CAFEi2012 - 101

DETERMINATION OF MOISTURE CONTENT IN THE *DIOSCOREA HISPIDA* TUBER USING MICROWAVE METHOD

Mohamad Faiz Zainuddin[1], Zulkifly Abbas[2], Mardiah Hafizah Muhammad Hafizi[2],
Mohamad Ashry Jusoh[3], Mohd Hudzari Hj Razali[4]

[1]Department of Environmental Sciences, Faculty of Environmental Studies, Universiti Putra Malaysia, 43400 UPM Serdang, Selangor.
[2]Department of Physics, Faculty of Science, Universiti Putra Malaysia, 43400 UPM Serdang, Selangor.
[3]Faculty of Industrial Science and Technology, Universiti Malaysia Pahang, 26300 Gambang, Kuantan, Pahang.
[4]Department of Agriculture, Faculty of Agriculture and Biotechnology, Universiti Sultan Zainal Abidin (UniSZA), 20400 Kuala Terengganu, Terengganu.
Email: za@science.upm.edu.my

ABSTRACT

This study introduces an alternative method to determine percentage moisture content in a tuberous crop such as *diosocorea hispida* using microwave technique. Moisture content is an important parameter determining the quality of an agricultural product and their harvesting, transportation and storage processes. A microwave sensor was used in the study to penetrate deeper into the soft flesh of *dioscorea hispida* tuber sample. The reflection coefficient of the sensor was measured between 2 MHz and 4 GHz. The true percentage of moisture content of the sample was determined by the conventional oven drying method. The linear relationship between the conductance of the sensor and the true percentage of moisture content in the sample was determined. From the measured data, calibration equations relating conductance and percentage moisture content in the samples were established. The highest positive and negative correlations between conductance and percentage moisture content were found to be at 1.22 GHz and 3.94 GHz, respectively. The mean errors of the calibration equations at 1.22 GHz and 3.94 GHz are 10.80 and 6.95, respectively.

Keywords: *Dioscorea hispida, moisture content, monopole antenna, admittance, microwave.*

INTRODUCTION

Dioscorea Hispida Dennst or locally known as ubi gadong is one of the 1137 *dioscorea* species in the *dioscoreacea* family [1]. *D. hispida* is consumed by millions of people in the tropical and subtropical countries [2, 3]. In Malaysia, *D. hispida* can be found in abundance in Kelantan and Terengganu and usually serves as cakes and snacks. In addition to food products, the wild yam species can also be processed into chemical and pharmaceutical products [4]. However, the production of *D. hispida* into food and other products is currently confined to small scale cottage industry. In order to help farmers and producers increase their productivity, extensive researches are currently undergoing at the Faculty of Agriculture and Biotechnology, University of Sultan Zainal Abidin (UniSZA) to improve existing technology or identify new technology applicable to *D. hispida* industry [5, 6].

Moisture content is a very important parameter determining the quality of agricultural products and their storability, processing and marketability. Currently, oven drying methods is one of the most widely used methods to determine moisture content in agricultural products. Although this technique is accurate, it is both time consuming and destructive. Therefore, currently there is a great interest to develop an alternative method to this technique. The microwave method has been demonstrated to be an accurate, quick and reliable technique in determining moisture content in corn, oil palm and latex [7-12]. The objective of this study is to extend this technique to determine moisture content in the *D. hispida* tuber and potentially other tuberous crops such as potato, yam and cassava.

