A COMPUTER-AIDED APPARATUS FOR MEASURING SOME FRUIT PRODUCTS QUALITY

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ABSTRACT

A computer driven device has been developed to measure the hardness of fruits easily and accurately. The apparatus can be used for fruits in either destructive or non-destructive conditions. Measurements include external covering layer and internal flesh compressive strength for persimmon and anna-apple fruits and bio-yield point of persimmon fruit. The testing apparatus consists of a step-motor controlled by a computer which drive a probe movement. A step-motor interface 6pin was used for connection to a standard PC from type 486 on. The motor may either be controlled by hand with the computer keyboard or via a program accompanying with the motor. Different types of probes can be used to penetrate or compress the fruit sample. The fruit sample was placed on a load cell under the probe, and the load cell reading was transferred to a digital indicator. Examples of measurements on persimmon and anna-apple were presented to demonstrate the performance of the apparatus.

The results showed that:

- *The maximum penetration force (F1) for persimmon fruit occurred at 3.3 N. and the rupture occurred at 4.2 N.*
- *maximum penetration force (F1) for anna-apple fruit occurred at 19.9 N. and the rupture occurred at 6.9 N.*
- *Bio-yield point for nondestructive condition of persimmon fruit occurred at 50.1 N. and the complete rupture occurred at 70 N.*
- *Repeating press to the fruit will lead to soften it.*

Keywords: *hardness; persimmon fruit; anna-apple; compressive strength; apparatus.*

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INTRODUCTION

Fresh food quality is an increasingly important factor in the production and marketing of biological products. Hardness/softness is one of the quality factors for fresh fruits and vegetables. Hardness/softness has been used as a criterion for acceptable fruits in the market, as the main indicator for assessing the latest acceptable shipping date for stored fruits, and as an indication of the handling characteristics including picking and grading of fruits as mentioned by **Harman (1981)**. **Altuntas et al. (2011)** mentioned that the external covering layer and flesh firmness of persimmon fruits are important criteria to maintain quality during the postharvest period. The agricultural engineering has an important role to play in the development of suitable testing methods.

Hardness/softness measurements in fruits and vegetables have been used for many years as guides to the quality of the product. A large number of different techniques involve applying low-pressure compression to intact fruits and vegetables. Traditionally hardness/softness has been measured by a penetrometer, in which a cylindrical rod (11 mm in diameter for anna-apples) is pushed into the fruit (9 mm in depth) and the force required is measured as a fruit hardness, **Abbott (1999)**. The penetration process takes place in the form of compression, shear, and tension, **Bourne (1980)**. **Mohsenin (1970)** mentioned the term bio-yield point is proposed for biological materials to differentiate this phenomenon from the yield point in engineering materials. The bio-yield point may occur at any point beyond the linear limit, where the curve deviates from the initial strait line portion. This is an indication of initial cell rupture in the cellular structure of the material.

Various types of devices have been developed to measure firmness either destructive or non-destructive; held by hand or stand mounted. The hand–held tester is a very poor test because its results dependent on the operator, **Voisey (1977)**. The most common one is the Magness Taylor, **Abbott et al. (1976)**. This device was originally developed for firm fruits such as apples and pears. This is less satisfactory for softer fruits such as persimmon. A major problem obtained with these traditional penetrometers often give variable results because the basis on which they are used to measure hardness is affected by the angle at which the force is applied. So modified versions and more complex systems have been developed using drill press stands. The tester mounted on a stand provides more consistent speed of punch and angle, **Bourne (1974)**. The stand mounted testers have been created for either destructive such as Magness Taylor Pressure Tester, **Bourne (1980)** or nondestructive as described by **Atta-Aly and Awady (1994)** and **Lu et al. (2005)** which depending on applying definite weights to fruit and measure deformation, **Mizrach et al. (1992)**. This system is accurate and easy to use but cannot be used for destructive mode.

Other nondestructive testing methods to assess hardness included optical methods **(Bellon et al., 1992; Kabany, 2002; Bhosale and Sundaram, 2015; Hosoya el al., 2017)** and impact approach by **Ozer et al. (1998)**. **Prussia et al. (1994)** developed a noncontact hardness detector, in which a short puff of pressurized air was used to deflect the product surface for less than 1 mm while a laser displacement sensor measured the amount of deflection.

Because of the large variance inherent in biological materials, each experiment shall be statistically designed with sufficient number of replications to result in an acceptable level of confidence insofar as significant differences are concerned. The variation due to shape, size, age and cellular structure are normally such that at least a minimum of twenty specimens are required to be tested for each sample **(ASAE Standards, 1991)**.

