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DEVELOPMENT OF AN IMPACT TESTING MACHINE

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Abstract

Assessment of impact response of fruits and vegetables can produce significant results which could be used to predict subsequent damages suffered by these produce in transit. Using the concept that energy at impact is a function of the mass of the sample and the height of drop, an impact testing equipment was developed. Combining some basic engineering design considerations with other functional requirements, the developed machine has a platform for holding and releasing of samples, impact surface platform, a supporting stand, a column(adjustable), measuring tape(digital), a box for collecting the falling sample and a spring loaded slide for releasing the sample from the platform. The developed machine which is simple in operation has been used to determine impact damages in some agricultural produce such as cracking of eggs and potato bruising. The machine was used to subject potatoes to impact damage in a study to assess the stability of the produce under set conditions of temperature and relative humidities. The results showed that sound *agria* potato is more stable than the impacted. The results of the performance tests showed that the developed machine can effectively be used to conduct experiments in this area which hitherto has received little attention due to lack of instrumentation.

Introduction

The shelf life of fresh produce depends on both the prevailing environmental condition and the level of tolerated loss before it is declared unsuitable for sale or consumption. Product marketing managers, researchers and development managers often request information on the expected shelf life of a product which requires long duration of experimentation to obtain the answer. Consequently, the researcher would often device means for accelerated shelf life testing procedures. This is more so now that the demand for high quality fruits and vegetables has risen worldwide (Porritt, 1982), thus increasing product mobility and range of distribution.

Research on mechanical damage in fruits and vegetables has been on for several years. It was found that most of these types of damages are from transporting, primary processing(sorting, washing, waxing etc.), handling and packaging (Jones *et al* 1991). Proferring solutions to mechanical damage problems in fresh fruits and vegetables require either actual (*in-situ*) evaluation of damages caused to the produce subjected to real life situations and conditions which is time consuming and quite often involves a very large groups of participants organisations and systems, or the simulation of the damages in the laboratory using appropriate equipment and methods. The latter is preferred since it could be easily monitored and controlled.

Mechanical damages could be from the following sources.

i) road
ii) vehicle
iii) the material
iv) packaging and packages
(v)primary processing.

The essential factor required in the study is the formulation of the overall system of simulation to reflect the effects of the load, road, vehicle, packaging and the material properties. This

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would involve the identification of the elements pertinent to the system and their interplay so properly relate these elements systematically. These elements among others would include the suspension system, vehicle velocity, types and nature of road deformation, road bumps, height of bumps, number of potholes, number of kerbs on the road, produce packing factor, height, stacking, number of produce resting on each other, package material's height and depth, packing cushioning, location of truck trays, monolithicity of loading, produce firmness, produce modulus of elasticity, coefficient of restitution and produce types.

However, it has been generally agreed that the majority of these factors result to injuries synonymous with impact (Altisent, 1991). Evaluation of mechanical damage studies in agricultural produce are still in early stages. Consequently, researchers often result to designing their own scale and equipment for assessment (Mohsenin, 1978). Early studies showed that the energy consumed during impact of materials could be expressed as:

$$\epsilon_{ab} = (1-\varepsilon^2)mgh \qquad (1)\ \text{(Mohsenin, 1978)}$$

where, ϵ_{ab} = energy absorbed, ε = coefficient of restitution, m, g, h = mass of material, gravitational pull and height of fall respectively. This equation essentially implies that the energy at impact is a function of the mass and height of drop.

Three major testing methods have been developed in recent times on the application of controlled impact to fresh agricultural materials. These are:

i) The instrumented procedures
ii) The free- falling instrumented devices
iii) The spring actuated falling rod. In the studies of impact damages on potatoes (Ajisegiri *et al*,2000), it was stated that for each produce, a threshold value of energy exists for each form of mechanical damage. Working on fresh potato tubers (*V.agria and granola*), it was stated that to cause internal injuries due to impact, the value of the energy required approximates 0.6 Joules. This implies that one could determine the mass and height of drop that is safe for the produce during handling and transportation (Ajisegiri *et al*, 2000).

