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Application of Acoustic Properties in Non – Destructive Quality Evaluation of Agricultural Products

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ABSTRACT

Recently a large number of tests and experiments have been done to evaluate the effects of their impact on agricultural products using high techniques like, vibration (acoustic, ultrasonic and sonic response).Some modification methods have been applied to impact probe and signal conditioning to improve the firmness prediction performance and reduce the potential for bruising. The inspection of quality and maturity are important to resist impact damage and bruises of agricultural products. The Magness Talor Firmness is a destructive device and used in post harvest while for non-destructive tests we used (optical , magnetic response and ultrasonic) techniques> There are several technological areas for measuring agricultural products and their properties of quality such as, Image processing:; Visible and Infrared Light Energies, Nuclear Magnetic Resonance and Mechanical Simulation. The free fall device is used to separate different maturity levels of papaya. The Nuclear Magnetic Resonance is device used to perform constituent analyses of agricultural products. The acceleration of mass during impact indicates the firmness of fruits, the large acceleration indicates a harder fruits and the small acceleration indicates a softer fruits. To measure firmness of spherical fruits the impulse response method is used. In this method impacting hammer to fruits and exciting the response signal is captured using a microphone and viberation response is analyzed which is related to the firmness. The method of impact force response is used for firmness detection measurement based on sonic and ultrasonic method for Non-destructive measurements of internal quality of agricultural products. To determine some basic acoustic properties a low frequency (50kHZz) ultrasonic excitation is used. Non-destructive techniques for measuring textural quality of apples and watermelons are based on the acoustic response of the fruits. Computer software has been developed to determine the first resonant frequency.

Keywords: *Agricultural products, acoustic response, ultrasonic response, firmness, impact, and maturity*

I. INTRODUCTION

During the past decade the inspection of impact quality and maturity for fruits and vegetables using different techniques method and devices have become the focus of extremely intensive research because the quality, maturity and firmness are more important parameters to resist the impact damage and bruises of fruits and vegetables. Abbott et al (1968), Galili et al (1998) developed several techniques and methodology to measure firmness; the most popular destructive test device is the Magness Taylor firmness tester used in post -harvest storage application and for nondestructive tests (optical, magnetic resonance and ultrasonic). Chen et al (1989) M C carthy et al (1989), indicated in recent research, nuclear magnetic resonance response (NMR) was investigated as mean to determine the internal quality of fruits and vegetables including water composition, oil content and sugar contents .There are several technological areas which were identified for stations to investigate sensor quantitatively to measure properties indicative of quality, the identified were image processing measurement using light (visible and near infrared) X-Ray mechanical, Acoustic and elector-magnetic (NMR) energies.

II. MEASUREMENT OF FRUIT AND VEGETABLE PROPERTIES QUALITY

There are several technological areas identified for stations to investigate for sensor that quantitatively measure properties indicative of quality as follows:

1) Image processing, many stations adapted and for developed software to analysis visible and near infrared images and other multidimensional sensing data from fruits and vegetables.
2) Visible and infrared light energies much of the inspection and vegetables is done by human with

advantages and disadvantages the spectral characteristics of quality parameters have been used to improve detection of defect (different between quality) by assertive devices (colors block, improved lighting) or by automating the process (electronic imaging systems).

3) Nuclear Magnetic Resonance, (NMR) techniques were developed for determining oil content in avocados, sugar contents in fresh prunes, presence of pits in cherries and tissue breakdown in melons (CA).
4) Mechanical stimulation. Abbot et al (1997), indicated the a actual and perceived quality of fruits and vegetables dependent on the mechanical characteristics use the PC portable controlled firmness tester for fruits destructive and nondestructive measurements of fruits quality has been a primary and widely established research objective. Also Chen et al (1996), reported that there are many different techniques, which have been developed and applied to create sensors to measure quality parameters as well as subsequent mathematical modes to predict quality evolution. Velero, et al. (2000) Obtained that The proposed quality controlled systems, structured in two control processes combines these of selected electronic measurement devices, statistical procedures and computer and obtain in a rigorous control of fruit center, and all the quality tests and inspections should be controlled by mean of computer, which will be responsible for the storage of the gathered data.

