INSTRUMENT FOR TESTING THE IMPACT RESPONSE OF DIFFERENT MATERIALS; APPLICATION TO APPLES AND PEARS.

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ABSTRACT

Based on two research projects, a device for testing the response to impact of fruits and related materials has been designed and tested during the last three years. As it is not related directly to potatoes, this contribution focuses mainly on the principles of impact and static loading and on the description of the device, and the type of results obtained up to now in different fruits..

INTRODUCTION

Mechanical properties of materials can be defined as those properties which respond to applied forces. A growing interest in the mechanical properties of fruits and vegetables has produced a considerable research effort to measure these properties.

The study of mechanical properties of horticultural products can cover different areas, for example: determination of the optimum time of harvest; evaluation of texture; methods for reducing mechanical damage during harvesting and transport; development of proper handling and processing methods, etc. All these areas of study are related to the quality of the products, such as the ability to resist damage produced by impact and compression during harvesting, transporting and processing; internal texture, resistance to mastication, etc.

There are very few commonly accepted standard methods and techniques for determining the mechanical properties which relate to the quality of the fruits and vegetables and this is why it is difficult to compare the results obtained by one investigator with those obtained by another. Some static tests (penetration and compression) are widely accepted. However, there are no standard methods for testing for quick loads or impacts in spite of the fact that impact is the most important cause of damage and losses in fruits and vegetables. Impact differentiates from a quick static load in the fact that forces act and disappear in a very short period of time (in the order of 10 miliseconds), that is the duration of time of impact.

Mohsenin (1972) made a comprehensive review of the research conducted during the sixties.He described several areas of study on mechanical properties of fruits and vegetables. He explained also the theory of impact as applied to fruits and vegetables, which includes three phases: elastic, plastic and elastic rebound. The application of the Hertz theory of elastic contact is appropriate as a starting approach for analysis.This theory assumes perfect elasticity,homogeneity,semi-infiniteness and other properties to the model, which only apply approximately to some agricultural materials. Nevertheless it has been successfully used by many investigators. On the basis of mechanical parameters:E: elasticity modulus (Pa) and ν : Poisson's ratio (%), and physical parameters:radii of curvature of both surfaces in contact (m), the model calculates stresses and strains caused by this contact on the surface and also inside the body; maximum values of these stresses and/or strains are supposed to be responsible for the iniciation of bruises in fruits. Their distribution, values and variation with the various "state" parameters of biological tissues, including cellular components, are thought to be responsible for the differences observed in the susceptibility to impact damage (Pitt, 1982, Jowitt, 1978).

The viscoelastic model implies that the force(i.e. the stress) relaxes (i.e. gets lower) with time. The analysis of this model has been solved (Chen and Fridley,1972; Gil,1982)and can be applied on materials using quasi static tests. It is important to state that,given the short times of duration of impacts,the importance of the viscous response will be lower in impact testing.Therefore,the elastic model is considered more accurate in testing fruits by impact than by quasi-static loading only if two important basic conditions are met: 1:deformations are very small and 2: no ruptures of the macrostructure of the product are produced(Mohsenin,1972;Rumsey and Fridley,1977).

DESCRIPTION OF THE INSTRUMENTATION

The schematic diagram of the impact-testing system is shown in figure 1. The impacting unit consists of a free-falling impacting rod, which is a sectional cylindrical steel rod with a changeable spherical tip. A small accelerometer is attached to the rod as one of its sections. An electromagnet, mounted on a vertical post, is used as a release mechanism for releasing the impacting rod at a specified height. As the impacting rod comes in contact with the sample, the signal from the accelerometer is fed to the microprocessor-based data acquisition unit which performs A/D conversion, high-speed data sampling,and data storage. At the end of the impact, the stored data are transferred from the data acquisition unit(DAU) to a desktop computer , which is programmed to perform data deduction and analysis and to display and save the results.

The impacting rod currently used is a 6.4 mm - diameter steel rod 85 mm-long with a 19 mm-diameter steel tip. The rod weighs 50.2 g. However, the mass and size of the impacting rod, as well as the shape of the impacting tip, can be changed as desired.

The DAU is interfaced with an IBM-AT desk-top computer through a serial port.

In operation, the operator first activates the electromagnet and sets the impacting rod at a desired height above the sample. Then the operator enters (from the IBM-AT computer key pad) the desired sampling rate, number of data points to be recorded, mass of the impacting rod, drop height, and sample number.The computer stores all the input data and sends the sampling rate and number of sample points to the DAU. The DAU then sends back a "ready" signal to the computer, and it displays a message asking the operator to hit the "RETURN" key and start the impact. The operator then presses the key and releases the impacting rod. As soon as the "RETURN" key is pressed, the microprocessor will read the digital output from the A/D converter