Assessment of impact response of fruits and vegetables can produce significant results which could be used to predict subsequent damages suffered by these fruits and vegetables in transit. Such assessment could further generate basic data that can be used to conceptualize appropriate handling devices that will result in minimum damage to these produce during handling. It is thus desirable to develop an impact testing machine that will be simple in operation, durable and affordable. Development of such a device will go a long way in providing most of the laboratories in Universities and research institutes opportunities to conduct experiments in these areas.

At the *Institut fur Landtechnik Universitat Bonn*, it was desired to find the effects of mechanical damage on the rate of weight loss, respiration rate and moisture content on fresh potatoes (Ajisegiri *et al*,2000). Seeing that placing a rule at the wall to determine the height of drop based on the measured weight was cumbersome with quite a few attended problems, an impact machine was developed.

Design Considerations

The concept of this equipment is based on impacting a predetermined threshold of force to cause damage on the fresh fruit or vegetable under test. Based on this the following considerations were made:

i) Height of produce fall
ii) Weight of the produce
iii) Free-falling condition
iv) Impacting surface

v) Rebounce

For the purposes of design, potato (a tuber vegetable) was used to calibrate the system. Studies showed that the energy consumed during the impact of material is expressed as:

$$E_{ab} = (1-c^2)mgh \quad (1)$$

Where $c = (h_2/h_1)$, and the ratio of h_2 to h_1 for general application is approximately 3.5:1, E_{ab} = energy absorbed, c = coefficient of restitution = 0.53, m = mass of the material, g = force due to gravity and h = height of fall.

It has been established that for potatoes the threshold value of 0.6 joules is sufficient to cause mechanical damage (Ajisegiri *et al* 2000). By this same concept, an actual height could be determined for any crop using the value as a guide. From visual perspective, it is assumed that an energy of the magnitude that could damage potatoes could also cause damage to other crops such as tomatoes, oranges, avocado, onions, cabbage etc.

To determine the height of operation, it is only required to determine the minimum weight of 50 g (approximately 0.05 kg) which was fixed for the crop.

The implication is that any crop with a weight less than this would have to utilise another method. With these parameters selected, a threshold height could be calculated thus:

$E_{ab} = (1-c^2)mgh = 0.6$ Joules

That is, $(1 - 0.(53)^2 \times 0.05 \times 9.81h = 0.6$ Joules

$H = 1.171$ m.

This implies that a minimum of 1.71 meters is required to produce this force. For the purpose of this design, a total height of 4.0 metres was used. This means that the equipment would be able to generate a total of 1.41 Joules on a sample of 0.05 kg. This force is considered adequate to cause fracture to most biological materials.

The impact machine has the following major components: platform for holding and releasing of sample, impact surface or platform, a supporting stand, a column (adjustable), a measuring tape (Digital), a box for collecting the falling sample and a spring loaded slide for releasing the sample from the platform.

Design

The design of the equipment was based on the principle that impact energy is a function of the drop height, (h) as given in equation (1). The machine consists of a vertical column, a material holding platform, a material releasing mechanism, an impact surface and a supporting stand. The various components were designed and constructed as follows:

The Column

The column formed the frame on which the other components are attached. The designed height and hence the selected dimensions were based on equation (1) above. It is made up of three units of aluminium pipes (60mm x 60mm x 1200mm) each. Holes were made at the ends of these units and smaller pipes (50mm x 50mm 160mm) are used to couple the three units together to form the complete column. The splitting of the unit is to facilitate easy handling and transportation of the equipment. The total height of the column is 3600mm.

Material Holding Platform

This comprised of two 100mm x 300mm stainless steel plates which are bolted to the units that swing easily on a steel rod which is actuated by a spring loaded slide. They are constructed to lap each other by means of a little extension from one plate.

