# A Study of Fruit Sweetness Monitoring with Reflection coefficient

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**Abstract** This paper proposes a non-destructive fruit sweetness monitoring method by using reflection coefficient. The reflection coefficient is obtained by collecting the reflected waves after the incident wave onto ripe and unripe fruit that is related to fruit sweetness. The fruit sweetness and the reflection coefficient were analyzed from scattering parameter by using network analyzer. The results depict the suitable operating frequency is in the range 2 to 3 GHz that there are apparent difference in reflection coefficient for fruit sweetness presented the possibility to design a simple sweetness monitoring system.

**Keyword** Fruit Sweetness, Non-Destructive Method, Free Space Method, Reflection Coefficient

## 1. INTRODUCTION

Fruits maturity level correlate sweetness that can be observed from peel color but some fruits are not show change in its peel color that is the difficult evaluation for mature fruit. The destructive and non-destructive methods are used for inspecting maturity level. The destructive method need to open fruit for checking pulp, sample is damage. Many studies presented fruit quality monitoring by using non-destructive method that is beneficial for grower, trader and buyer. Several methods for non-destructive method such as the acoustic method used voice from knocking [1]-[5], peel color analysis by image processing [6]-[10], visible and near-infrared method [11]-[13], etc. However, these methods use expensive device for evaluating the fruit maturity level. The microwave method has been proposed that is reflection measurement and used reflection coefficient for determining fruit sweetness. This paper presents fruit sweetness inspection with reflection coefficient for ripeness of fruit to estimate the suitable frequency for design fruit sweetness monitoring system.

## 2. PRINCIPLE

This work uses free space method for determining the reflection coefficient from reflected wave at various fruit sweetness. The measured scattering parameter was estimated in a wide range of frequencies for analyzing the correlation between reflection coefficient and sugar content (Brix). The principle of reflection measurement in free space for monitoring sweetness was used by transmitter and receiver at same position, an antenna is both transmitter and receiver, the distance between sample and antenna is far-field. The plane wave illuminated by transmitter and incidents on the sample surface and reflects from the inside and also sample surface.

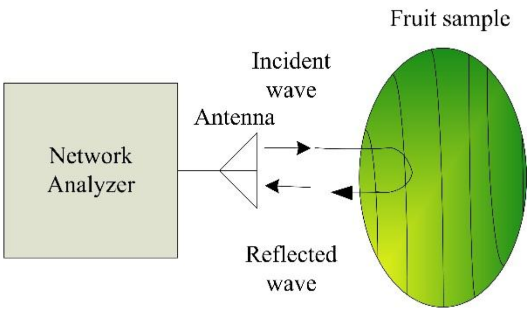



Fig. 1. Reflection measurement in free space.

The reflection coefficient was expressed in shown [14]. We can calculate reflection coefficient by using the measured results of watermelon [15] for monitoring correlation between reflection coefficient and sugar content. For example, the frequency is range 0.8 to 3 GHz, the peel of 7 mm, SSC: 7.1% and 9.6%, we found that the depth of penetration is range 25 to 40 mm and the magnitude of reflection coefficient of SSC: 7.1% and SSC: 9.6% are 0.76 and 0.78, respectively. The reflection coefficient of small sugar content is higher than high sugar content.

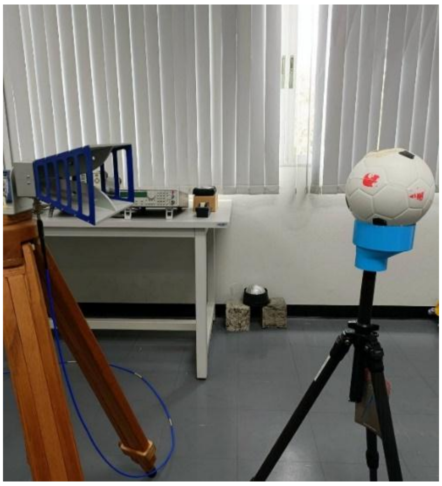
## 3. RESULTS

The samples of experiment consist of spherical plastic, watermelon and pineapple fruit were measured by using a Rohde & Schwarz ZVL network analyzer in the frequency range of 0.8 to 3 GHz with power of 10 dBm connected a HA-08M18G-NF horn antenna for sample measurement. The distance between a horn antenna and a sample surface is 60 cm and height is 120 cm. The calibration of reflection coefficient ($\Gamma$) was calculated from placing an aluminum plate on the sample surface, $\Gamma = S_{11}\text{measured}/S_{11}\text{aluminum}$.

