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MECHANICAL RESISTANCE OF APPLE IN DIFFERENT PLACE OF FRUIT

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A b s t r a c t. Recent intensification of pomiculture production involves an increased exposure of the product to hazards of mechanical damage (mainly bruise). This damage, caused by external loading, leads to changes in structure, colour and taste of the fruit tissue. An engineering approach has been used by several investigators to analysing the mechanical properties of fruits.

The authors tried to describd the mechanical resistance of apple's flesh, skin and under-skin layer in different place of fruit, using various static tests (bending, compression and tension).

The energy, force and deformation caused damage of the apple tissue were noticed. The values for modulus of elasticity have been determined from the force-deformation curves resulting from subjecting the material samples to quasi-static, loading tests. The determination of the effect of such factors as variety, place of sampling and type of test on the variability of the mechanical properties of fruits was studied.

K e y w o r d s: apple fruit, mechanical resistance

INTRODUCTION

Recent intensification of pomiculture production involves an increased exposure of the product to hazards of mechanical damage (mainly bruise). This damage, caused by external loading, leads to changes in structure, colour and taste of the superficial of fruit tissue. The resistance of apples to bruising and the potential for good storability are related to its firmness. Firmness can be quantified by mechanical loads simulating realistic stresses, and is commonly measured by hand-held penetrometer as the force required to puncture exposed flesh with a 11.1 mm blunt cylindrical tip [5].

Fruit bruises are caused by three types of loading: compression, impact, and vibration [2]. The quasi-static loading has been used by several investigators to analysing the mechanical properties of fruits [1,6,7]. They have attempted to provide the mechanical characteristics of apple flesh and skin. The values for modulus of elasticity have been determined from the force-deformation curves resulting from subjecting the material samples to quasi-static, loading tests [3,4,6,7].

Determination of the mechanical resistance of apple flesh, skin and under-skin layer in different place of fruit, using various static tests (bending, compression and tension) was the main aim of this study.

MATERIAL AND METHODS

Apples of varieties: James Grieve, Jerseymac and Melba, for this study were hand-picked from trees in the Lublin University of Agriculture orchard. Each variety was harvested on a date when it reached the state of maturity normal for harvest in a commercial operation.

Each fruit was divided into three parts: I - near the stalk, II - the middle part, III - near the cup and only 8 mm superficial layer of apple was used (Fig. 1). Three samples of each apple part were cut out for bending, tension and compression tests. Thirty samples were used as one combination. The maximum force, the deformation and energy were noticed using three tests. The beam of apple

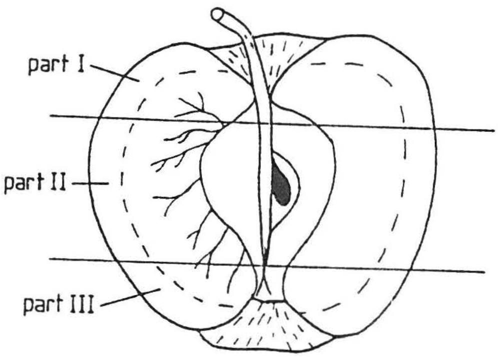

Fig. 1. Sampling location.

flesh, the beam of flesh with the skin over and the beam with the skin under the flesh were loaded in bending test. The cross-section of the beam was 3x3 mm, the distance between the points of support was 10 mm. The flesh cube (3x3x3 mm) was compressed between two parallel plates. The skin belt (2 mm width and 0.2-0.3 mm thick) was disrupt in tension test.

Forces-caused deformations: 0.2, 0.3, 0.4 and 1 mm were used to calculate the modulus of elasticity from the formulas:

- for the bending test:

$$EL = \frac{L^3(F_2 - F_1)}{4\,b\,h^3(d_2 - d_1)} \quad (1)$$

where E - modulus of elasticity (MPa), L - distance between the points of support (mm), F_1 - force causing deformation 0.3 mm (N), F_2 - force causing deformation 0.4 mm (N), b - width of the beam (mm), h - height of the beam (mm), d_1 - deformation 0.3 mm, d_2 - deformation 0.4 mm.

- for the compression and tensile tests:

$$EL = \frac{(F_2 - F_1)}{A\,(e_2 - e_1)} \quad (2)$$

where E - modulus of elasticity (MPa), F_1- force causing deformation 0.2 mm for the compression test and 0.4 mm for the tension test, F_2 - force causing deformation 0.3 mm for the compressiontest and 1 mm for the tension test, A - cross-sectional area relative strain for the deformation 0.2 mm for the compression test and 0.4 mm for the tension test, e_2 - relative strain for the deformation 0.3 mm for the compression test and 1 mm for the tension test. The values of force and deformation for calculation were chosen from the straight-line part of the curve. All routine calculations (average value, standard deviation and coefficient of variance) were made. These tests were carried out on the universal apparatus INSTRON 6022. The speed of the cross head of the machine was 5 mm/min.

