, pp. 845-869, 1991.
- [5] Zulhusin, *et al.*, "Feasibility study of a non-destructive fruit maturity testing system on banana utilising capacitive properties," in *Electronic Design, 2008. ICED 2008. International Conference on*, 2008, pp. 1-4.
- [6] H. Dang, *et al.*, "A fruit size detecting and grading system based on image processing," 2010, pp. 83-86.
- [7] K. M. Juni, *et al.*, "Harum Manis Mango Dielectric Properties Based on Maturity," in *RF and Microwave Conference (RFM), 2011 IEEE Int. Conf.*, 2011, pp. 19-20.
- [8] 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, 2012/02/01 2012.
- [9] S. O. Nelson, *et al.*, "Sensing quality of watermelons through dielectric permittivity," in *Antennas and Propagation Society International Symposium, 2007 IEEE*, 2007, pp. 285-288.
- [10] S. O. Nelson, "Agricultural applications of dielectric measurements," *Dielectrics and Electrical Insulation, IEEE Transactions on*, vol. 13, pp. 688-702, 2006.