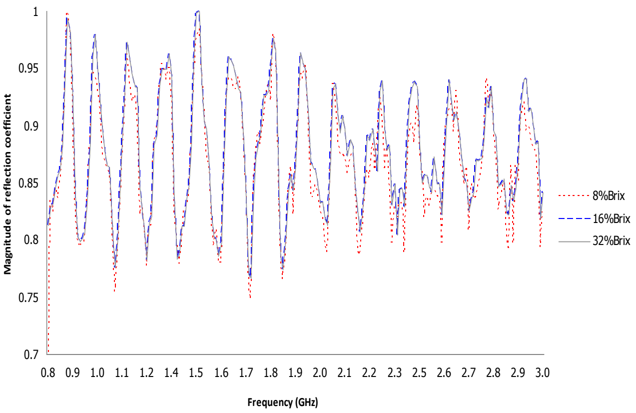
### *A. Spherical plastic*

The experimental setup is the sweetness definition to relate low sweetness, medium sweetness, and high sweetness that it relevant the reflection coefficient, fruit shape and frequency.

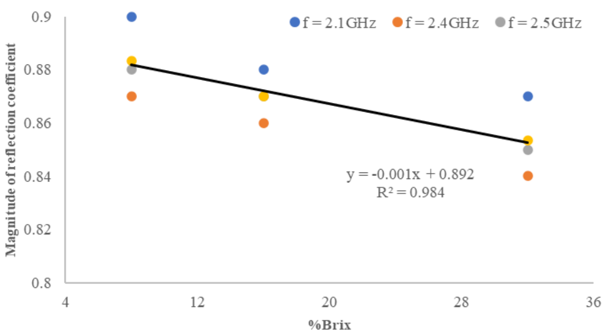
The sample size of spherical plastic is 18 cm and the plastic thickness of 1 mm that contains syrup at 8%, 16% and 32%Brix, respectively. The magnitude of reflection coefficient versus frequency is shown in Fig. 2.



(a)




(b)




(c)

Fig. 2. The reflection measurement of spherical plastic (a) the experimental setting (b) magnitude of reflection coefficient versus frequency (c) magnitude of reflection coefficient versus %Brix.

An apparent difference fluctuation of reflection coefficient is in the frequency range 2 to 3 GHz that the magnitude analysis is simple than phase for determining the different sugar content.

### *B. Watermelon fruit*

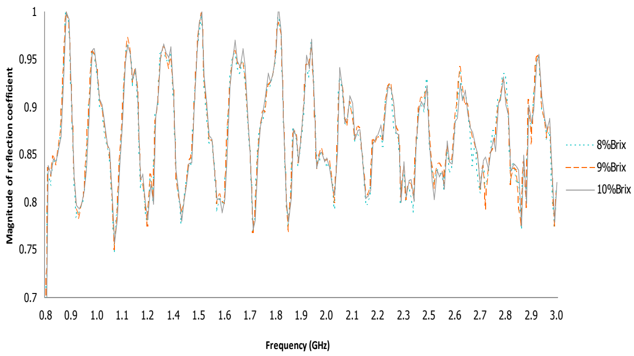
(a)

(b)

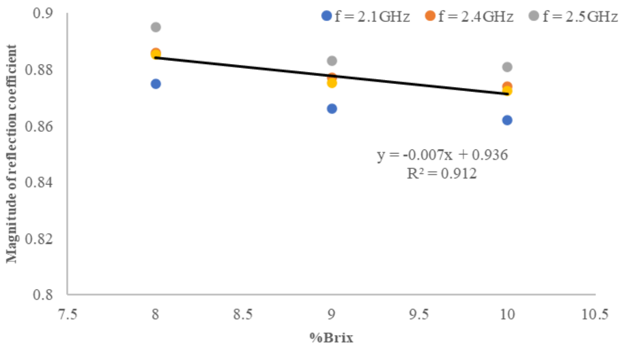
Fig. 3. Watermelon (a) the outer shape (b) the inner shape.