e-ISBN 978-967-960-322-4

MATERIALS AND METHODS

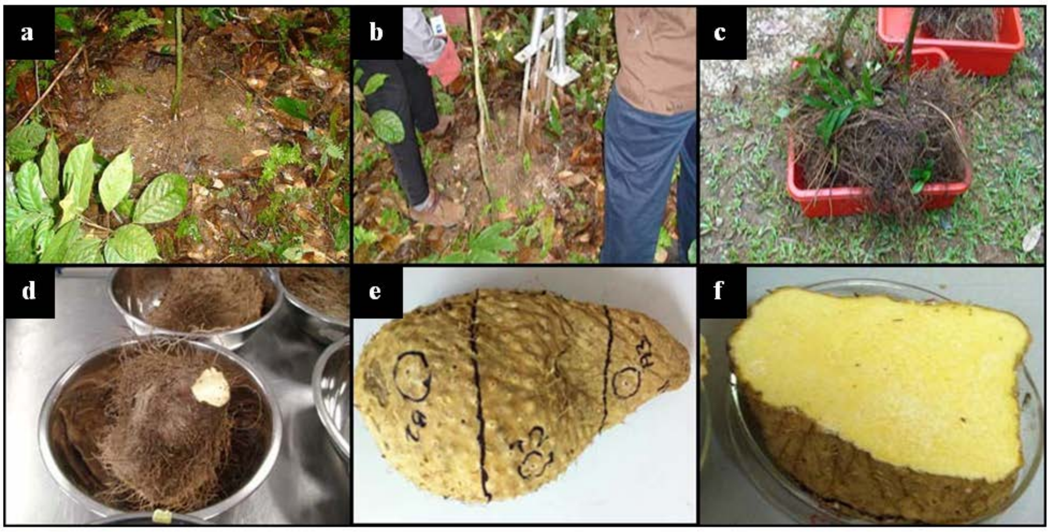

Fig. 1: (a) *D. hispida* plant before harvesting; (b) Harvesting *D. hispida* tuber ; (c) The *D. hispida* tuber after harvesting; (d) A single *D. hispida* tuber with roots and rootlets; (e) A single *D. hispida* tuber with roots and rootlets removed; (f) A 3 cm thick *D. hispida* tuber sample.

All *D. hispida* tuber samples were harvested and collected from Kampung Kudat, Ajil, Terengganu as shown in Fig. 1(a)-(c). A *D. hispida* tuber sample was prepared as shown in Fig. 1(e) and (f). Prior to drying, the sample was weighted using a weight balance.

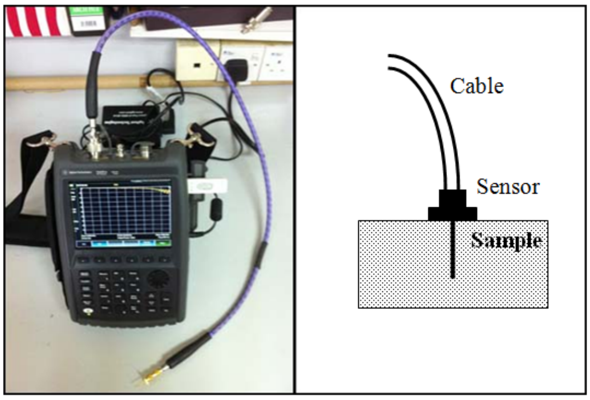

Fig. 2: The network analyser, 50-ohm cable and sensor (left). The schematic diagram of the experimental works (right).

Before measurement was made, the sensor was calibrated. The sensor was inserted into the sample as shown in Fig. 2. Then, the reflection coefficient of the sensor was measured using a network analyser. After that, the sample was heated for 70°C for three hours. Then, the sample was taken out from the oven and let cool to ambient temperature for at least two hours. The weight of the sample was then measured. Then the reflection coefficient measurement from the sample was taken. This process was repeated until there was no significant drop in the sample's weight. The percentage moisture content (*%MC*) in the sample is calculated as follows:

$$MC = \frac{m_{wet} - m_{dry}}{m_{wet}} \times 100\% \quad (1)$$

where m_{wet} the weight of the sample before each drying process
m_{dry} the final weight of the sample after drying was completed

RESULTS AND DISCUSSIONS

The impedance, *Z*, of the sensor can be calculated from measured reflection coefficient, Γ:

$$Z = Z_o\left(\frac{1+\Gamma}{1-\Gamma}\right) \quad (2)$$

where Z_o characteristic impedance of the cable, 50 Ohm

The admittance, *Y*, of the sensor is just the inverse of impedance. The conductance, *G*, is the real part of admittance as follows:

$$G = Re\left\{ \frac{1}{Z} \right\} \quad (3)$$

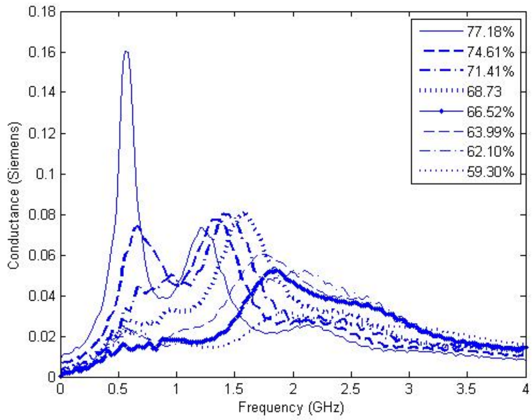

Fig. 3: The conductance of the sensor inserted in different %MC of *D. hispida* tuber sample.

The plot of conductance against frequency for different *%MC* of *D. hispda* tuber is shown in Fig. 3. Only measurements from 77.18 *%MC* to 59.30 *%MC* are shown in this plot. Below 59.30 *%MC*, the shape and the size of the sample are significantly changed due to loss of water. The thickness of the sample became less than 3 cm rendering it unsuitable for reflection coefficient measurement. From Fig. 3, it can be observed that the plot of *G* changes as *%MC* changes. The figure also shows that the plot of *G* is not consistent for all frequency. Therefore, it is important to perform statistical analysis to determine which frequency has the largest linear correlation between *G* and *%MC*.

