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SHAPE AND STRENGTH OF *RED HAVEN* PEACHES AT THE DIFFERENT STAGES OF THEIR MATURITY

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Abstract

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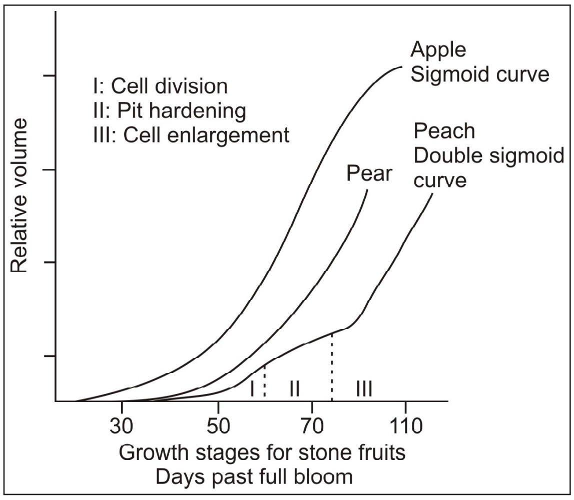
Global shape of the peaches of the *Red Haven* variety (harvested on different days during July, 2007) has been characterized by calculating the *H*/*D*s, *H*/*D*c and *D*c/*D*s ratios. There is no, or nearly no, differences between peaches harvested at the different days. The shape of the all tested peaches was very close to round one. The more detailed description of the peach shape is based on the Elliptic Fourier analysis (EFDs) of the digital photos. The knowledge of the parameters (curvature etc.) is very useful e.g. for the evaluation of the results of the strength tests. Compression tests have been also perforemd – the whole peaches have been compressed between two plates at the constant cross–head velocity 20 mm/min. The force–displacement curves are characterised by certain monotonic increase and the point called bioyield, where force exhibits a drop. The bioyield significantly decreases with the date of the harvesting. There is no evidence of the dependence of this parameter on the direction of loading. The same result is approximatively valid for apparent modulus of elasticity *E*. The force–displacement curves have been successfully modelled by non-linear mathematical models.

peach, strength properties, shape analysis, maturity

The quality of peaches at consumption depends highly on maturity and ripeness at harvest. There are three stages of peach fruit development. Following bloom, Stage I is a period of cell division and rapid fruit growth, during which the endocarp accounts for most of the size increase (Ryugo, 1988). Stage I ceases about 50 to 60 days after bloom. Stage II, which can last for varying lengths of time, is marked by pit hardening and slow fruit growth, whereas rapid growth until harvest occurs in Stage III. Fruit growth during the final period is through enlargement of the mesocarp cells (Ryugo, 1988). Stage III usually lasts approximately six weeks see Fig. 1.



1: *Schematic of the fruit growth curves (redesigned picture from Jackson, 1975)*

As peach fruit development is completed, the fruit become mature and subsequently ripen. In this study, the terms "mature" and "physiological maturity" refer to the stage of development where a fruit has the ability to "ripen". Maturity must occur on the tree, while ripening can occur on or off the tree. Mature is synonymous with completeness of development, while the term ripe implies readiness for use (Haller, 1952). Changes that occur during maturation and ripening include a gradual decrease in flesh firmness, a change in ground colour from mainly green to mainly yellow, increases in the area and intensity of overlying red colour (blush), a change in flesh colour from whitish green to pale yellow, and a marked increase in flavour. Changes in quality occurring during maturity and ripening include increases in sugar concentration and aromatic compounds, decreases in acid concentration, and development of a less crunchy texture (Lott, 1965).

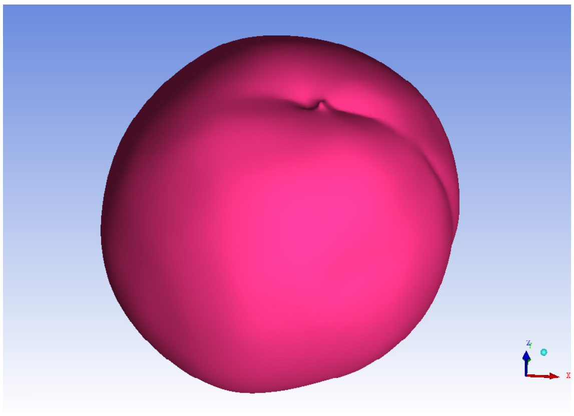
Next aspects of the fruit quality consists in the regularity of fruit shape and proportion of the compartments of the fruit of interest to the consumers (mesocarp in the case of peach). In general, selection criteria of peach fruit should also focus on obtaining a round fruit with a little round well–centered stone, even though some programs concern in obtaining a flatish fruit (Pascal, 1998).