RESULTS

The energy, the maximum force and the deformation (caused damage) noticed during compression test are showed in Fig. 2, and the highest values were obtained for variety James Grieve. There were not differences between testing parts of fruit.

Among the varieties, the lowest elastic modulus of the flesh in compression test was obtained for Melba variety (0.97 MPa), and the highest for James Grieve (1.33 MPa) variety (Fig. 2). The lowest modulus of elasticity was observed for middle part of apple (1.02 MPa). There were not differences between two other parts of fruit. The similar tendency was noticed for tension test of the skin (Fig. 3). Among the varieties, the highest elastic modulus of skin was obtained for Melba (14.26 MPa) variety, and lowest for Jerseymac (10.30 MPa) variety.

The energy, the maximum force and the deformation caused damage obtained for the skin measurements are showed in Fig. 3.

The highest values of force (1.32-2.67 N), deformation (1.61-1.72 mm) and energy (1.26-2.45 mJ) for the beam with the skin under the flesh were observed in bending test. The lowest force (0.45-1.30 N) and energy (0.19-0.90 mJ) for the beam without skin and the deformation (0.58-1.17 mm) for beam with the skin over the flesh were obtained.

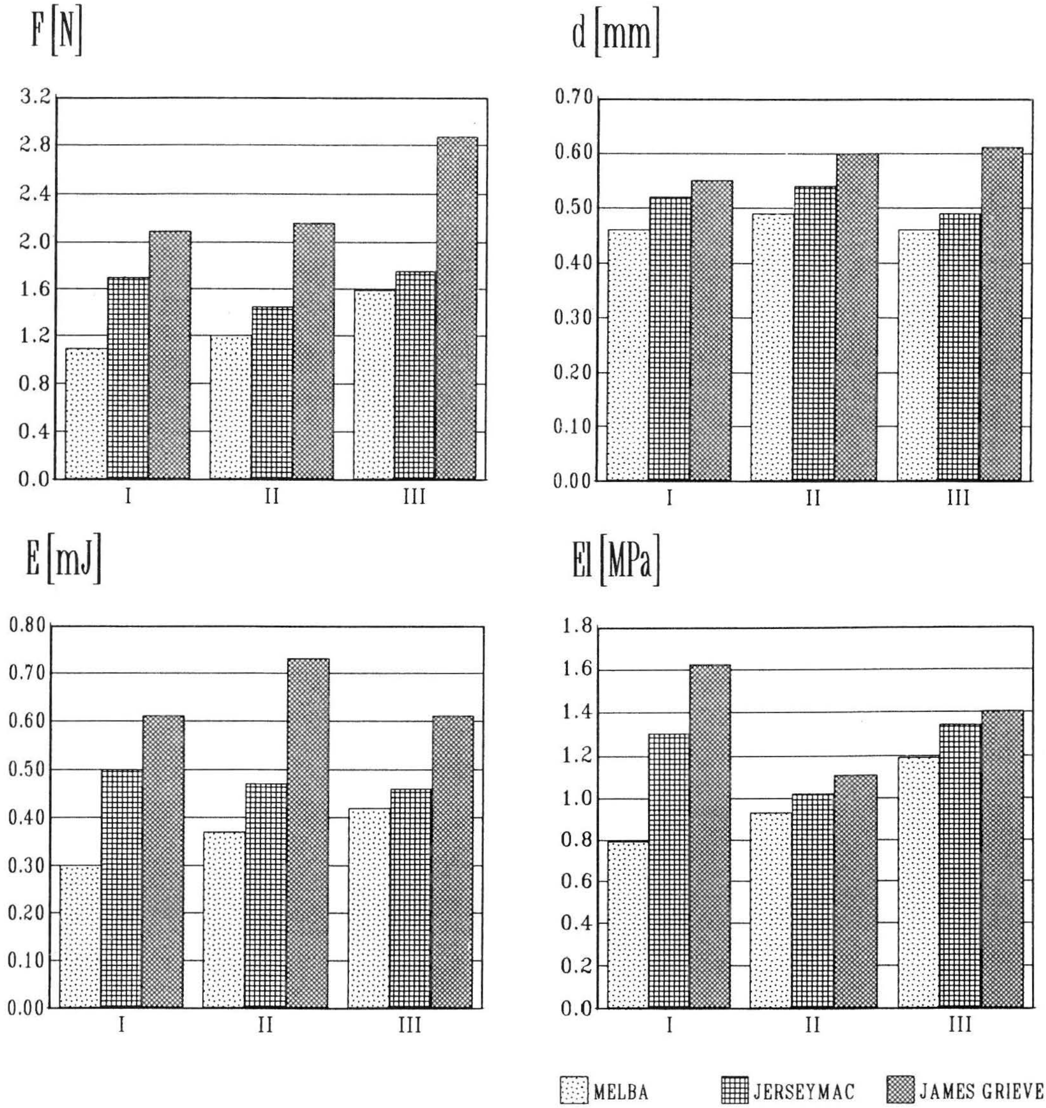

Fig. 2. Damage force (F), deformation (d), energy (E) and modulus of elasticity (El) of apple flesh for Melba, Jerseymac and James Grieve varieties.

