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An Ultrasonic System for Determining Mango Physiological Properties

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***Abstract*—There is an increasing requirement for high quality fruits such as mango. Hence it is vital to have a fast, accurate and reliable method for measuring and monitoring the quality of fruit from the field to the consumer. This paper presents an investigation on the use of an ultrasonic measurement system for determining the quality of mango.**

***Keywords*—mango; physiology; sensor; ultrasound**

Introduction

Various methods have been invented to monitor and evaluate agricultural products quality [1]. Fruits are part of our everyday life and they have a high demand in the fresh market and food industry. Without the use of technology normally human beings evaluate fruits by combining their senses but human judgments are generally subjective and unreliable. Hence these evaluations can lead to distorted determination of the fruit quality. Thus there is an increased requirement for improved quality monitoring.

The increasing pattern in mango fruits export means that it is vital to have good, reliable and precise measurement methods to evaluate the quality and the maturity of this fruit [2]. There are few traditional methods utilized for measuring mango qualities. In the old days the farmers made use of a calendar where they would record the first day the plug of the mango begin to develop until it reached a point where it is ready for harvest.

Normally mango maturity is evaluated based on visualization of the mango skin. If some area of the mango skin becomes yellow, then, the mango is said to be matured. This method has a lot of risk as it relies totally on human perception and is not very accurate.

The common method utilized in measuring mango quality is by carrying out penetration test. In the penetration test the needle are inserted inside the mango and then the sample is obtained to evaluate the quality of mango.

The methods mentioned previously destroyed the mangos, takes a lot of time, cost a lot of money and complicated. As such, the market for high quality mangos is huge and demands a reliable, quick, non-destructive and non- invasive method for evaluating the maturity of mangos. The study of non-destructive technique in this project is based on ultrasonic sensor technology. Non-destructive techniques (NDT) do not harm mangoes, provide a real-time measurement, inexpensive, and do not take a lot of time. As such NDT can be used to measure the maturity of mangos.

Mango Physiological Properties

Mango is well-known for its excellent taste, nice fragrance and high nutrition. Mango is widely popular and is produced in nearly 90 countries [3]. The height of mango trees can reach up to 35–40 m tall, with a radius of 10 m. The trees have a long life span with some species still produced fruits even after 300 years. The taproot of mango can reach a depth of up to 6 m, with abundant, wide-spreading roots; the tree also sends down many anchor roots, which goes deep several meters of soil. The green foliages of mangos are evergreen, alternate, simple, 15–35 cm long, and 6–16 cm broad; when the leaves are young they are orange-pink, quickly changing to a dark, glossy red, then dark green as they mature. Production of the flowers are in the form of terminal panicles which are 10 to 40 cm long. Each flower is small and white in colour with five petals 5 to10 mm long, with a mild, sweet odor suggestive of lily of the valley. There are more than 400 types of mangoes in which many of which ripen in summer, while some give double crop. It takes mango three to six months to ripen [4].

When mango is ripe, it is the form of various sizes and colours. The colours of cultivars are yellow, orange, red, or green, and they have a single flat, oblong pit that can be fibrous or hairy on the surface, and which does not separate easily from the pulp. Mangoes which are ripe and unpeeled let off a unique resinous, nice smell. Inside the pit 1–2 mm thick is a thin lining covering a single seed, 4–7 cm long. The seed contains the plant embryo. Mangos have recalcitrant seeds and as such they cannot withstand they freezing and drying [5].

THE MEASUREMENT SYSTEM

Fig. 1 shows the block diagram of the non-destructive technique ultrasonic system used in this research. The block diagram contains six modules and they are a function generator, a signal generator, an ultrasonic sensor transmitter(40kHz), an ultrasonic sensor receiver (40kHz), signal conditioning and a digital oscilloscope.

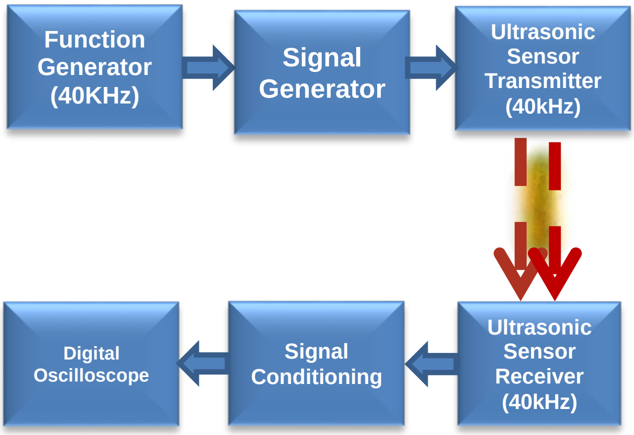

Fig. 1 Block diagram of the measurement system

The function generator provides a 40 kHz square wave with two types of supply voltages with amplitudes of 10V and 20V. The signal generator amplifies the signal from the function generator. The ultrasonic transmitter transmits the square wave into the mango and this signal is received by the ultrasonic receiver. The signal conditioning then amplifies and filters the received signal which is then displayed on a digital oscilloscope.

The relationship between the transmitted and the received ultrasonic signal is as follows:

$$A = A_0 e^{-\alpha d} \quad (1)$$

where

A = amplitude of the transmitted signal,

A_0 = amplitude of the received signal,

d = distance between transmitter and receiver,

α = attenuation coefficient.