Measurement of maturity

Several stations will emphasize the development of techniques to be better predicting maturity and shelf life of fruits and vegetable, the firmness is often used for estimating maturity of fruits and vegetables. Sam NRRP (1997), developed the free fall impact device (CA) was use to separate different maturity levels of papaya. Cho et al (1993) Stroshine et al (1994) Indicated the Nuclear magnetic Resonance (NMR) is being used to perform constituent analysis of fruits and vegetables, particularly soluble solids and oil contents and maturity, the tests was performed on fresh, ripe, over - ripe apples of unknown ripeness. ASTEQ Newsletters (2000) reported that Some apples were weighed to calculated the stiffness factor from the mass and natural frequency and result which was obtained, the natural frequency it self is not adequate to classify the ripeness of the apples, with the calculated stiffness of the measured apples, only two classes fresh or ripe and “over-rope” were recognized, no correlation was found between non-destructive tests.

Measurement of firmness

Paleg Kalman (1997) he examined that the techniques for measuring the firmness in order to establish their ripeness or maturity stage, obtained firmness by feeding the obtained signal after deducting the impact signal from the out put signal to computer means and obtain the firmness index by the quoting of the root mean square of the out put acceleration signal divided by the root mean square of the relative acceleration signal, also the firmness is pentrometer which records the force required to puncture the flesh with a cylindrical tip of fixed diameter , were the pentrometer is subjected to variation caused by fruits characteristics and operator response. Michael, et al (1991) reported that the acceleration of the mass during impact indicates the firmness of the fruits large accelerations correspond to hard fruits while small accelerations indicate softer fruit, show in fig , He also conducted research to development of a prototype system to sort fruit by flesh firmness and signal conditioning improve the firmness production performance and reduce the potential for bruising. The probe impact mass changed to machine aluminum surface to reduce contact stress during impact. Michael, et al (1991) indicated that the improvement orientation an alignment chute was formed from a selection of plastic pipe, cut in half a long it is length, and placed between the feed belt and the alignment belt shown as fig: 2, The sliding friction was reduced by covering the chute with telfon (30 mil) and applying water to the upper surface with a atogger nozzle. Also tests were run on stationary and moving pears (static and dynamic tests) with firmness uniformly distributed in the range of 3 - 20 Ibs. The static results are shown in fig: 3a and 3b.

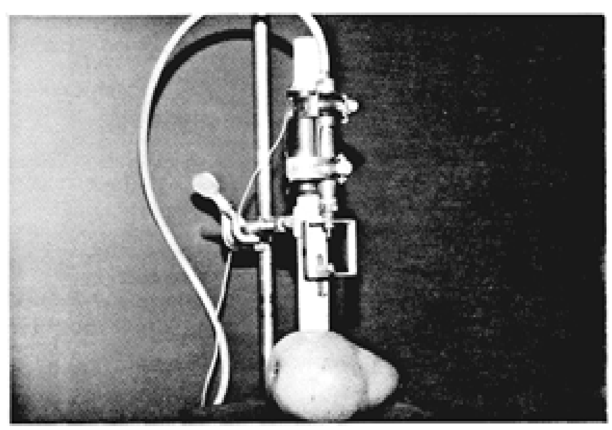

Figure 1: A photograph of the impact probe with the impact mass in the return position

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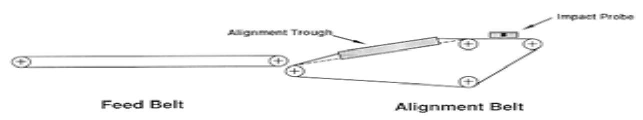

Figure 2: A side-view of the prototype handling system, with fruit flow from left to right