Material Release Mechanism

This comprises of a handle, a coil, a slide and a spring. The handle is coupled to a plate of 110mm x 50mm which is bolted to the column by means of another plate of 30mm x 110mm. The trigger handle is 180mm long. The wire coil housed in a rubber tube is connected to the material holding plate. Attached on this unit is a measuring tape which measures the height from the impact surface to the material holding platform.

Impact Surface (platform)

This is the unit on which the sample or the material to be assessed falls on to . It was constructed from steel plate of 200mm x 300mm and bolted on the column frame by means of other plates (110mm x 50mm and 110mm x 30mm). The unit is made in such a way that various padding materials can be placed on the platform depending on the type of experiment to be conducted.

Supporting Stand

The stand was constructed from steel plate and bar. The bars were of dimensions 570mm x 50mm (2units) which were slanted and 460mm x 50mm (2units) also slightly slanted also. The plate which holds these units in place is of dimensions 530mm long and 100mm wide. The unit was constructed in form of a trapezium. A leveling unit is attached to the stand.

Operation Principle

When the three pieces of the aluminium pipes are connected, they are then bolted to the stand. The other components are bolted on this column. The material to be assessed is placed on the material holding platform. the handle of the releasing mechanism is then depressed while the slide is pulled by the action of the spring. The plates are splitted by this action while the material falls freely on to the impacting surface. The impact parameter to be measured can then be determined. For instance, knowing the height of drop, the energy required to cause such impact can be determined from equation (1). Impact parameters such as deformation, rebound energy and duration of impact can also be determined. Bruising can be determined by measuring the diameter and depth of indentation.

Performnce Test

The designed machine was fabricated and used to subject potatoes to impact damages in order to investigate the stability of the tubers under certain conditions of temperatures and relative humidities.

Test Results

Ten (10) tubers of two varieties of potatoes *agria* and *granola* were randomly selected and used for the experiment on impact damage. Each of this tubers was weighed and based on the weight. they were dropped at heights corresponding to the individual weights to impact a force of 0.6 Joules on each tuber. The corresponding height determined based on each weight is given as in Table1.

An approximate 5 kg of each sample of tubers subjected to impact and sound ones were stored for 15 days at 4° C and the stability quotient is presented as Figure 2.

It was shown that the sound *agria* potato is more stable than the impacted. This proves that the equipment is effective as an impact applicator.

Conclusion

The developed equipment has been used to impact damages on potato in a study to assess the effect of such damages on storage stability. The results of these studies showed that damaged potatoes require higher temperature and relative humidity for stability than sound tubers. Hence, the developed equipment can effectively be used to determine the impact energy of several fresh agricultural produce thus making researches in this area very promising

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Table 1: Variation in mass and height of of potato during the test

Mass of potato (kg)	Height of drop (m)
0.157	0.534
0.214	0.392
0.110	0.762
0.204	0.411
0.211	0.397
0.180	0.466
0.144	0.582
0.097	0.864
0.115	0.730
0.217	0.386