The objective of this work is to develop a fruit hardness apparatus which can be used for both destructive and non-destructive measurements, in addition to control the probe movement by using a step-motor controlled by a computer and a load cell.

MATERIALS AND METHODS

The purpose of this study is to investigate the relationship between force applied and deformation of *persimmon and anna-apple* fruits.

Materials: Fruit selected with a uniform size to avoid variation in hardness due to size (large fruits are usually softer than small ones).

The apparatus as shown in Fig. (1) was designed to measure force applied versus deformation of fruit. The apparatus consists of a probe mounted on an arm, which is raised and lowered on 2-mm pitch screw thread by a computer driven step-motor operating at 200 steps per revolution. The motor gives 0.01 mm movement in the arm per step. A step-motor interface 6pin was used for connection to a standard PC from type 486 on. The motor may either be controlled by hand with the computer keyboard or via a program accompanying with the motor. The interface has to be connected at the printer port of a PC. By means of the software the motor can be operated forward or backward with an adjusted number of cycles. The specimen to be sampled was placed on a load cell under the probe column, and the output from the load cell is red through a digital indicator connected with it. The load cell model is YL31-98.07N capacity and capable of measuring 0.01 N.

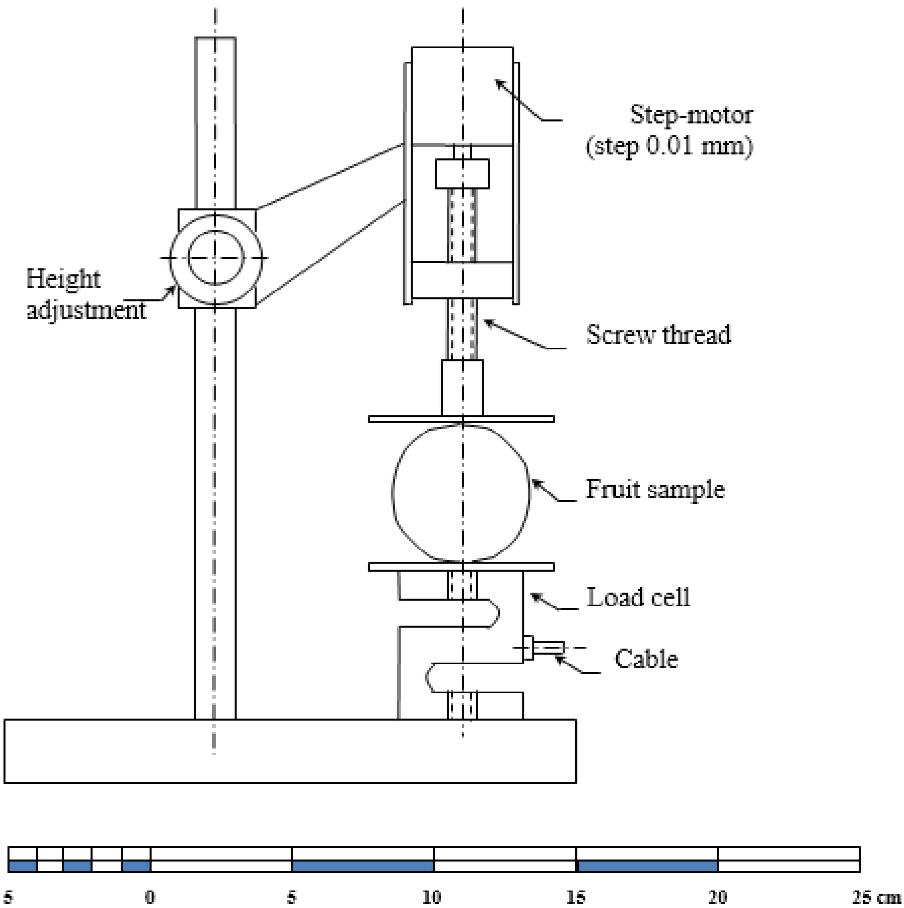

Fig. 1: Schematic diagram of fruit hardness apparatus.

Methods: The investigation can be conducted by Measuring the no load condition of the fruit. Start to applying force gradually to the fruit, in equal increments. The deformation was measured of the persimmon fruit as each increment of force is applied. Deformation can be measured by the distance traveled by the screw by each 0.01mm per step of step-motor. Continue loading to the fruit until it fails (ruptures). The graph of force versus deformation was ploted to identify the proportional limit (linear limit), the bio-yield point, and the rupture point. The puncture test made on the midway between the stem and blossom end. An external covering layer puncture test and a whole fruit compressive test could be performed at the same time. The prob consisted of a 2 mm diameter cylindrical probe 10 mm long **(Duprat et al., 1995)**, mounted on a flat plate. The external covering layer puncture force was conducted first, and then the prob was pushed further into the fruit until the plate made contact with the fruit surface. After that the whole fruit was compressed to rupture.