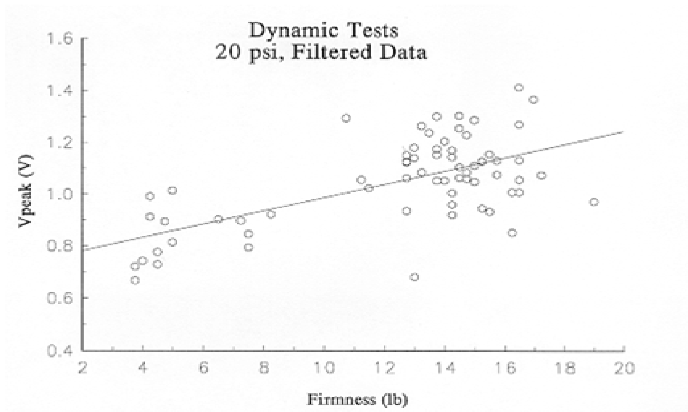

Figure 3: A Impact tests to pears moving through handling system with air pressure 20 psi

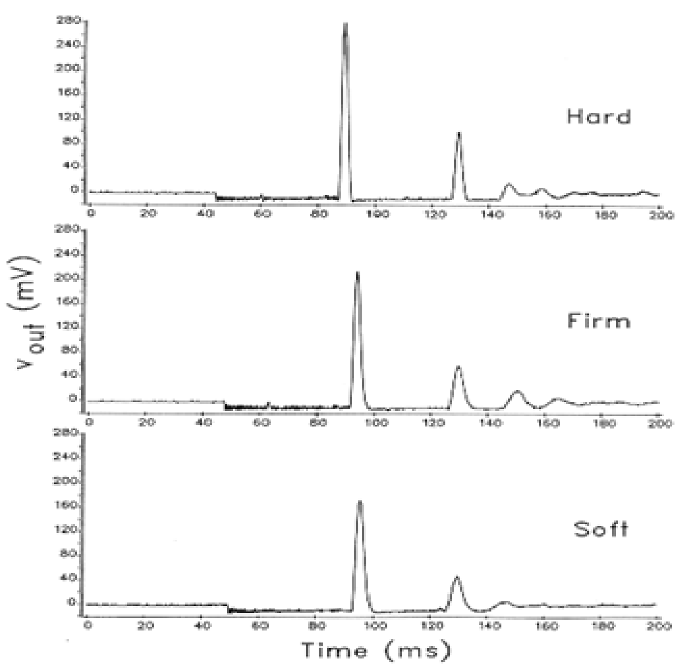

Figure 3: b Impact probe out put for hard (f=84.5N) firm (f=50.0N) and soft (f=13.3) pears

Nissim, et al. (1995) reported that the quality of fruits is a combination of numerous parameters such as firmness, total soluble solids (TSS) acidity, aroma, color, color uniformity, bruises, scars cut, presence of soil, size shape, insector or disease. A system has been developed to classified fruits based upon several of these parameters by using multi- sensors data a acquisition (vision firmness, small and weight) .A software was developed to determine melon size and quality parameters, techniques were developed and implemented to determine melon texture and to locate bruises by using sensor fusion system includes multivariate statistical methods . Valero, et al (2000) used La-Magness-TaylorPentrometer device to measure the firmness of hard fruits (apple) and Darometer for soft fruits (peach, tomatoes). Reid. (1995) reported that the numbers of physical properties are used to quantify the maturity of fruits at or near harvest, including size, shape, color, (internal and external) flesh textures and internal composition (sugar, starch, acid, oil etc). Chodhury et al (1995) used the finite element modeling techniques to simulate bruising due to quasi - static loading and resonant vibration as affected by materials properties. Jancsok, et al (2001) indicated that to measure firmness of spherical fruits by the impulse response method, by impacting hammer fruits and excited and the response signal is captured using an microphone. This vibration response signal is analysis and related to the firmness of the fruits. De Kaerdeemaeker et al, (2000) resulted that tomato vibration analysis after automatically impacts and capture the response; the resonance frequency of the first elliptical mode of the tomatoes is related to its firmness. Flitsanov, et al (2000) found that the tests of nondestructive ultrasonic and destructive penetration measurements were carried to determine the attenuation and tissue firmness and the ultrasonic attenuation there is good correlation between the firmness and the ultrasonic attenuation and it depend upon the storage time temperature history. Abbott et al, (1976) reported that the firmness is commonly measured by hand - held pentrometer as the force required to puncture exposed fruit flesh. Abbott et al, (1984) also have found the relationship to consumers' perceptions of texture. Delwiche et al, (1987) used impact force response as a method for firmness detection measurement techniques based on sonic and ultrasonic transmission, force /detection, and vibrational response have also been reported, signal processing representative data record for hard, firm and soft pears are shown fig. 4. Delwiche et al, (1991) developed a probe impact sensor for measuring the impact characteristics of various fruits and predicting texture, the sensor was operated by using air cylinder which released and returned an impact mass in the probe body, shown in fig. 5.

