Nondestructive Maturity Determination of Durian by Using Microwave Moisture Sensing

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Abstract

Since durian has specific properties, such as the thickness of peel, non-uniform shape, rough skin, etc., the nondestructive determination of the maturity is hard to perform. Microwave is high freqency wave which have better penetration than another lower frequency wave. This paper proposes a simple and inexpensive microwave technique by using the optimal open-ended coaxial probe operates at 3 GHz which matches to the design of coaxial probe and durian. In this experiment, 3GHz of microwave with low power gets the best response output. The system operates with network analyzer whose the magnitude of reflection coefficient shows linear correlation to moisture content of durian. The result of % moisture content is compared to % dry-weight of durian in oven. This nondestructive technique shows great promise for maturity determination of durian.

1. Introduction

Durian (Durio zibethinus Murray cv. Monthong) is one of commercial fruit in Thailand. It needs to know the stage of its maturity before exporting. Since durian has specific properties, such as the thickness of peel, non-uniform shape, rough skin, etc., the nondestructive determination of the maturity is hard to perform.

In quality determination of fruit, Ketsa and Dangkanit [1] presented the relation between the maturity and chemical compound of durian which is a destructive technique. Slaughter [2] used near infrared to determine chemical structure inside tomato and peach. However the infrared is not appropriate for the pericarp fruit. T.Anupun et. al [3] presented maturity determination of durian by knocking and then took its signal to analyze for determination of frequency response. But the result showed low accuracy because of non-linearization of knocking. W.Kongrattanaprasert et. al [4] presented nondestructive maturity determination of durian by force vibration and ultrasonic. However this method need the expert operator and high-cost of components.

Microwave is the electromagnetic wave with high frequency ranges from 300 MHz to 100 GHz which have better penetration than another lower frequency wave. In microwave measurement, there are two nondestructive techniques 1. free-space methods operating in the far-field region employing spot-focusing horn lens antennas (contactless) 2. waveguide methods operating in the near-field region which employ open-ended coaxial lines, rectangular waveguides, microstrip lines and cavity resonators as probes (close contact)

An open-ended coaxial probe has been used as an electromagnetic sensor for various industrial and scientific applications. [5]-[7] Most of these applications based on the principal that the signal reflected by the coaxial line which carry the desired information about the material. There are some advantages for these near-field microwave techniques The advantages of microwave technology over the other methods include

Measurement: Microwave can pass through the material for measuring because of good penetration of wave.

Calibration: microwave equipment is easy to calibrate, either using periodic gravimetric checks or a series of calibrated cells provided by the manufacturer.

Operation: microwave equipment is easy to operate and to locate at the correct process point. Modern data processing software enables full process control and statistical recording to be carried out at low cost.

This paper proposes a simple and low-cost microwave technique by using open-ended coaxial probe

2. Basic concept

The dielectric properties of most materials vary with several factors. In agricultural products, the amount of water in the materials is generally a diminant factor. The dielectric properties also depend on frequency of applied electric field, temperature, density, structure and chemical composition of materials.

Nature of durian, immature durian consists of pulp, peel and prinkle skin. When durian becomes mature, the chemical compound is changed such as moisture content, air cavity between pulp and peel. After durian are harvested, the moisture content inside the peel continuously decreased but moisture content in the pulp continuously increased by the time. From here, It can show that moisture content inside the peel is inversely correlated to moisture content inside the pulp. Since there are some differences in moisture content between mature and immature durian so this is the point that can separates these two classes.

2.1 Measurement and Expression of Bulk Moisture Percentages

Moisture percentage is usually expressed as the ratio of mass to dry mass i.e.

% (weight of water)/(dry weight of substrate)

This percentage is traditionally obtained by gravimetric methods ie weighing a sample of substrate, drying it out thoroughly and weighing it again. In this method the formula for the percentage moisture is obtained from:

Moisture Content = (W - D)/D x 100 percent

Where,
W = the initial weight and
D = the weight after complete drying

3. Measurement methods

An optimal open-ended coaxial probe is designed with an inner conductor of radius a , outer conductor of radius b , and a length of h above ground plane. It is shown in Fig.1. The reflection coefficient depends on the geometry of coaxial probe, ground plane, the operating frequency and the length of the designed probe [7].