RESULTS AND DISCUSSION

Persimmon fruit destructive condition:

Table (1) shows 20 samples measurements on persimmon fruit including force applied and corresponding defformation.

Fig. (2) shows the formation of small pits in the persimmon surface using the probe for measuring both external covering layer hardness and whole fruit compression. The relationship between the addition of force and the amount of deformation is linear in the beginning until the first peak (F1) which represented the external covering layer explosion strength, while the second (F2) was the maximum obtained before fruit rupture between two plates. Results obtained from this test were 3.3 and 4.2 N respectively, and the percentage compressed fruit at rupture was 9.0% of the original fruit diameter.

Anna-apple destructive condition

Table (2) shows 20 samples measurements on anna-apple fruit including force applied and corresponding defformation.

Table 1: Samples measurements on persimmon fruit.

Sample #	*Diameter,(D) mm*	*Deformation, mm*	*F1, N*	*F2, N*
1	73	2.7	3.7	4.2
2	74	2.5	3.4	4.3
3	72	2.8	3.75	4.2
4	75	2.5	3.25	4.1
5	73	2.6	3.4	4.1
6	70	2.9	3.85	4.25
7	74	2.6	3.3	4.2
8	77	2.3	3.0	4.2
9	73	2.5	3.3	4.3
10	74	2.7	3.27	4.36
11	77	2.2	2.95	4.1
12	77	2.3	3.13	4.16
13	74	2.1	2.84	4.0
14	72	2.75	3.78	4.24
15	71	2.85	3.77	4.16
16	78	2.3	2.8	4.4
17	79	2.2	2.6	4.2
18	73	2.2	2.9	4.2
19	71	2.9	3.8	4.5
20	72	2.68	3.74	4.11

(F1) which represented the external covering layer explosion strength

(F2) the maximum obtained before fruit rupture between two plates.

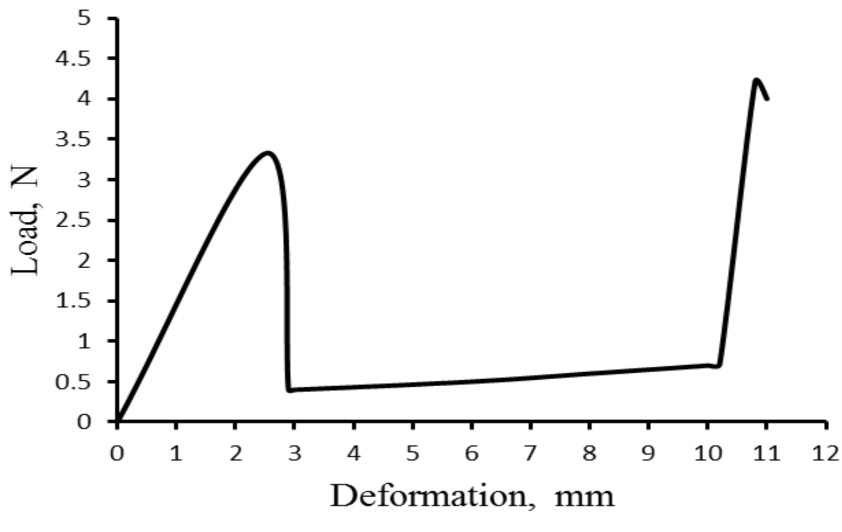

Fig. 2: Load vs. deformation for a persimmon fruit (destructive mode).

Table 2: Samples measurements on anna-apple.

Sample #	Diameter,(D) mm	*Deformation, mm**	*F1, N*	*F2, N*
1	76	3.3	21.6	6.75
2	75	2.5	15.6	7.0
3	73	3.4	20.0	6.7
4	73	3.2	20.75	7.86
5	76	3.0	20.15	6.5
6	78	2.7	18	6.8
7	69	3.7	24	6.4
8	76	2.8	20	7.4
9	71	3.4	23.5	6.6
10	79	2.2	14.4	6.4
11	68	3.1	18.7	7.6
12	72	3.8	22.6	7.2
13	76	2.9	19.8	6.65
14	71	3.2	22.8	7.7
15	76	2.7	17	6.5
16	66	3.3	21.5	6.7
17	71	3.1	21.7	7.3
18	72	3.4	20.8	6.7
19	73	2.7	18.2	7.5
20	72	2.5	16.15	6.3

D is the diameter of the anna-apple, * is the deformation of the anna-apple at the external covering layer rupture, F1 is the force to penetrate the external covering layer, and F2 is the fruit internal flesh hardness.