In order to determine the ultrasonic equation coefficient, α, the following equation is used:

$$\alpha = \frac{1}{d}\left[\lambda n \frac{A}{A_0}\right] \quad (2)$$

The attenuation coefficient contains data on the attenuated reflection on the surface of the material as well as the attenuation caused by absorption and scattering in material throughout the thickness [6]. In order to minimize the error caused by the surface, the specimen is placed parallel and perpendicular with the transducers.

Several experiments were conducted to observe the effect of propagating ultrasonic waves into mangoes. Five samples of mangoes were selected and they were measured ten times with voltage amplitudes of 10V and 20V. These measurements were repeated until the eleventh day i.e. when the mangoes became rotten. The mangoes were placed between the transmitter and receiver which are 8 cm apart. Every day values of attenuation coefficients were recorded and the average values were noted.

RESULTS AND DISCUSSION

Fig. 2 shows the graph representing the result of attenuation versus time (days) carried out on one of the mango samples. During the unripe stage, the attenuation changed only slightly. It steadily increased during the ripe and rotten stage. The trends are numerically and graphically analyzed using curve fitting procedures. A quadratic expression or a second-order polynomial was shown to be a good fit to the changes in attenuation which represents the relationship between the attenuation in the ultrasonic signals and time. A simple curve fitting for the experimental results defined constants for the parabolic function.

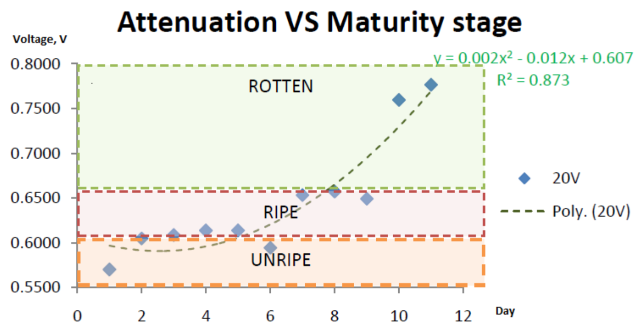

Fig. 2 Graph of attenuation versus maturity stage

Fig. 3 shows the graph of total sugar in mangoes versus the number of days. The graph shows that when the mangoes are not ripe, there is very little fluctuations but when the mangoes becomes ripe and rotten, the graph shows an increase. The graph shows that a perfect fit (R^2 = 1) was obtained. The trend in attenuation is similar to the trend in total sugar. The graphs show that the total sugar and attenuation are time dependent.

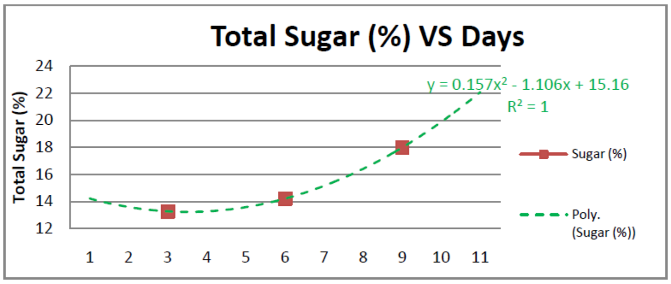

Fig. 3 Graph of total sugar (%) versus number of days

Fig. 4 shows the graph of attenuation coefficient plotted agins the number of days which shows a trend similar to the previous two graphs. However the curve does not have a good fit compared to the previous two graphs.

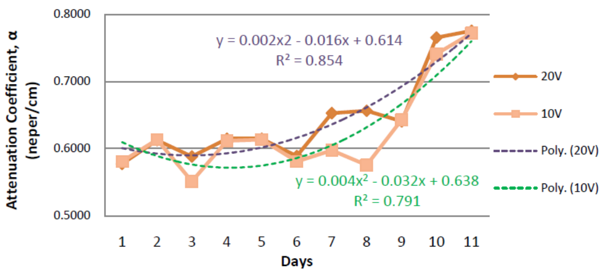

Fig . 4 Graph of attenuation coefficient versus number of days

The fluctuations in acoustic properties can be related to density fluctuations in mango [4]. The changes in the attenuation is due to the ripening process of mango fruit which involved a series of biochemical reactions or metabolic activities that cause chemical changes, increased respiration, ethylene production, change in structural polysaccharides causing softening, degradation of chlorophyll develops pigments by carotenoids biosynthesis, changes in carbohydrates or starch conversion into sugars, organic acids, lipids, phenolics and volatile compounds, thus leading to ripening of fruit with softening of texture to acceptable quality [5].

Conclusions

High quality fresh fruits and vegetables are vital in the agricultural industry. As such it is important to identify the optimal fruit maturity and control of fruit when it ripens and softens. This is because fruit undergoes fluctuations in the composition of sugar, acidity and firmness. These fluctuations must be monitored in order to save cost and to obtain high quality fruits The development of a nondestructive ultrasonic system to monitor the changes in **mango** provide a noninvasive, low cost, simple, rapid and effective way of assessing the quality of fruits. This investigation shows that there is a relationship between the ultrasonic attenuation coefficient as well as phase shift and changes in the physiological parameters of fruits.

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