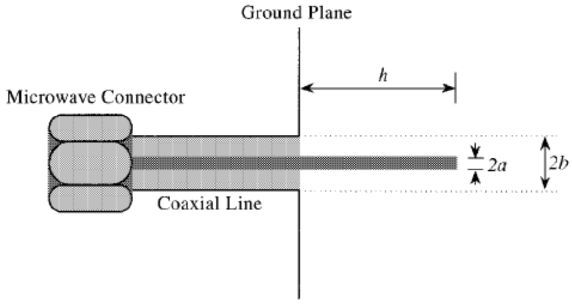

Fig. 1 An optimal open-ended coaxial probe

Due to the extensive used of open-ended coaxial probes in the measurement of biological substances, several probes model have been developed for dielectric properties calculation. For our experiment, we use the Misra-Blackham model which is described below

For the TEM propagation, Misra [9] has shown that the input admittance of probe (reflection coefficient) can be written as

$$Y = j\frac{k^2}{\pi k_c \ln(b/a)}\int_a^b\int_a^b\int_0^\pi \cos(\phi)\frac{\exp(-jkR)}{R}\,d\phi\,dr\,dr' \tag{1}$$

with

$$k = \omega\sqrt{\varepsilon^*\varepsilon_0\mu_0}$$
$$k_c = \omega\sqrt{\varepsilon_c\varepsilon_0\mu_0}$$
$$R = \sqrt{r^2 + r'^2 - 2rr'\cos(\phi)}$$

where ω is the angular frequency

ω_c is the permittivity of the dielectric material inside the probe

ε* is the complex permittivity of unknown material under test

By expanding the exponential term in the integrand into a Taylor series (1) can be approximated to

$$Y = j\frac{k^2}{\pi k_c \ln(b/a)}\left[j\left(I_1 - \frac{k^2 I_3}{2} + \frac{k^4 I_5}{24} - \frac{k^6 I_7}{720} + \cdots\right) + \left(I_2 k + \frac{k^3 I_4}{6} - \frac{k^5 I_6}{120} - \cdots\right)\right]$$

where

$$I_n = \int_a^b\int_a^b\int_0^\pi R^{n-2}\cos(\phi)\,d\phi\,dr\,dr' \qquad n = 1,2,3\cdots$$

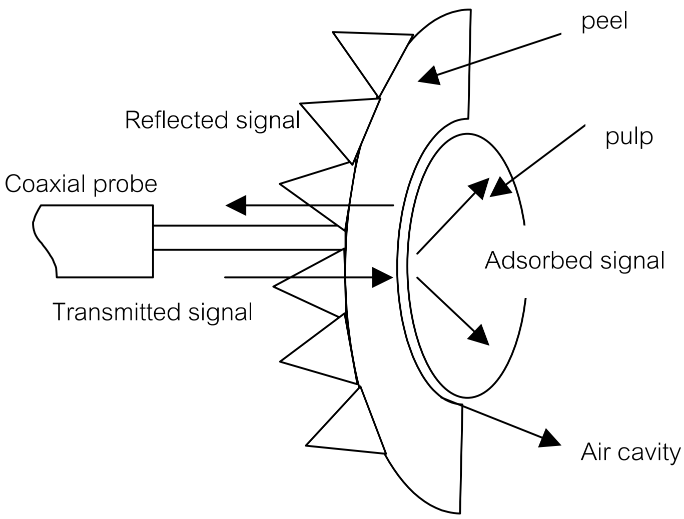

Fig . 2 Proposed system

In Fig. 2, microwave signal propagates to the layer of durian by passing throught the peel at the thinnest part, some signal reflected back to coaxial probe and another signal absorbed in the pulp due to the air cavity and pulp adsorption. The reflected signal is used to determine the reflection coefficient which is a related factor to moisture content