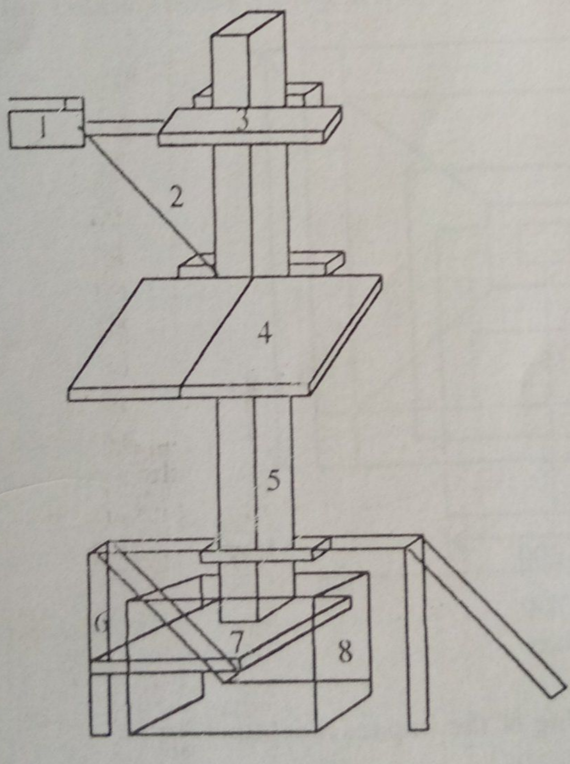

Figure 1. Assembly Drawing of the Impact Machine

1. Trigger handle
2. Material release mechanism
3. Digital tape holder
4. Material holding platform
5. Column
6. Supporting stand
7. Impact surface
8. Collecting box