The watermelon samples in experiment are Kinnaree variety of 45 units as shown Fig.3. The sample size of 18 cm, the peel thickness of 7 mm and weight of 2 kg on average were used. The watermelon sweetness was determined at 8%, 9% and 10%Brix from OPTIK handheld refractometer B-32 for sugar content measurement. The measured results are shown in Fig. 4.

(a)




(b)




(c)

Fig. 4. The reflection measurement of watermelon (a) the experiment setting (b) the magnitude of reflection coefficient of watermelon versus frequency (c) the magnitude of reflection coefficient of watermelon versus %Brix

## *C. Pineapple fruit*

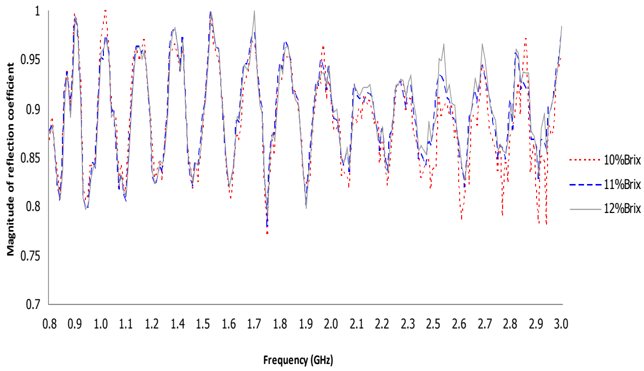
(a)

(b)

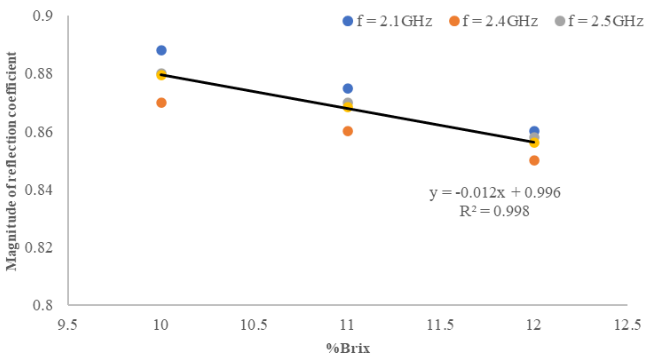
Fig. 5. Pineapple (a) the outer shape (b) the inner shape.

The pineapple samples in experiment are Patavia variety of 50 units as shown Fig. 5. The sample size of 16 cm, the peel thickness of 3 mm and weight of 1.5 kg on average were used. The pineapple sweetness was measured and determined as well as watermelon sample at 10%, 11% and 12%Brix, respectively. The correlation between magnitude of reflection coefficient and frequency are shown in Fig. 6.

(a)




(b)




(c)

Fig. 6. The reflection measurement of pineapple (a) the experimental setting (b) the magnitude of reflection coefficient of pineapple versus frequency (c) the magnitude of reflection coefficient of pineapple versus %Brix.

The resulted experiment found that the reflection coefficient varies frequency, peel thickness, sample size and Brix. The peel thickness increased (1 mm, 3 mm and 7 mm) and the Brix remained constant, it was found that the reflection coefficient remained unchanged. Another hand the sample size (16 cm to

18 cm) variation is cause reflection coefficients to change accordingly.

For sweetness monitoring, a small Brix level provides magnitude of reflection coefficient is higher than a high Brix level that according to instance calculation in [15]. The measured results of samples (spherical plastic of $R^2$ = 0.984, watermelon of $R^2$ = 0.912 and pineapple of $R^2$ = 0.998) indicated the apparent difference for magnitude of reflection coefficient (0.8 - 0.9 versus 8% - 32%Brix) in the suitable frequency at 2.1 GHz, 2.4 GHz and 2.5 GHz, respectively. Therefore, we can choose the suitable frequency for creating a tool to detect sweetness in fruits.

## 4. CONCLUSION

This paper presented the fruit sweetness monitoring by a non-destructive method from the reflection measurement in free space. The suitable operating frequency range has been demonstrated. The range of change at sugar levels 8% -32% Brix is different, which is clearly visible in the frequency range of 2 to 3 GHz (2.1 GHz, 2.4 GHz and 2.5 GHz) with a reflection coefficient of 0.8 - 0.9. This frequency range is interested to build a tool for checking fruit sweetness. An apparent difference in magnitude of reflection coefficient with sweetness presented feasibility to design only magnitude of reflection coefficient for fruit sweetness monitoring system.

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