4.System

The system has been set up as in Fig.2, R3762A Network Analyzer connected to the R3961A S-Parameter Test Set for applying microwave signal. Coaxial probe is connected in port 2 (S_{22}) and contacting the probe tip to the region between prikles located at the middle of durian because this region is the thinnest part of the peel so microwave signal can penatrate to the pulp easier. In order to ensure a good contact with the probe tip, the smooth surface is selected for contacting of probe tip. In our experiment, coaxial probe comercial type is designed with h=5cm.,a=1.5mm.,b=4mm which gets the maximun output response at 3GHz.

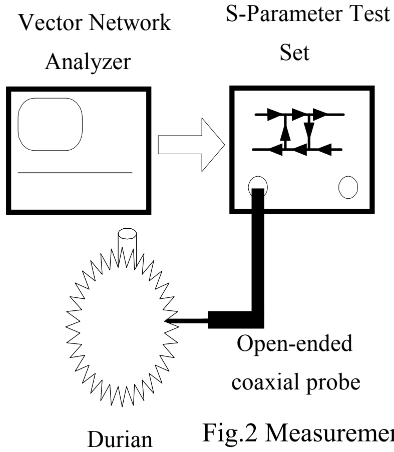

Fig.2 Measurement setup

4.1 Input signal selection

By varying frequencies from 2.5 GHz to 3.5 GHz, the results from the experiment indicated that the best magnitude of reflection coefficient response is obtained around 3 GHz. This frequency has shown to be optimal for determining moisture content in durian which has shown in Fig.3

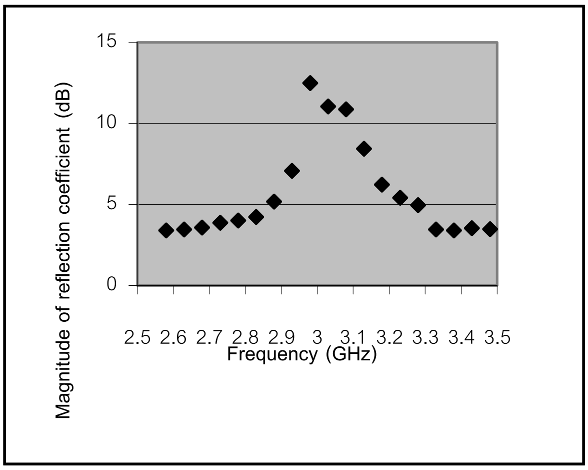

Fig.3 Magnitude of reflection coefficient versus applied frequencies from 2.5 GHz to 3.5GHz

4.2 Processing step

The durian samples are selected with standard exporting size (4-4.5 kg.) Firstly, measure the magnitude of reflection coefficient by contacting coaxial probe tip to the middle of durian peel, the room temperature is fixed at 28° C and then take 50 g. of durian pulp in the region that we have contacted the probe tip for moisure content determination in oven for 48 hours. Finally compared the results between magnitude of reflection coefficient with moisture content in oven

4.3 Dry-weight percentage determination

The dry-weight percentage which is proposed by Peerapong [8] has been used in our experiment. To classify two classes of durian (mature and Immature),30% of dry-weight is the indicator for classifying. If %dry-weight is less than 30% it will be immature and the other way round. In this experiment 50 g. of durian pulp is used to fume at 65° C for 48 hours, %dry-weight can be obtained from

$$\%\text{dry-weight} = \frac{W_{after}}{W_{before}} \times 100$$

Where W_{after} is the weight after fumming

W_{before} is the weight before fumming

5. Experimental results

The sample (Monthong) was taken from exported market with high quality 4-4.5 kg. weight. At our selected frequency (3 GHz), the magnitude of reflection coefficient related to the day after post harvested which has shown in the Fig.4