The average values of the elastic modulus for bending test are shown in Fig. 4. The lowest values were stated in bending test for flesh without skin (1.6-2.74 MPa). The highest values of elastic modulus was obtained for variety Jerseymac for beam with the skin independently to the skin position (4.87-4.96 MPa).

CONCLUSIONS

1. The elaborated methods of determining the mechanical properties of apple skin and flesh allowed to estimate superficial layer of apple fruits.
2. The highest values of energy, maximum force and deformation (caused damage) noticed during compression test were obtained for variety James Grieve.

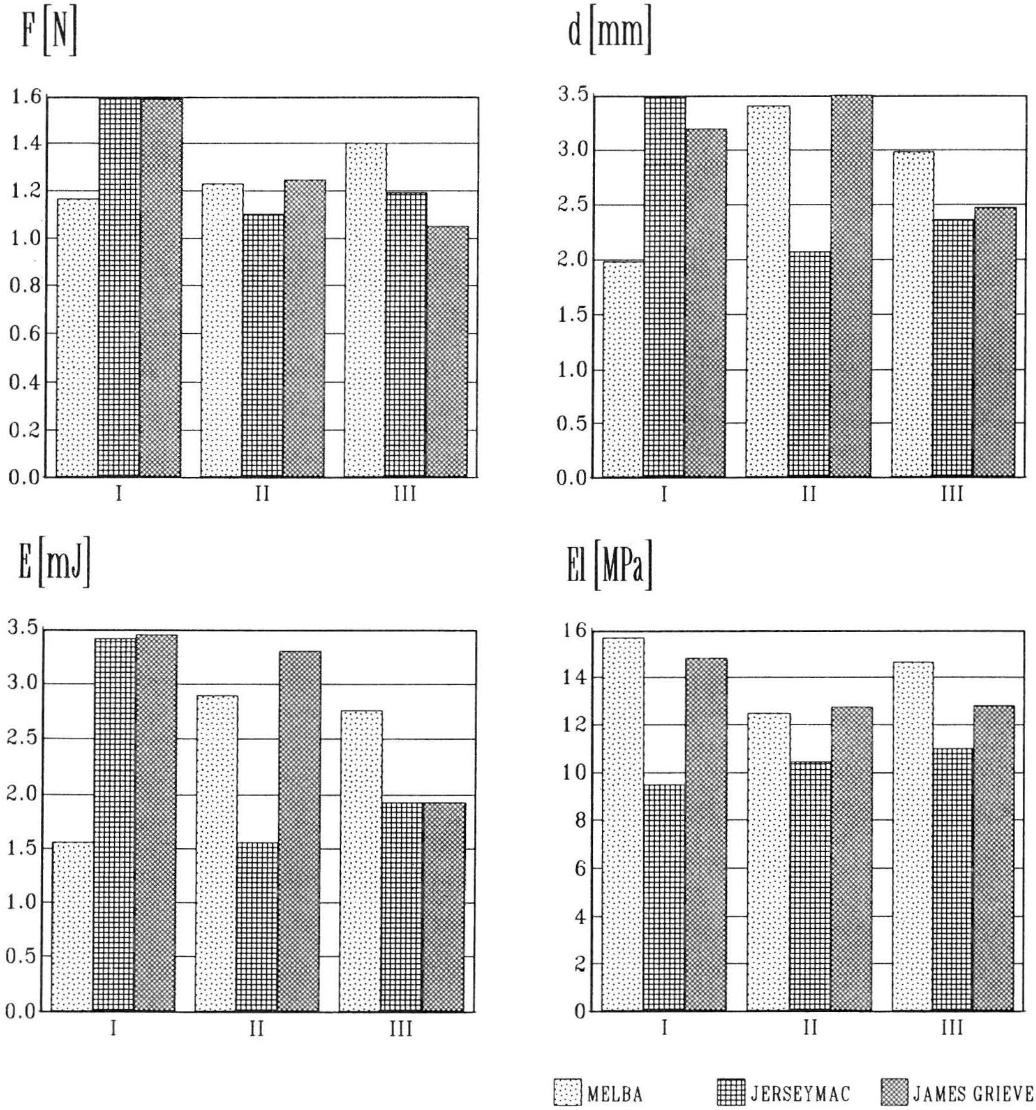

Fig. 3. Damage force (F), deformation (d), energy (E) and modulus of elasticity (El) of apple skin for Melba, Jerseymac and James Grieve varieties.