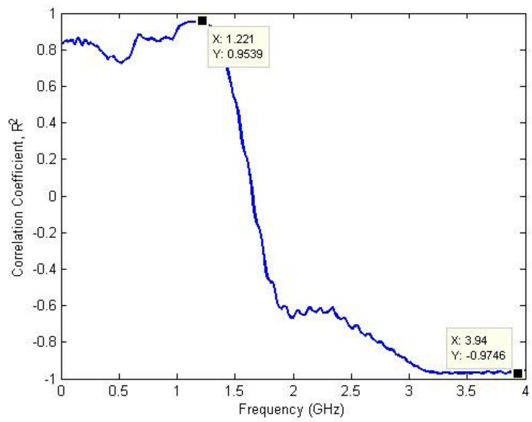

Fig. 4: The plot of correlation coefficient vs frequency.

e-ISBN 978-967-960-322-4

The plot in Fig. 4 shows that the correlation between G and *%MC* is positive between 2 MHz to approximately 1.64 GHz. This means that *G* increases as *%MC* increases which can be observed in Fig. 3. Between 1.64 GHz and 4 GHz, the correlation between *G* and *%MC* is negative. This means that *G* decreases as *%MC* increases which can also be observed in Fig. 3. The highest positive correlation coefficient, 0.9593, is at 1.22 GHz while the highest negative correlation coefficient, 0.9746, is at 3.94 GHz.

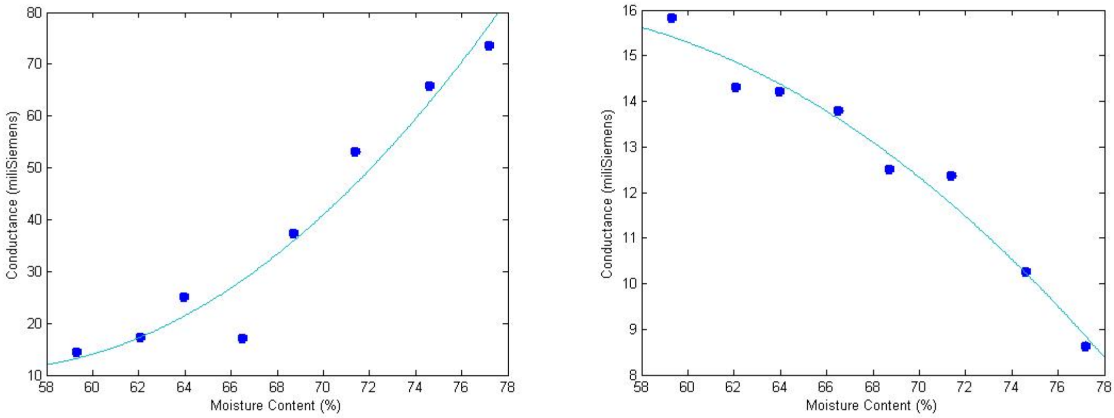

Fig. 5: The relationship between *G* and *%MC* at 1.22 GHz (left) and 3.94 GHz (right).

Table 1: Calibration equation of the sensor at 3.94 GHz

Frequency	Calibration equation
1.22 GHz	G(mS) = 0.14 * $\%MC^2$ – 15.48 * $\%MC$ + 439.68
3.94 GHz	G(mS) = -0.04 * $\%MC^2$ + 1.13 * $\%MC$ – 13.00

From measured data at 1.22 GHz and 3.94 GHz, two models describing the relationship between *G* and *%MC* were established as shown in Fig. 5 and Table 1. These models were validated with another set of measurement data as shown in Table 2 and 3. The error analysis is essential to test the accuracy of the models in predicting the actual *%MC* of the *D. hispida* tuber sample.