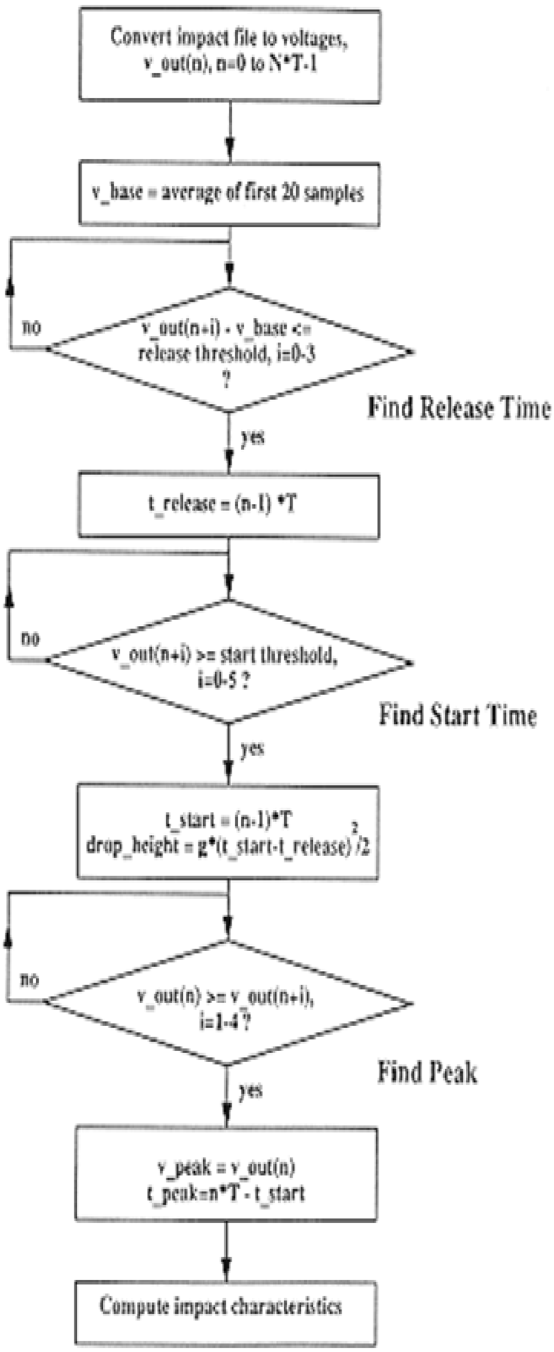

Figure 4: Signal processing algorithm to compute the Impact shape characteristics