3. The highest values of elastic modulus was obtained for variety Jerseymac for beam with the skin independently to the skin position (4.87-4.96 MPa).

4. The lowest modulus of elasticity determined in compression test was observed for Melba (0.97 MPa) variety and in the middle partof apple (1.02 MPa) for all studied varieties.

5. Among the varieties, the highest elastic modulus of the skin was obtained for Melba (14.26 MPa) variety, and lowest for Jerseymac (10.3 MPa) variety.

6. The modulus of elasticity determined in bending test of apple beam includes in one parameter mechanical properties of flesh and skin.

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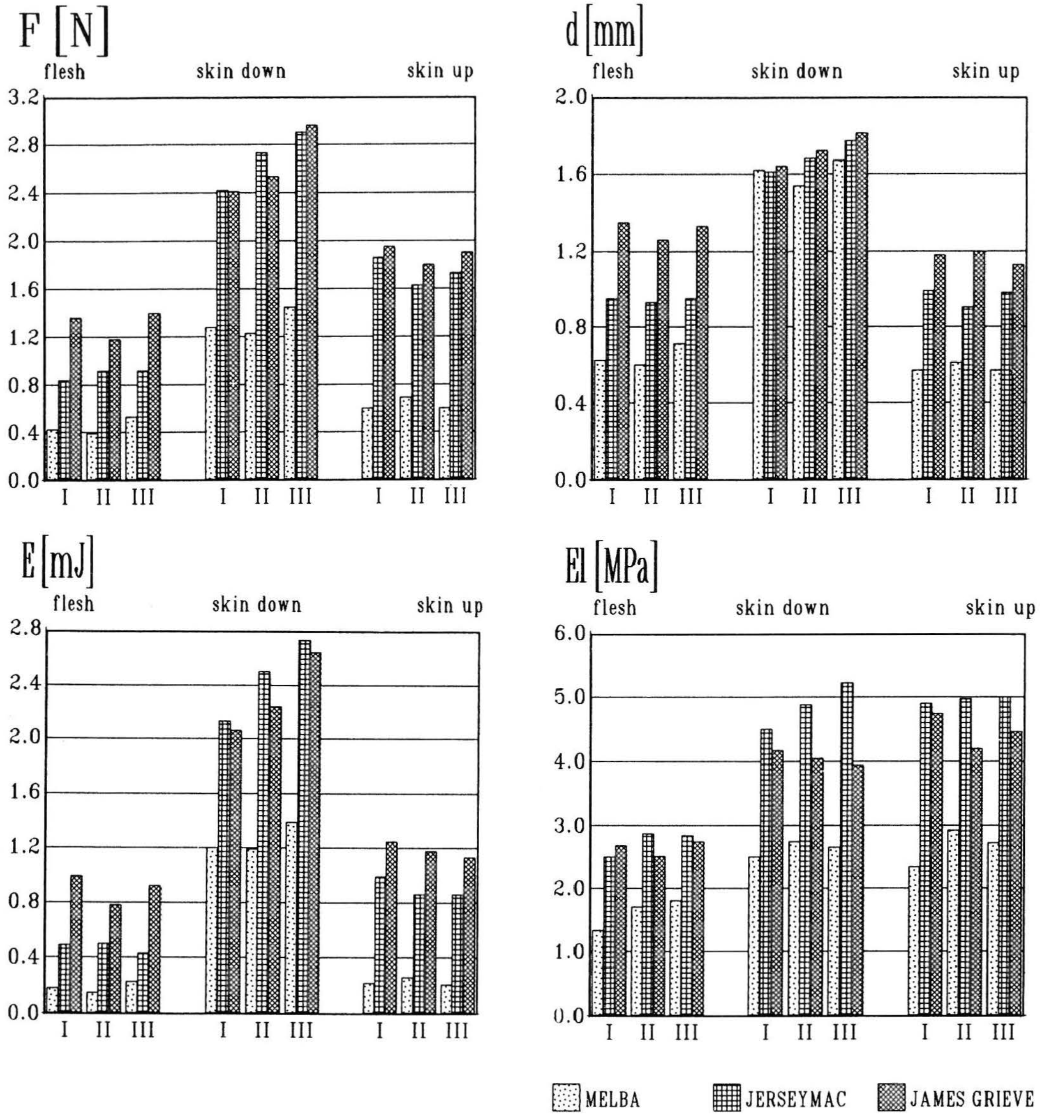

Fig. 4. Damage force (F), deformation (d), energy (E) and modulus of elasticity (El) of apple beam for Melba, Jerseymac and James Grieve varieties.

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