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Development of a compression test rig for evaluation of mechanical properties related to design for containerization and transportation of fruits

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Abstract

Relevant literatures necessary for design of testing equipment for mechanical properties of biological materials are reviewed. A digitized compression testing system has been developed to evaluate the mechanical properties of agricultural produce fruits in Nigeria. The designed equipment performed satisfactorily by estimating precisely some basic mechanical properties like Poisson's ratio, elastic modulus, bioyield strength, ultimate load, fracture load and elastic limit of tested materials. The system consists of the top platen, the lower platen, the moving platen, the Support Column, the threaded shaft, the arm, the digital linear scale and the digital load scale and has the ability to instantaneously evaluate both load and displacement from where the mechanical properties.

Keywords: fruit; compression; experimentation; platen; rig; mechanical properties

1. Introduction

The existing designs of the universal testing machines does not consider the need that the mechanical properties of biological materials need to be ascertained before any design associated with them need to be carried out. Most of the existing testers need a test piece to be fabricated. A particular load ranges must be applied in the existing testers before any property is evaluated. These are some of the reasons why the existing universal testing machines like the Hounfield tensometer popularly used in the laboratories are not effectively used for testing of most fruits and seeds. The load ranges of existing destructive tester are in the range 31.25Kg-2000Kg (Rajan etal., 1988).

Although there exists some non indigenous test rigs that are not amenable to most common fruit shapes, Abbott (1999), Harker et al. (1996); LehmanSalada(1996), Abbott et al.(1997); Gunasekaran(2001); Lu and Abbott (2004); Lu etal.(2005), Fekete (1993), Takao and Ohmori (1994), Bellon et al. (1993), Timm et al. (1993) had worked on the determination of the firmness of fruits using various improvised rigs that are not commonly available.

2. Theoretical analysis and equipment design

The digital compression test rig is designed on the principle of power screw adapted to high precision strain gauge sensors. The basic theory of mechanical principles of power screw employed in this design is found in Shigley and Mischke (1989).

3. Equipment assembly and operational features

3.1. Equipment components description

The equipment shown in Fig. 1 consists of:

i. The Top Platen- This is the top-most part of the machine and it supports the threaded shaft. It also provides support to the moving platen when a test piece is under compression.
ii. The Lower Platen- This acts as the base of the machine on which the digital load scales. It also provides support to the test piece under compression.
iii. The Moving Platen- This is the moving part of the machine. It consists of a circular plate which is held in position by two support studs. The studs with the help of grooved end running on the support columns, ensures that the circular plate is restrained in all directions but allowed to move up

and down. The motion of the entire moving platen is derived from the threaded shaft which is connected to the upper platen.

iv. The Support Column- This is used to rigidly connect the top platen to the lower platen. It is built to withstand al the stresses associated with testing as they all act on it. It also acts as a guide to restrain the motion of the moving platen to only up and down motion.
v. The Threaded Shaft- This member provides the axial motion that is required for compression when it is rotated. The thread on the shaft provides an axial movement of the moving platen, corresponding to the pitch of the thread, 1mm.
vi. The Arm- At the other end of the threaded shaft is the arms. They provide the moment that drives the screw when a force is applied to them by the moment arm. The arm is two in number so that we have a couple that ensures that the force required for compression to the maximum range of the digital load scale is within ergonomic range.
vii. The Digital Linear Scale- This device measures the axial deformation within the range of the machine.
viii. The Digital Load Scale- This is a digital device that measures the force applied to the test piece.

The equipment determines the compressive properties of the test piece by:

1. Measuring the axial/longitudinal deformation of the test piece. This is measured with linear scale.
2. A second linear digital scale measures the lateral/latitudinal of the test piece. This linear scale is not attached to the equipment but provided as an ancillary.
3. The force of deformation of the test piece is measured with the digital load scale.

3.2. The digital load scale

This is a digital scale with a surface made of synthetic glass. Its reading could be set to read in units of kilogram (kg) or in units of pounds (lb). Its features are as follows:

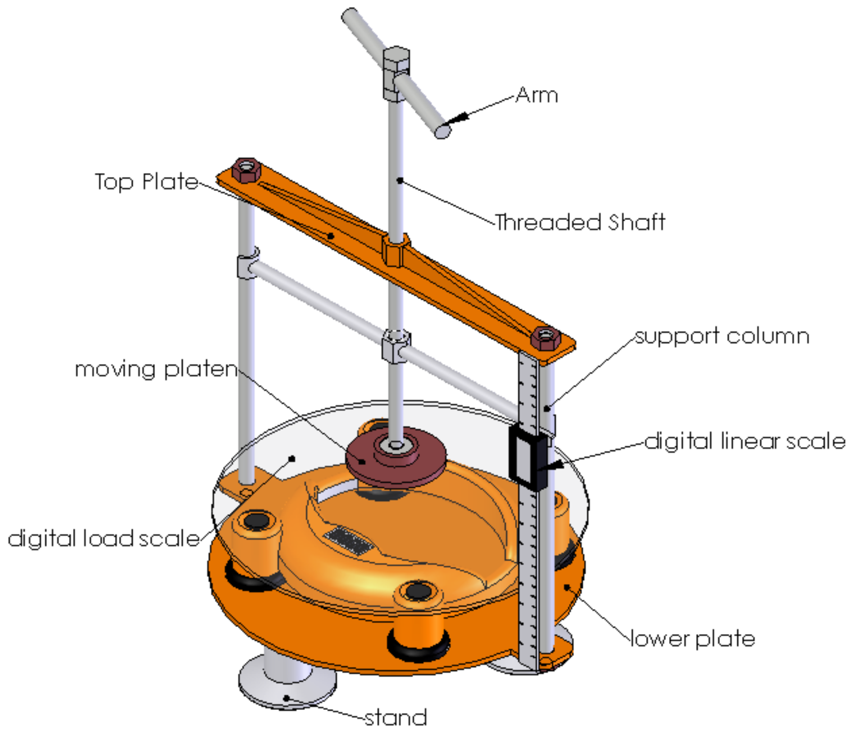

Fig. 1. Depiction of digital compressive test rig assembly.

a. High precision strain guage sensor.
b. 8mm tempered safety glass platform.
c. Size of LCD digits: 25mm.
d. Automatic zero resetting and automatic turning off.
e. Low power indicator and over loading indicator.
f. Capacity; 150Kg
g. Division: d = 100g

3.3. The digital linear scale

This is digital linear scale is made of austempered stainless steel material. Its reading could be set to read in millimeters (mm) or in units of inches. It consists of:

1. Metric/Inch change over.
2. LCD display

3. Power off button
4. Zero setting and power on button
5. Battery cover

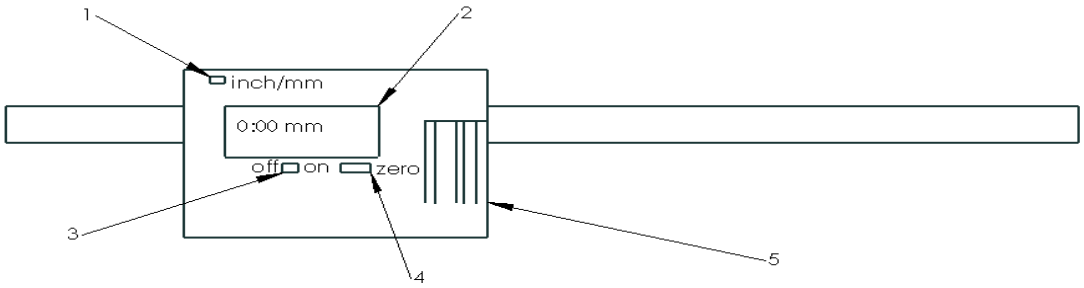

Fig. 2. Linear Scale

Table 1
The Digital linear scale and technical specifications

	Technical specifications
Measuring range:	0-150mm/0-6′
Resolution:	0.01mm/0.0005′′
Accuracy:	±0.02mm/0.001" (<100mm).
Repeatability:	0.01mm/0.0005".
Maximum measuring speed:	Linear captive measuring system.
Display:	LCD display.
Power:	1 silver oxide battery SR44, 1.55V.
Capacity:	165mAh.
Working temperature:	5°C-40°C/41-104°F.
Influence of humidity:	Not important under 80% of relative humidity

4. Operational instructions

1. At the onset of any test, the test piece must have been prepared using the appropriate method.
2. The test piece is placed on the digital load scale and the load scale is zeroed by pressing the top of the load scale slightly to initiate auto zero sequence.
3. The screw is rotated in the clockwise direction until the circular plate just touches the test piece. In this position the linear scale is zeroed. The zeroing of both the load scale and the linear scale is important in that the subsequent measurement gives the value of the deformation and deformation force without requiring any form of conversion.
4. The moving platen is moved progressively and the deformation and force values taken intermittently until the desired deformation range is obtained or until the point when the test piece fails structurally.
5. The threaded shaft is rotated in an anticlockwise direction to move the moving platen up and away from the test piece.
6. The tested piece is removed from the machine and the machine is cleaned in the preparation for another test.
7. Steps 1-6 is again repeated fer the next test piece.

5. Equipment maintenance

- Ensure that the scale is well balanced.
- Make sure the surface is clean and dry. Do not use abrasive cleaners.
- Keep the unit in a dry place to protect the electronic components.

5.1. Maintenance and care

- In order to save power, turn off the unit when it is going to stay idle for some time.
- Never apply any electric pressure on any part of the unit and never use an electric pen on it lest its chip is damaged.
- Accidental wrong display may happen replacing the battery. Take out the battery and put it in again after 30 seconds until the display returns to normal.
- Battery replacement: Flashing of digits shows a flat battery. Take off battery cover and replace the battery (positive side facing out).

6. Validation of design

The equipment was used to evaluate the mechanical properties of some selected agricultural materials such as ripe tomato and orange fruit. The mechanical properties such as Poisson’s ratio evaluated for ripe orange was about 0.0-0.3 which is in line with standard for materials. Also evaluated was the Poisson’s ratio of tomato which was evaluated as 0-0.3. These agreed with the result of Ezeike (1986).

7. Conclusion

The designed equipment performed satisfactorily by estimating precisely some basic mechanical properties like Poisson's ratio, elastic modulus, bioyield strength, ultimate load, fracture load and elastic limit of tested materials.

The compression test rig can convincingly be used to determine the compressive properties of fruits, seed and other semi hard agricultural produce, however, the test of hard coated agricultural produce like Kernel, nuts, hard wood etc may require higher capacity of the same testing equipment.

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