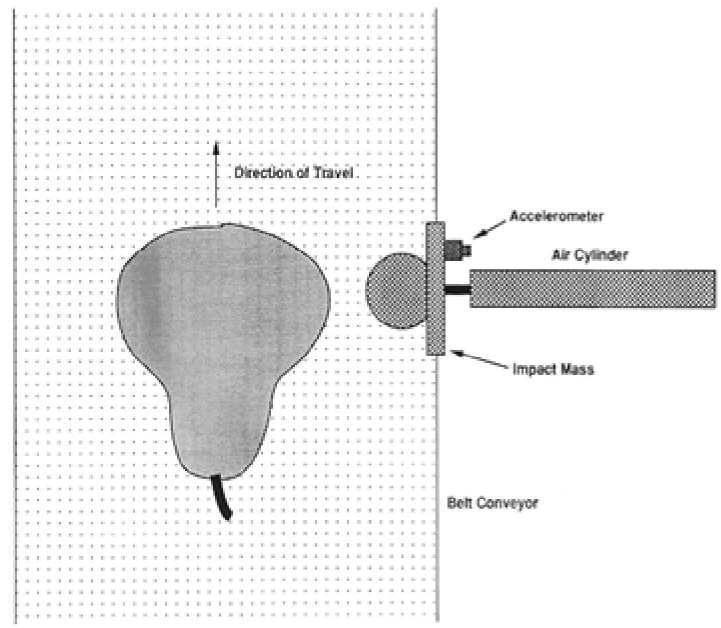

Figure 5: A top –view of the modified impact probe mounted on a belt conveyor

Measurements of Ultrasonic

Mizrach, et al (2000) reported that the nondestructive ultrasonic measurement system was depended for the assessment of same transmission parameters which might have quantitative relation with the maturity, firmness and other quality - related properties of avocado and mango fruit. Also they found that the attenuation of the ultrasonic waves transmitted through the fruits tissue changes as a result of the ripening and softening of the fruit during storage Cheng Ap (2000) reported that, when modeling and experimental analysis on the vibrations of agricultural products of ellipsoidal shape such as water melon and cantaloupe and different vibration characteristics are expected. The result was reveal that the vibrations ellipsoidal fruits are more complicated and also different from those of spherical ones. Barrachina, et al (2000) indicated that the mechanical stress can be observed in fruits when they are expressed to compression, impact and /or vibration during handling and lines there is some evidence to support the hypothesis that (PAS) plant polyamines could also playas important role in this stress. When the system implementing an ultrasonic method for nondestructive measurements of internal quality of fruits and vegetables was tested by pair of ultrasonic transducers, one acts as transmitted and the other as a receiver for some transmission of sound wave through the fruits peel and flesh and the reception of the transient signal. The result indicated as follows:

1) It was necessary to choose appropriate range of data generally between 15 to 25 force units.
2) Linear regression was applied for this range.
3) Promising correlations were observed between ultrasound response and firmness.

Jancsok, et al, (1998) reported that the length/diameter L/D ratio of the fruit has a linear effect at the oblate - prolate modes and large quadratic effect at bending and compression modes on the resonance frequency increases when the young's modules increases. Sarkar and wolf (1983) conducted an investigation to assess the potential of ultrasonic techniques for quality evaluation of fresh and processed foods. They found that ultrasonic transmission could be used to evaluate the stability of reconstituted orange juice, reflectance measurements could be used to characterize orange skin texture, and a back-scatter technique could be used to detect cracks in tomatoes. However, they also found that the attenuation coefficient measurements of potato, cantaloupe, and apple tissues showed extremely high values with in the frequency range of 0.5 to 1.0 MHZ. Similar results were found by Upchurch et al (1987) who tried unsuccessfully to use 1MHZ ultrasound to distinguish between damaged and undamaged apple tissue. They concluded that, because of the porous nature of fruit tissues, high-frequency ultrasound cannot pentrate deeply into the fruit. For this reason it was difficult to use high-frequency ultrasound to evaluate internal quality of fruits and vegetables. Mizrach et al (1989) observed some success in using low frequency (50 KHZ) ultrasonic excitation to determine some basic a acoustic properties (wave propagation velocity, attenuation coefficient, and reflection loss) of certain fruits and vegetables.

