AN ULTRASONIC SYSTEM FOR MEASURING THE QUALITY OF BANANAS

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ABSTRACT

This thesis is about using ultrasonic technique to measure the quality of bananas by distinguishing the maturity stages of bananas. Ultrasonic waves which are propagated through banana specimens will be attenuated. The attenuation can be calculated and used to determine the maturity level of the bananas. Ultrasonic properties such as wave propagation velocity and attenuation were investigated when ultrasonic signals are transmitted through banana specimens. The objective of this research is to find the relationship between ultrasonic properties and the stages of banana maturity. The banana samples were tested from three categories standardized by the MARDI (Malaysian Agricultural Research and Development Institute). The three categories include Unripe, Ripe and Over-ripe. The samples were also tested for its firmness using a modified universal non-ferrous tester. The firmness and attenuation values are correlated. The pattern emerged is that the over-ripe bananas show more signal attenuation compared to the other two categories.

ABSTRAK

Kajian ini dijalankan untuk menentukan kualiti buah pisang dengan membezakan tahap kematangan buah menerusi kaedah perambatan gelombang ultrasonik melalui buah tersebut. Gelombang ultrasonik yang menembusi buah pisang akan mengalami pelemahan. Pelemahan kuasa pada gelombang boleh dikira dan digunakan untuk menentukan tahap kematangan buah pisang. Sifat-sifat fizikal gelombang ultrasonik seperti kelajuan gelomabang dan pelemahan dikaji apabila buah pisang dirambat dengan gelombang ultrasonik. Objektif kajian ini ialah untuk memperolehi perhubungan di antara kematangan buah pisang dan pelemahan kuasa gelombang ultrasonik yang dipancar melaluinya. Hubungan ini ditentukan dengan mengkorelasi parameter kekerasan isi buah pisang dengan pelemahan kuasa gelombang ultrasonic. Sampel buah pisang diambil mengikut tiga kateegori utama yang ditetatpkan oleh piawaian Institut Penyelidikan dan Pembangunan Pertanian Malaysia (MARDI) iaitu Belum masak, Masak dan Terlebih masak. Kekuatan isi buah pisang dari sampel-sampel ini diuji mennggunakan modified universal non-ferrous tester. Kekarasan isi buah dan pelemahan kuasa gelombang dikorelasi untuk memperolehi hubungan. Buah pisang yang terlebih masak mempunyai nilai pelemahan kuasa gelombang yang lebih tinggi dari dua kategori yang lain.

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A	-	attenuated amplitude
A_o	-	maximum amplitude
α	-	attenuation

LIST OF ABBREVIATIONS

UT	-	Ultrasonic Transducer
SSC	-	Soluble Solid Content
MARDI	-	Malaysian Agricultural Research and Development Institute

CHAPTER 1

INTRODUCTION

1.1 Research Background

Fruit quality measurements are essential to the fruit production industry. There are many types of quality measuring systems that are available to test the quality of various agricultural produce. These tests can be divided into two main categories which is the destructive type and the non-destructive type. Destructive types of testing system requires specimen to be destroyed. Chemical and firmness are usually tested by destructive methods. Non-destructive methods include infrared imaging and spectroscopy, ultrasound imaging and ultrasound wave analysis. Ultrasound waves beams directed to fruits at high frequencies (more than 20,000KHz) penetrate the skin and flesh and bounced back. The wave that is bounced back is attenuated. The attenuated waves can be used to analyze the quality of fruits. Quality parameter in most fruits are determined from the firmness of the flesh. Ultrasound technique has been developed in the 1970s to detect the quality of metal welded joints. Mizarach (1990), developed ultrasonic testing methods of plums and melons. Ultrasonic pulses are beamed through the fruits and the attenuated ultrasound signals are analyzed. The main concept behind ultrasound testing method is the attenuation of waves from the fruit tissues. Attenuation is related to the fruit firmness. Fruit firmness relates to fruit maturity. Fruit maturity relates to the quality of fruit. Mature fruits are ready to be sold or consumed. Fruit producers determine quality of fruits using various parameters such as skin colour and texture, firmness,

odour and contents. Both destructive and non-destructive methods are used to determine these parameters.

1.2 Background of the problem

Ultrasound waves beams directed to fruits at high frequencies (more than 20,000KHz) penetrate the skin (peel) and flesh and bounced back. The wave that is bounced back is attenuated. The attenuated waves can be used to analyze the quality of fruits. Quality parameter in most fruits are determined from the firmness of the flesh. The project proposed by Associate Professor Dr. Sallehuddin Ibrahim is developing Ultrasonic System for Measurement of Quality in Bananas. Currently ultrasound non- destructive testing has not been used in measuring the quality of bananas. Other techniques using near infrared spectrometry and wavelet image processing [1]. These methods are costly and require skilled personnel to use it. Associate Professor Dr. Sallehuddin proposes a development of a low-cost user friendly ultrasound non-destructive testing device to determine the quality of bananas.

Banana quality is measured by the firmness of its flesh. The most popular variety of bananas produced in Malaysia is the *Musa Cavendish* variety. Firmness in flesh is closely related to the maturity of the fruit. Fruit with firmness in the range of 0.4 kgf-0.7 kgf (kilogram force) are optimal to be eaten i.e. the quality is good. Frimness which is beyond that range shows that the banana is immature and not ready to be consumed. Firmness below that specified range is over-riped or the flesh of the fruit is starting to decay [2].

Based on those parameters, the ultrasound technique is developed for the measurement of quality in bananas.

