A NEW RECTANGULAR DIELECTRIC WAVEGUIDE TECHNIQUE FOR RIPENESS DETERMINATION OF PALM FRUITS

By

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Thesis Submitted to the School of Graduates Studies, Universiti Putra Malaysia, in Fulfilment of the Requirements for Degree of Master of Science

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To My Family and Friends.

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirements for the degree of Master of Science

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October 2004

Chairman : Zulkifly Abbas, Ph.D.

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The thesis describes an investigation into the use of rectangular dielectric waveguide (RDWG) as a new technique for the determination of both complex permittivity and moisture content of oil palm fruits. The technique is analysed from the viewpoint of assessing its suitability as a simple, quick and flexible approach to permittivity and moisture measurements. An effective permittivity model is proposed where the rectangular dielectric waveguide/sample/rectangular dielectric waveguide interfaces are represented by a homogeneous medium with an effective permittivity obtained from the solution to the wave equation in the rectangular dielectric waveguide whilst the effective permittivity of the sample was found using a dielectric mixture model. The transmission and reflection coefficients are considered to be the effective values due to various interactions at the rectangular dielectric waveguide/sample/rectangular dielectric waveguide interfaces, which include both the radiation and guided modes. The measurement system consists of a HP8720B Vector Network Analyzer (VNA), rectangular dielectric waveguide, WR-90 standard waveguides and horn antennas. All microwave measurements were carried out using the VNA in the frequency range between 8 GHz and 12 GHz. A dielectric measurement software has been developed to control and retrieve data from the VNA using Agilent Visual Engineering

Environment Software. The actual moisture content was found by applying standard oven drying method. A calibration equation relating the measured return loss and actual moisture content was established. The sensitivity of the rectangular dielectric waveguide sensor at 10 GHz is 0.046 ± 0.002 dB/% moisture content. The complex permittivity of the fruit samples was calculated using two methods. In the first method, the permittivity was calculated by inserting predicted moisture content values from an empirical relationship between the return loss and moisture content in the oil palm fruits into a dielectric mixture model. The second method directly calculates both the moisture content and permittivity using an optimization routine. The accuracy of the technique for the determination of moisture content was tested on 500 different fruit samples and was found to be within ±5% of the mean moisture content value from the standard oven drying method. The rectangular dielectric waveguide technique can be used to monitor fruit ripeness based on the measurement of the magnitude of the reflection coefficient alone. Fruit bunch with return loss values between 4.4 and 4.7 dB are considered ripe.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Master Sains

TEKNIK BARU PANDUGELOMBANG SEGIEMPAT DIELEKTRIK UNTUK PENENTUAN KEMATANGAN BUAH KELAPA SAWIT

Oleh

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Tesis ini memperihalkan tentang kegunaan pandugelombang segiempat dielektrik (RDWG) sebagai satu teknik baru untuk menentukan ketelusan kompleks dan kelengasan buah kelapa sawit. Teknik ini dikaji dengan mengambil kira kesesuaiannya sebagai suatu teknik yang mudah, cepat dan fleksibel untuk mengukur ketelusan dan kelengasan. Satu model ketelusan berkesan dipaparkan di mana antaramuka pandugelombang segiempat dielektrik/sampel/pandugelombang segiempat dielektrik dianggap sebagai medium sejenis dengan ketelusan berkesan diperolehi daripada persamaan gelombang dalam pandugelombang segiempat dielektrik sementara ketelusan berkesan bagi sampel diperolehi daripada model campuran dielektrik. Pemalar pantulan dan penghantaran dianggap sebagai nilai berkesan akibat daripada beberapa interaksi terhadap antaramuka pandugelombang segiempat dielektrik/sampel/pandugelombang segiempat dielektrik, di mana melibatkan mod radiasi dan mod panduan. Sistem pengukuran terdiri daripada Rangkaian Penganalisis Vektor (VNA) HP8720B, pandugelombang segiempat dielektrik, pandugelombang dielektrik piawai WR-90 dan antena hon. Semua pengukuran gelombang mikro dilaksanakan dengan menggunakan VNA dalam julat frekuensi diantara 8 GHz dan 12 GHz. Satu perisian pengukuran dielektrik

dihasilkan untuk mengawal dan memperoleh data daripada VNA, iaitu dengan menggunakan perisian Agilent Visual Engineering Environment. Kelengasan sebenar buah kelapa sawit diperolehi dengan mengaplikasikan kaedah pengeringan ketuhar piawai. Persamaan kalibrasi yang mengaitkan kehilangan balikan yang diukur dengan kelengasan sebenar dihasilkan. Kesensitifan pengesan pandugelombang segiempat dielektrik pada 10 GHz ialah 0.046±0.002 dB / % kelengasan. Ketelusan kompleks bagi sampel buah dikira dengan menggunakan dua kaedah. Dalam kaedah pertama, ketelusan dikira dengan memasukkan kelengasan ramalan yang diperolehi daripada hubungan empirikal diantara kehilangan balikan dan kelengasan buah kelapa sawit, ke dalam model campuran dielektrik. Kaedah kedua pula mengira secara terus kelengasan dan ketelusan dengan menggunakan rutin pengoptimuman. Ketepatan teknik ini untuk menentukan kelengasan diuji ke atas 500 sampel buah yang berbeza dan didapati bahawa ianya tepat, dalam julat ±5% apabila dibandingkan dengan kaedah pengeringan ketuhar piawai. Teknik pandugelombang segiempat dielektrik boleh digunakan untuk memerhatikan tahap kematangan buah berdasarkan pengukuran pemalar pantulan sahaja. Tandan buah dengan kehilangan balikan diantara 4.4 dan 4.7 dB dianggap sudah matang.

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I certify that an Examination Committee met on 15th October 2004 to conduct the final examination of Roslina binti Mokhtar on her Master of Science thesis entitled "A New Rectangular Dielectric Waveguide Technique for Ripeness Determination of Palm Fruits" in accordance with Universiti Pertanian Malaysia (Higher Degree) Act 1980 and Universiti Pertanian Malaysia (Higher Degree) Regulations 1981. The Committee recommends that the candidate be awarded the relevant degree. Members of the Examination Committee are as follows:

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DECLARATION

I hereby declare that the thesis is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at UPM or other institutions.

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ROSLINA BINTI MOKHTAR

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