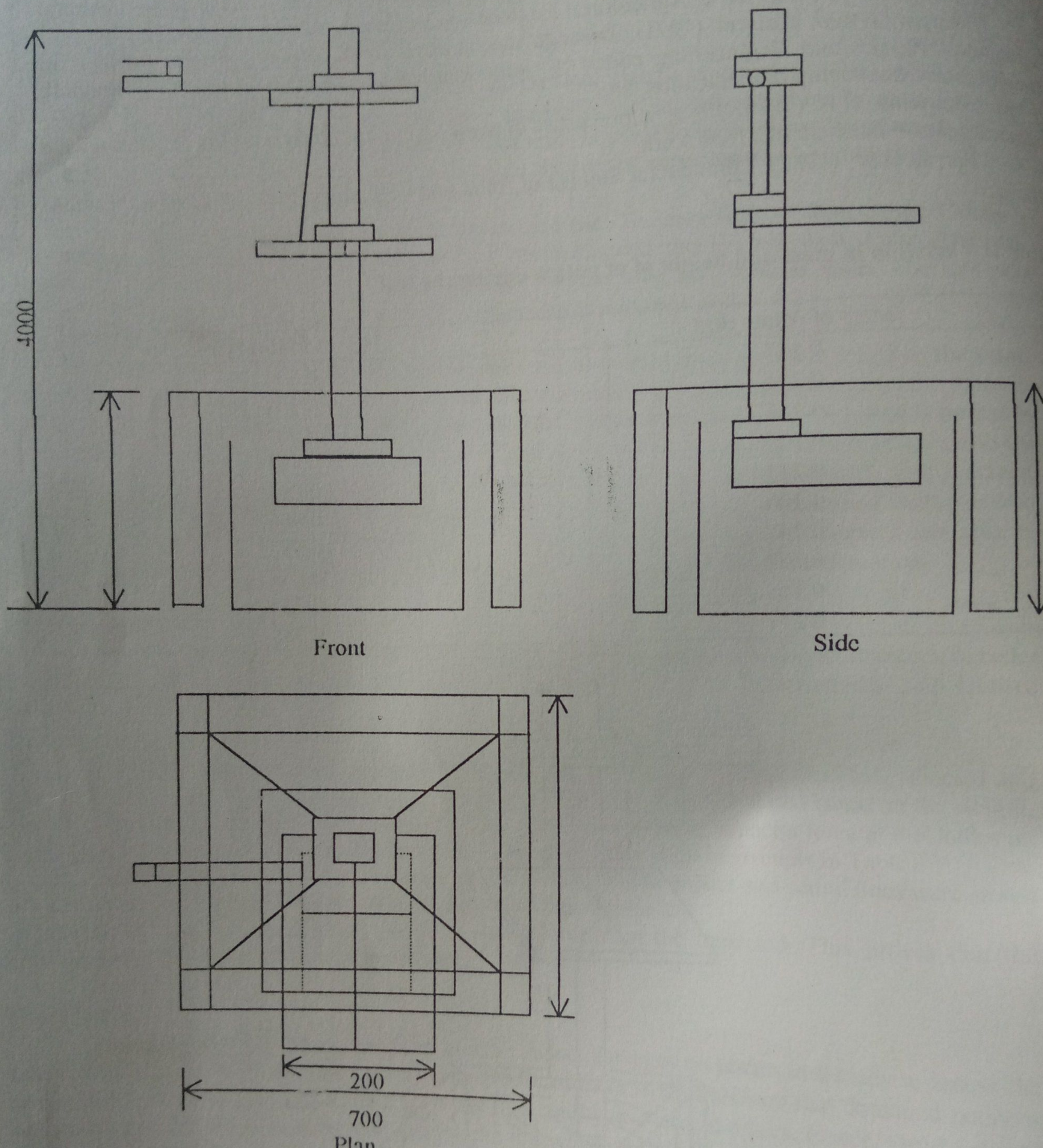

Figure 1b: Orthographic drawing of the impact machine

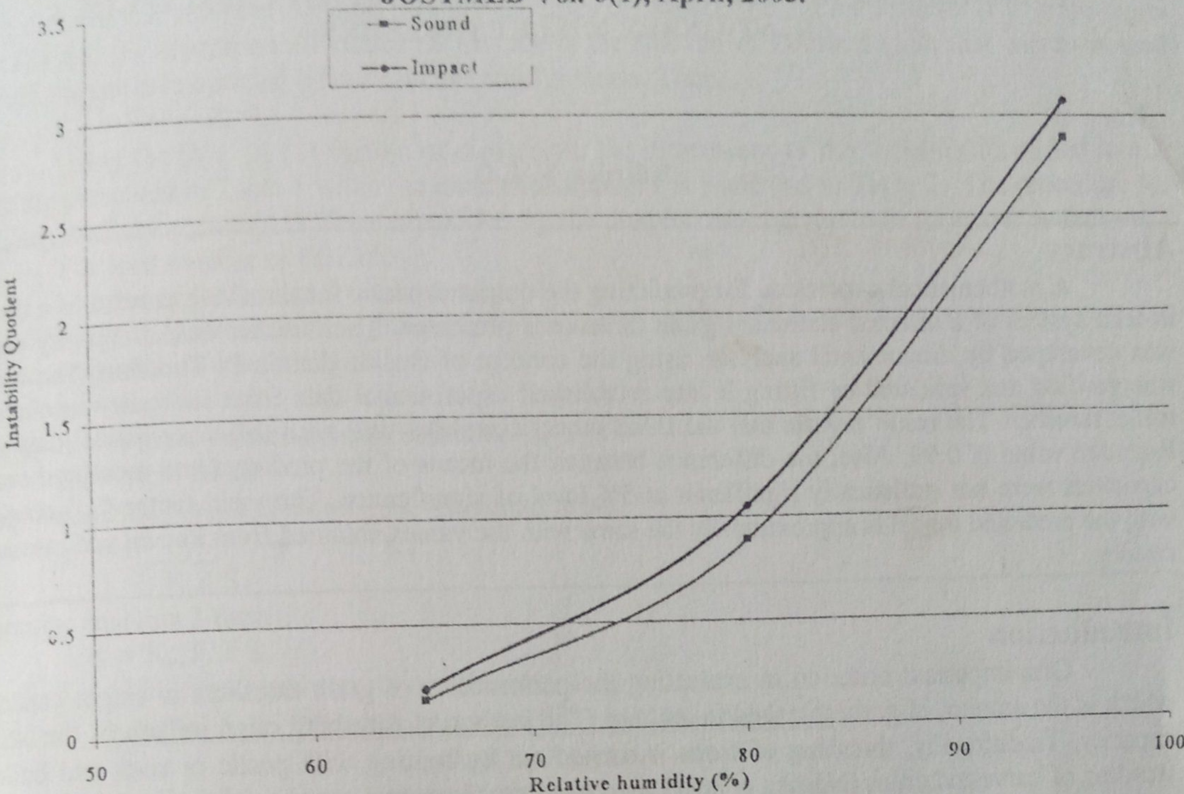

Fig. 2: Stability Curve for Potato Tubers Stored at 4^{0}C