Measurement of acoustic response

Many people have claimed that the maturity and other qualities of some fruits. Such as apples, melon, and pineapples, can be determined by listening to the sound produced by striking them. Many researchers have tried to verify such claims by studying the acoustic responses of fruits,Yamamoto et al, (1980) developed non-destructive techniques for measuring textural quality of apples and watermelons based on the acoustic response of the fruits. They obtained the natural frequencies of the intact fruit by first recording the sound that is produced by hitting the fruit with a wooden ball pendulum and then performing Fourier transformation on this sound signal. They found that the natural frequencies of both apples and watermelons decreased with storage time. They also showed that the natural frequencies and firmness indices, expressed as functions of the natural frequency, mass, and the density of the fruit, are significantly correlated with fruit firmness and sensory measurements. Salveit et al, (1985) Tried to used acoustic methods to determine the maturity of green tomatoes, but they did not obtain conclusive results.

Measurement of impact

Chen, et al (1998) conducted tests to evaluate the sorting speed and the accuracy in firmness detection, the firmness readings extracted from the acceleration history were compared to those obtained with an Instron universal testing machine, have found the result showed that impact readings correlated well with the Instron test parameters. Coefficients of determination of 0.85 were obtained with peaches. Reseachers have found that the impact of a fruit on a rigid surface can be closely modeled by the impact of a fruit has a direct effect on the impact force response. Nahir et al (1986) reported that when tomatoes are dropped from a 70 mm highly corrected with fruit weight and fruit firmness. They subsequently developed an experimental tomato-grading machine, which by measuring and analyzing the impact force response of the fruit can separate tomatoes on the basis of weight and color. Delwiche et al, (1987) analyzed impact forces of peaches striking a rigid surface and found that certain impact force characteristics were highly corrected with the fruits elastic modulus and pentrometer measurements of flesh firmness. Raize et al, (1993) developed a system which used the impact parameters to classify fruits (apples, pears and avocados) into different groups. Chen et al (1996) indicated that using a low-mass impactor can result in the following additional desirable features: It increases both the magnitude of the calculated firmness index and the rate of the change of firmness index with respect to fruit firmness (The firmness index is highly sensitive to the change in fruit firmness), minimizes the error due to movement of the fruit during the impact, minimizes fruit damage caused by the impact, and facilitates high speed sensing. The availability of high-speed data acquisition and processing technology in recent years has renewed researchers interests in the development of sonic vibration and acoustic response techniques. Several teams are currently conducting research in this area. They include researchers in t he U.S. in Michigan (Armstrong et al., 1990, Abbott and Massie, 1993), and California (Chen, p. et al., 1992; Chen and De Baerdemaeker, 1992); in Israel (kimmel et al., 1992;shmulevich et al., 1996); and in Japan (sugiyama et al., 1994).

CONCLUSION

A different technical method was reviewed for inspecting the impact of quality, ultrasonic and acoustic response techniques. Starting with fruits and vegetable properties quality. There are six properties of quality fruits and vegetable, (a) Image processing (b) Visible and infrared light energies (c) X-Ray (d) Nuclear Magnetic Resonance (f) Mechanical stimulation. The second step the maturity using (NMR) to perform constituent analysis of fruits and vegetables (soluble solid and oil content and maturity). The third step to measure the firmness by feeding the obtained signal after detecting the impact signal from out put signal and obtain firmness index by the quotient of the root mean square of the out put of the acceleration signal divided by root mean square of the relative acceleration signal. The acceleration of mass during impact indicates the firmness of fruits and vegetables; large acceleration indicates hard fruits while small acceleration indicates soft fruits. The (La Magness Pentrometer) device to measure the firmness for hard fruits and Durometer for soft fruits is being used. The fourth step is measurement of ultrasonic, wave transmitted through the fruits tissues changes as the results of ripening and softening of the fruit during storage. There is some complication on the vibrations of the ellipsoidal fruits. The system implements an ultrasonic method for nondestructive measurements of internal quality of fruits and vegetables. Non-destructive techniques were used to measure textural quality of plants based on the acoustic response of fruits .The fruits and vegetables are classified in different group using impact parameters methods. The low mass impactor use to inspect the firmness of fruit is more advantageous other techniques.

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