1.3 Problem Statement

The demand for high quality fruits and vegetables by consumers worldwide has increased. Fast, efficient and cost effective quality control is needed to achieve this. Right now fruits are tested and discarded, expensive equipment set up needed by authorities to ensure quality of bananas. If fruit producers do not market quality fruits, they will lose market share. If they use expensive testing methods such as Near infra-red spectrometer. If fruit producers do not market quality fruits, they will lose market share. If they use expensive testing methods such as Near infra-red spectroscopy, they will incur high cost over-runs and make their products expensive. A low cost non- destructive ultrasound testing system is developed to solve the quality assurance issue of the agricultural produce.

1.4 Purpose and objective

The main purpose of this study is to develop a low cost non-destructive ultrasonic testing system to measure the quality of bananas. The objectives of this study is as follows :-

i. To establish a mathematical relationship between the firmness of banana flesh and wave attenuation.
ii. To design and develop ultrasonic system for the measurement of quality of bananas.
iii. To develop low cost non-destructive quality testing system using ultrasound for bananas.

1.5 Research scope

In accomplishing this research, the work has been divided into a few parts. As a beginning part, the literature review on the physical properties of the ultrasound waves. The second part is the method or techniques used to measure the quality of fruits using the ultrasound waves. The third part is analyzing the various quality parameters and establishing the right quality parameter to be measured and correlated to the wave attenuation. The final part is on designing a

low cost test device based on current technology. The scope of the research is to firstly establish a relationship between fruit firmness and ultrasound wave attenuation. Based on the relationship, we develop a model to test the quality of bananas. Secondly to design and develop an ultrasonic system to measure the quality of bananas.

1.6 Significance of research

Banana physiology properties can be studied by using ultrasonic wave penetration. Bananas with reduced or decaying flesh show reduced firmness. The firmness and attenuation values can be correlated to obtain a relationship. This relationship can later developed into an intelligent system where the testing is autonomous utilizing fuzzy logic schemes.

1.7 Thesis Outline

The dissertation is divided into several sections which illustrates the outline of the project. Each section is explained in details in order to give an overall idea of the project. The sections are as follows:

CHAPTER 1 Present the introduction, overview and objectives of the project

CHAPTER 2 Discuss the background theory of ultrasonic waves and banana physiology. This chapter includes information on research done by others on ultrasonic non-destructive testing on fruits.

CHAPTER 3 Describe and explain about methodology that has been used to complete this project. The discussions are concentrating about the circuit and testing method.

CHAPTER 4 Present the project result. This section covers the result and comments.

CHAPTER 5 Conclusions and Suggestions

REFERENCES

[1]Amos Mizrach, Uri Flitsanov, R.El-Batsri and C.Degani (1999)Determination of avocado maturity by ultrasonic attentuation measurement. *Scientia Horticulturae.* Volume 80 (3-4) 173-180.

[2]Amos Mirzach (2000). Determination of avocado and mango fruit properties by ultrasonic technique. *Ultrasonic.* Volume 38 (1-8) 717-722.

[3]Amos Mirzach, Uri Flitsanov (1990) .Nondestructive Ultrasonic Determination of avocado softening process. *Journal of Food Engineering*.(40)139-144.

[4]Amos Mirzach, Uri Flitsanov, Ze'ev Schmilovitch and Yoram Fuchs (1999). Determination of mango physiological indices by mechanical wave analysis. *Postharvest Biology and Technology*. Volume 16(2)179-186.

[5]Amos Mirzach (2004). Assessing plum fruit quality attributes with an ultrasonic method. *Food Research International Journal.* Volume 37(6)627-631.

[6]Sarah Schotte, Nele De Belie and Josse De Baerdemaeker (1999). Acoustic impulse-response technique for evaluation and modelling of tomato fruit. *Postharvest Biology and Technology*. Volume 17(2)105 –115.

[7]Suthawee Suwannarat, Thanate Khaorapapong and Mitchai Chongcheawchamnan (2011). Predicting Oil Content of fresh palm fruit using transmission mode ultrasonic technique. *World academy of science, engineering and technology.* (57) 859-862.

[8]R.C Chivers, Helen Russell and L.W.Anson (1995) Ultrasonic Studies of Preserved Peaches.*Ultrasonics.* Volume 33 (1) 75-77.

[9] Liew, C.Y. and Lau, C.Y. (2012). Determination of quality parameters in Cavendish banana during ripening by NIR spectroscopy. *International Food Research Journal*. Volume 19(2): 751-758.

[10]Noboru Muramatsu, Naoki Sakurai, Ryoichi Yamamoto, DonanldJ.Nevins, Toshio Takahara and Tatsushi Ogata (1997) Comparison of A Non-Destructive Acoustic Method with an Intrusive Method for Firmness Measurement of Kiwi Fruit. *Postharvest Biology and Technology*. Volume 12(3) 221-228.

[11]M.Nielsen and H.J. Martens (2006). Low Frequency Ultrasonic for Texture Measurement in Cooked Carrot. *Journal of Food Science.* Volume 62(6) 1167-1175.

[12]Amos Mizrach and Uri Flitsanov (1995). Ultrasonic Device for Avocado Shelf life Predicting and Maturity Detection. *Proc. Of The World Avocado Congress III*. Volume (1),300-306.

[13]Jayani Chandrapala, Christine Oliver, Sandra Kentish and Muthupandian Ashokumar (2012). Ultrasonics in food processing. *Ultrasonic Sonochemistry*. Volume 19 (5) 975-983.

[14]Padungsak Wanitchang, AnupunTerdwongworakul, Jaitip Wanitchang and Natrapee Nakawajana (2011). Non-destrutive Maturity Classification of Mango Based on Physical, Mechanical and Optical Properties. *Journal of Food Engineering.* Volume 105 (3)477-484.