Fig. (3) shows the result from an anna-apple test. The first and largest peak (F1) gave the explosion strength of the external covering layer of the anna-apple (in this case 20N). After that, the load down to a lower position as the probe moved through the fruit flesh. more measurements included the tissue hardness at 7 mm depth (7 N), could be detected from the figure (F2). A sample set of data for 20 anna-apples is shown in Table 2.

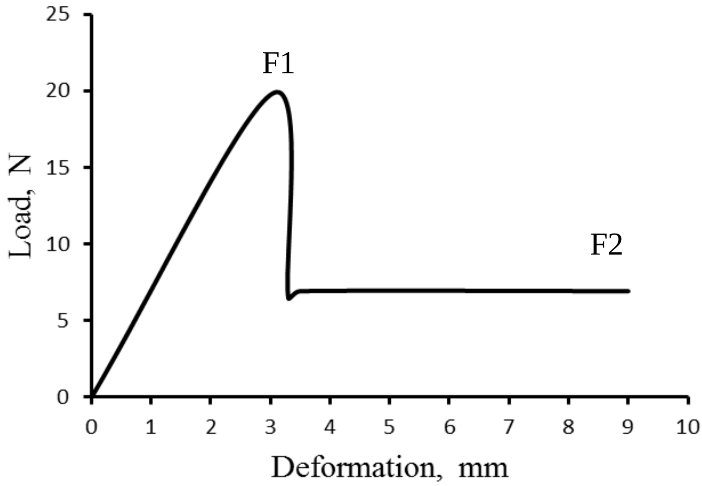

Fig. 3: Load vs. deformation for anna-apple fruit (destructive mode).

Yield strength of Nondestructive test:

A point “y” in Fig. 4 on the load-deformation (stress-strain) curve at which there occurs an increase in deformation (distortion) with a decrease of load. The bio-yield point “y” for persimmon fruit was 50.1 N, where deformation will continue without any additional force. Once the yield point is reached, the graphed line will go downward sloping line. This bio-yield point is an indication of initial cell rupture in the cellular structure of the persimmon material. As the force continue after the yield point, the rupture occurs at 70 N. This rupture point (R) on the curve occurs beyond the bio-yield point where the axially loaded sample ruptures under a load.

Repeating force for nondestructive condition:

Fig.(5) shows nondestructive compression test performed with flat plate. The test applied loading and unloading to the fruit when the plate moves about 7% of fruit original diameter. Pausing 5 seconds and then reloading to the same plate position. The load measured in Newton was expressed as a displacement function. It can be seen from the figure that the 1st and 2nd force followed clearly different force curves, but the unloading curves were almost the same.

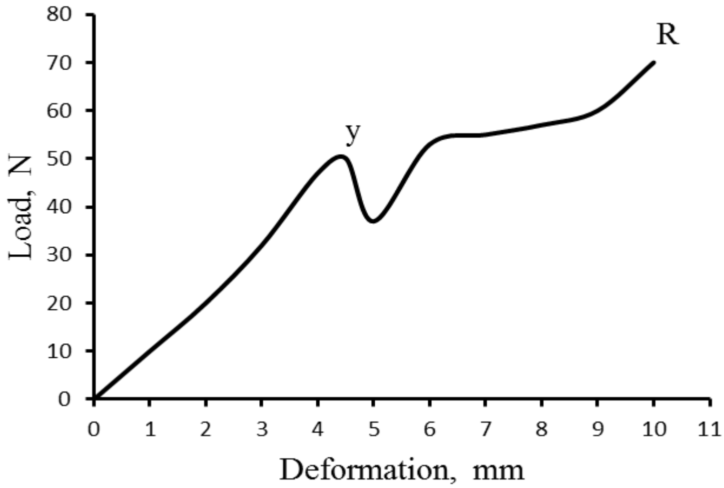

Fig. 4: Load-deformation curve for persimmon fruit samples in the parallel plate compression test.