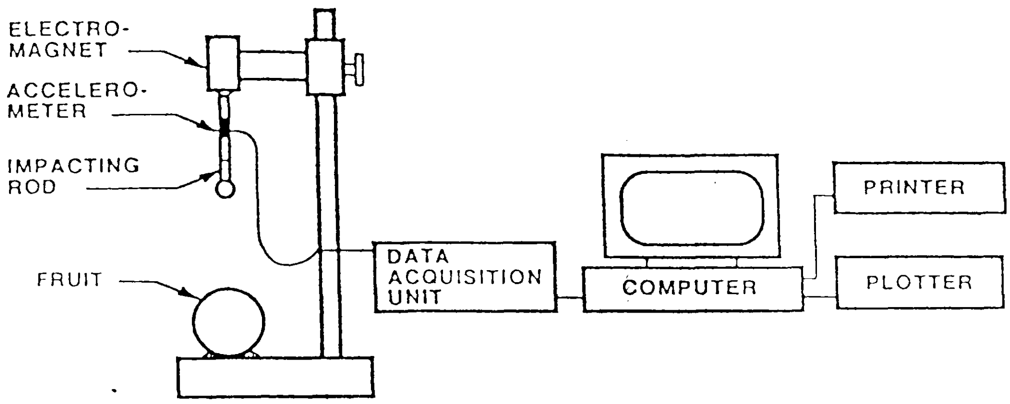

Figure 1.- Schematic representation of the impact-testing device.

and store the data in the ring memory at the desired sampling rate and at the same time check the magnitude of the signal to determine whether impact has been initiated. Once the beginning of impact is detected (the signal is higher than a specified level), the microprocessor will put a marker at the address of the ring memory at that instance and then continue to read the output from the A/C converter and store the data in the ring memory. When the desired number of data points beyond the marker are collected, the microprocessor will stop collecting the data and start sending the desired number of data, starting from the marker, to the computer through the serial port. The computer calculates the force, velocity, and deformation during the impact and displays the force, velocity, and deformation curves on the screen (fig. 2). The operator, after inspecting the curves, can decide to either discard or store the data on a floppy disk.

The software of the system has been reprogrammed lately. Right now, there are interconnected programs, which carry out following operations:

a) creation of a data file with all descriptor variables, and the values of the accelerations (100 for each impact);

b) display of force, velocity and deformation histories, and maximum values on the screen;

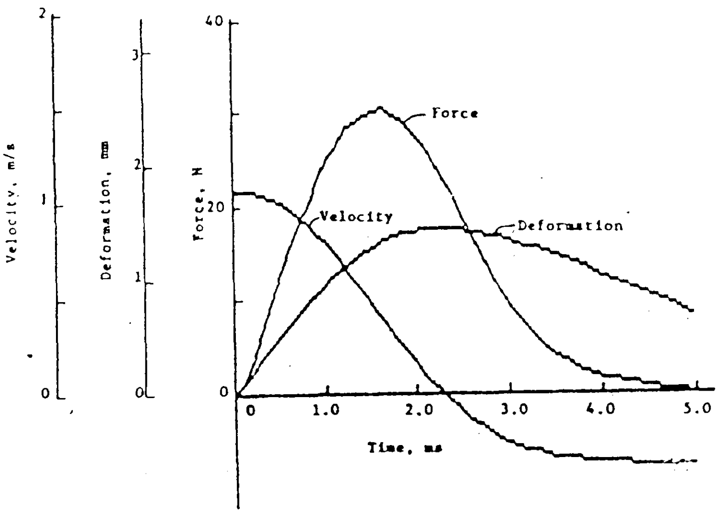

Figure 2.- Impact curves sample; pear Ya-Li, 6 cm drop.

c) calculation of forces, deformations, maximum and absorbed energies, duration of impact, to be printed; also, calculation of all parameters to be analyzed, eg : rate of change of the force, modulus of elasticity; discontinuities in the force (bio-yield points), times to maximum force and to maximum deformation, and others;

d) calculation of stresses and strains based on the elastic model;

e) graphics of the different data and models, to be used as a comparison with other observations and parameters on the fruits.

There are a few other programs prepared for different applications, and analysis of the results.

SOME CURRENT APPLICATIONS

1. Study of impact and compression damage on Asian pears. (Chen, P. et al., 1986).

Impact and quasi static compression tests using the same indenters were made on four varieties of pears, during a 5 month period. The fruits were held in cold storage and at monthly intervals, 30 of them were taken and ripened in a 20°C room. In addition to the physical aspects measured in these tests, ripeness (Brix, firmness), and damage (size and shape of the bruises formed) were assessed.

It was concluded that the four varieties differed in their susceptibility to damage and in their responses to 0°C storage and 20°C ripening treatments. In addition, it was observed that the shape of bruises was different when caused by compression than when caused by impact (even when using the same type of indenter). (Fig.3).

Figure 3.- Compression and impact bruise patterns in Asian pears.

2. Effect of impact bruises on selected varieties of apples.

An investigation is being carried out on the causes of bruises in apples. Different aspects such as histological, biochemical and physiological factors have an important influence. Some biochemical tests, eg. catechol and epinephrine solutions, have given good results for the rapid detection of bruises in apples and pears whilst optical and electron microscopy permit the recognition of fracture lines, which may be correlated with the results of the impact tests.

3. Mechanical parameters in impact and static tests that affect the formation of bruises in fruits. Effects of temperature and ripening.

Important parameters like viscoelastic relaxation and resistance to tangential stresses (using a device made to determine tangential resistance in fruit (probes) were correlated with the appearance and development of bruises. Also, in these tests, on 2 varieties of apples and 3 varieties of pears, a whole series of parameters (including compression and viscoelastic tests on fruit probes) were determined in relation to impact, varying time of storage and temperature of the fruits.

The results of both static and impact tests indicate that temperature affects pears (var. Blanquilla) much more than apples (var. Golden Delicious).

Further tests at present include selecting the optimum height of the impacting rod for detecting relevant impact parameters that describe better the bruise susceptibility, as well as the ripeness level for different fruits.

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