Table 2: Validation to the calibration equation at 1.22 GHz

%MC	Predicted *G*	Actual *G*	% error
77.18	77.53	74.28	4.19
74.61	62.79	76.74	22.22
71.41	47.02	56.85	20.91
68.73	36.01	42.34	17.59
66.52	28.44	26.79	5.81
63.99	21.46	22.11	3.02
62.10	17.41	17.26	0.83
59.30	13.24	14.81	11.82
		mean error	**10.80**

Table 3: Validation to the calibration equation at 3.94 GHz

%MC	Predicted *G*	Actual *G*	% error
77.18	8.85	8.71	1.60
74.61	10.23	9.26	9.45
71.41	11.74	10.66	9.17
68.73	12.83	12.40	3.33
66.52	13.61	13.95	2.51
63.99	14.37	15.20	5.77
62.10	14.85	16.89	13.74
59.30	15.41	13.87	10.02
		mean error	**6.95**

The error analysis to the models reveals that the mean errors of both models are greater than five percent. This implies that both models are not very accurate in predicting the actual *%MC* of *D. hispida* tuber sample based on *G* measurement of the sensor. More experimental works are necessary to improve the modeling and understand the relationship between *G* and *%MC* such as obtaining more measurements or using higher degree polynomial models.

CONCLUSIONS

This study demonstrated a rapid and minimally destructive technique to determine moisture content in *D. hispida* tuber which can be potentially used for other tuberous crops such as potato, yam, and cassava. The technique utilizes a monopole sensor inserted in the soft flesh of *D. hispida* tuber sample. A direct correlation was found between the conductance of the sensor and the percentage moisture content of the sample. Two models were developed based on the relationship between conductance and percentage moisture content. The accuracies of the models were tested with another set of measurement. Though the models are not accurate in predicting the actual moisture content of the sample, the objective of the study is still met.

ACKNOWLEDGEMENT

This work was financially supported by the Fundamental Research Grant Scheme (FRGS), the Terengganu State Economy Planning Unit (UPEN) and the Ministry of Higher Education (MOHE).

REFERENCES

[1] Mat, N., Tajuddin, S., Ngah, N. and Md Rejab, M. R. (2010) Dioscorea hispida dennst. (dioscoreacea): overview (pp. 12-13). Buletin UniSZA, Universiti Sultan Zainal Abidin, Terengganu, Malaysia.

[2] Hahn, S. K.. (1995) Yams: Dioscorea spp. (Dioscoreacea). In J. Smartt and N. W. Simmonds (Eds.), *Evolution of Crop Plants* (pp.112-120), Longman Scientific and Technical, UK.

[3] Udensi E. A., Oselebe H. O. and Iweala O. O. (2008) The Investigation of chemical composition and functional properties of water yam (Dioscorea Alata): Effect of varietal differences, *Pakistan Journal of Nutrition* (pp. 324-344), Asian Network for Scientific Information, Pakistan.

[4] Yam holds promise: Terengganu spending RM2.2 million on ubi gadong research (2009) The Star.

[5] Razali, M. H. H., Roslan, S., Mustafa, K. A., Zainuddin, M. F. and Abbas, Z. (2011) Development of non-destructive device for determination of alkoloid level in dioscorea hispida, *International Journal of Machine Intelligence* (pp. 181-186), Bioinfo Publications, India.

[6] Razali, M. H. H., Muhammad, H. H., Mohd, N. A. and Ismail, W. I. W. (2011) A review on farm mechanization and analysis aspect for dioscorea hispida, *Journal of Crop Science* (pp. 21-26), Bioinfo Publications, India.

[7] Abbas, Z., Yeow, Y. K., Shaari, A. H., Khalid, K., Hassan, J. and Saion, E. (2005) Complex permittivity and moisture measurements of oil palm fruits using an open-ended coaxial sensor. *IEEE Sensors Journal* (pp. 1281-1287).

[8] Jusoh, M. A., Abbas, Z., Hassan, J., Azmi, B. Z. and Ahmad, A. F. (2011) A simple procedure to determine complex permittivity of moist material using standard commercial coaxial sensor. *Measurement Science Review* (pp. 19-22), Versita ltd., London, UK.

[9] Yee, L. K., Abbas, Z., Jusoh, M. A., Yeow, Y. K., Meng, C.E. (2011) Determination of moisture content in oil palm fruits using a five-port reflectometer. *Sensors* (pp. 4073-4084), MDPI Publishing, Basel, Switzerland.

[10] Yeow, Y. K., Abbas, Z. and Khalid, K. (2010) Application of microwave moisture sensor for determination of oil palm fruit ripeness. *Measurement Science Review* (pp. 7-14), Versita ltd., London, UK.

[11] Ali, H. A., Abbas, Z., Hassan, J., Jusoh, A., Zahari, R. M. (2011) Microwave antenna sensing technique for determination of moisture content in hevea latex from hevea brasiliensis tree. *Australian Journal of Crop Science* (pp. 1326-1333), Southern Cross Publishing Group, Australia.

[12] Ansarudin, F., Abbas, Z., Ali, H. A., Ismail, M. A. (2012) Reflection technique for the determination of moisture content in hevea rubber latex. Proceedings, Progress in Electromagnetics Research Symposium, Kuala Lumpur.