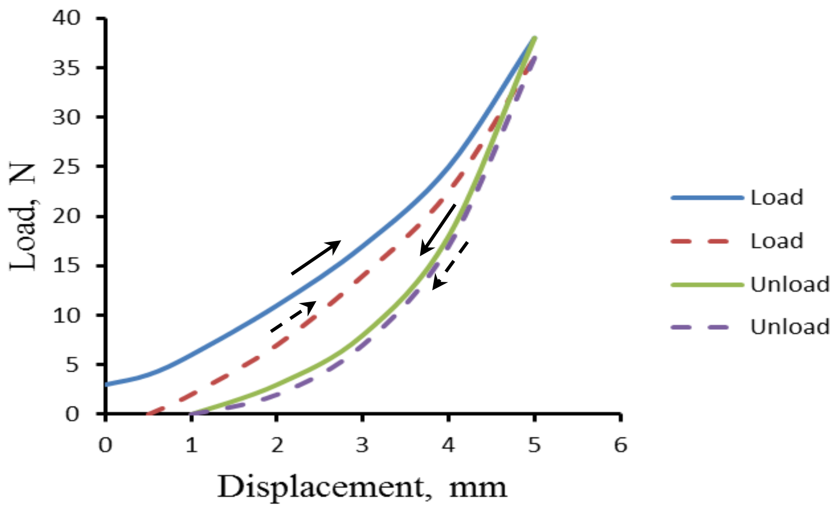

Fig. 5: Two successive load-displacement curves for anna-apple by using a 2-plates compressive test. The cycles include two loading and unloading stages.

CONCLUSIONS

An apparatus for measuing the hardness of fruits accurately has been described. The apparatus has been controlled by a computer to conduct either destructive or nondestructive tests depending on the fruit to be tested. Typical results for persimmon and anna-apple have been presented. Repeating press to the fruit will lead to soften it, this is very important when handling fruits by customers or packegers.

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الملخص العربى

جهاز لقياس جودة بعض المنتجات الثمرية بمساعدة الحاسب

عبد الفضيل جابر القبانى*

تم تطوير جهاز قياس بمساعدة الحاسب لقياس نضج ثمار الفاكهة والخضروات بسهولة ودقة. يمكن إستخدام الجهاز فى حالتى إتلاف وعدم إتلاف للثمار عن طريق تغيير رأس إختراق أو إنضغاط. تشمل القياسات صلابة القشرة، صلابة اللب لثمار التين الكاكى والتفاح أنا.

يتركب جهاز الإختبار من حاسب آلى يتحكم فى تشغيل موتور خطوى والذى بدوره يتحكم فى حركة الرأس. يمكن إستخدام أنواع مختلفة من الرؤوس إما لإختراق أو إنضغاط عينة الثمار. توضع عينة الثمار فوق خلية حمل تحت الرأس، ويتم التأثير بالحمل تدريجياً عن طريق حركة الموتور، ويتم إستقبال قراءة خلية الحمل والتى تمثل قوة إختراق أو إنضغاط الثمار من خلال مؤشر رقمى.

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لإختبار الجهاز إستخدمت عينات متجانسة الحجم تقريباً (٢٠ عينة) لتجنب الإختلاف فى صلابة الثمار الناتج عن الحجم (عادة الثمار الصغيرة أكثر صلابة من الثمار الكبيرة).

تم إجراء إختبار إختراق القشرة وإنضغاط الثمرة فى نفس الوقت، حيث يتم إختراق للقشرة أولاً، ثم بعد ذلك يندفع المسبار أكثر داخل الثمرة إلى أن يتلامس قرص الإنضغاط مع سطح الثمرة. بعد ذلك تنضغط الثمرة كلها حتى الإنهيار.

<u>وأظهرت النتائج ما يلى:</u>

- حدوث الاختراق فى الاختبار المتلف لثمار التين الكاكى عند ٣,٣ ن ويحدث الانهيار الكامل للثمرة عند ٤,٢ ن. حدوث زيادة طفيفة للقوة بين الاختراق والانهيار الكامل نتيجة للاحتكاك بين المسبار والجزء الداخلى من الثمرة.
- حدوث الاختراق لثمار التفاح المصرى فى الاختبار المتلف عند ١٩,٩ ن. والانهيار الكامل عند ٦,٩ ن.
- نقطة الإذعان لثمار التين الكاكى فى الاختبار غير المتلف ٥٠,١ ن. حيث يستمر تشوه الثمرة بدون تأثير اى قوى إضافية، وهذا مؤشر لإنهيار أولى فى البناء الخلوى، ويحدث الانهيار الكامل للثمرة عند ٧٠ ن.
- يؤدى تكرار الضغط على الثمار إلى طراوتها، وهذا هام جداً عند تداول الثمار بواسطة المستهلكين أو القائمين بالتعبئة.