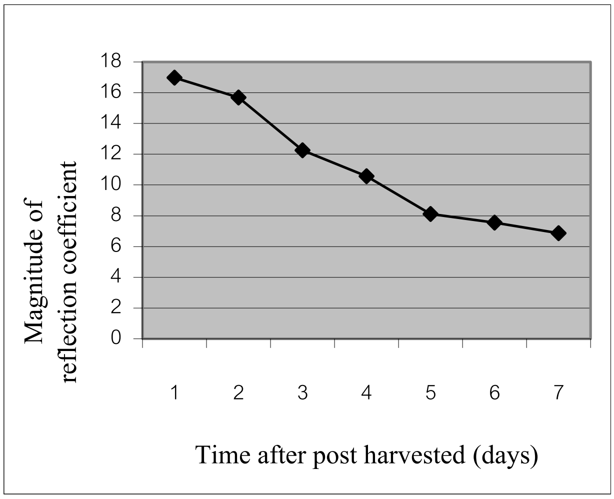

Fig.4 The relationship between moisture content of durian peel and the time after post harvested

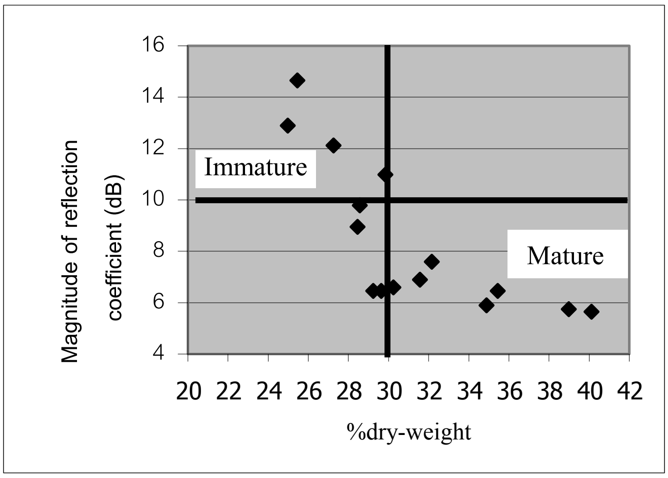

Fig.5 The maturity determination of durian by using |Γ| of durian peel at 3GHz compared with % dry-weight of durian pulp

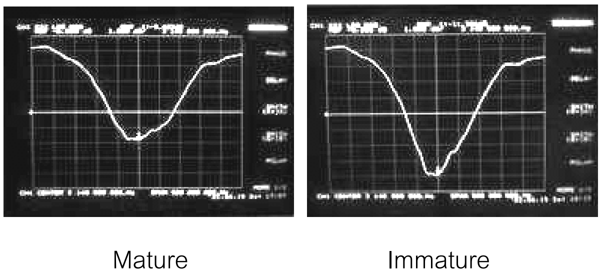

Fig.6 The result shows the difference of |Γ| output signal between two classes of durian by using network analyzer at 3 GHz

6.Discussion

The results from the experiment in Fig.4 show that the magnitude of reflection coefficient of durian peel inversely correlated to the number of time after post harvested because the moisture content of durian peel reduced as the moisture content in durian pulp increased when they changed from immature stage to mature stage. It knew by %dry-weight [8] as an standard consideration. From Fig.5, the maturity dertermination of durian is classified by comparing |Γ| and %dry-weight. In the experiment, we observed that above 10 dB of |Γ| and below 30%dry-weight, durians are immature and the other way round. But there are some error occurred at the opposite sides of the immature and mature graph region because of contacting area of the probe tip and thickness of peel. From Fig.6, showed that |Γ| of mature durian is 9.822dB and |Γ| of immature one is 11.906dB which can be classified by setting 10dB as an seperated point

7.Conclusion

This paper presented nondestructive maturity determination of durian by using microwave moisture sensing. The open-ended coaxial probe can provide the measurement of moisture content at microwave frequency. The results show that this technique can give an accurate measurement of moisture content inside durian at 3GHz and it can be used to predict the day after post harvested.

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