The present paper is focused on the investigation of the peach shape and on the strain behaviour of the whole peaches, which were harvested at the different days.

MATERIAL AND METHODS

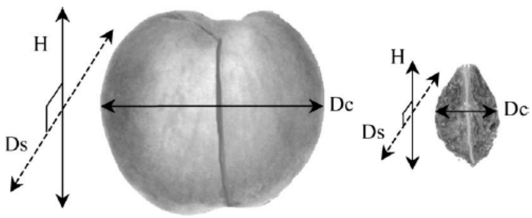
Peach shape evaluation

The shape of the peach is generally very complicated – see Fig. 2 as an example. The complete geometrical model must be based on the 3D scanning of this fruit. Such procedure is very expensive. This is why another approach have been used.



2: *3D scan of the peach*

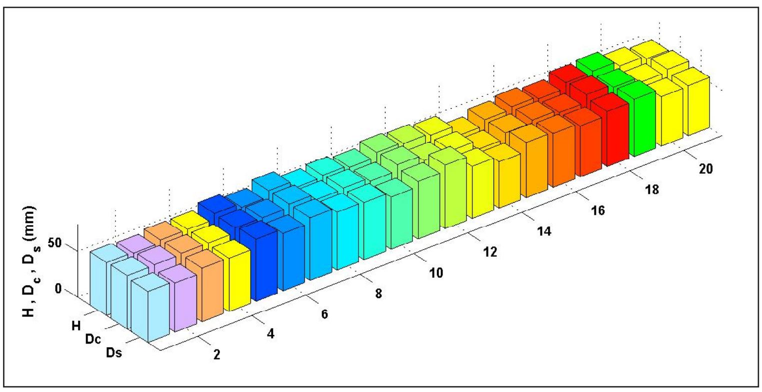
In order to describe the peach shape the three dimensions of the whole fruit and of the stone, i.e. height (*H*), cheek diameter (*Dc*) and suture diameter (*Ds*) are evaluated – see Fig. 3.



3: *Three different dimensions measured on the fruit and the stone*

Global shape of the fruit and stone were characterized by calculating the *H*/*Ds*, *H*/*Dc* and *Dc*/*Ds* ratios. When the ratio was found to be 1, the shape was globally round. When they were different from 1, the shape was oval.

For the experiments the peaches of the *Red Haven* variety have been used. Peaches have been harvested on different days during July, 2007. The total mass of the peaches, m, and the parameters shown in the Fig. 3 have been evaluated. The example of the variation of these parameters is given in the Fig. 4.

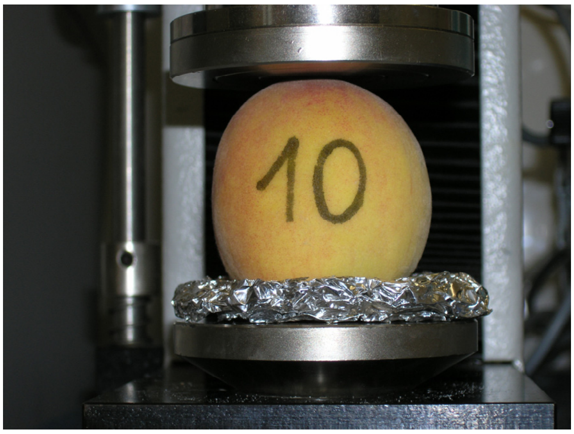


4: *The parameters of the shape of the peach. Peaches harvested on July 12, 2007*

The more detailed description of the peach shape is based on the analysis of the digital photo. Such methods are valuable for researchers in various fields, such as genetics, agriculture, ecology and taxonomy. Elliptic Fourier descriptors (EFDs), originally proposed by Kuhl and Giardina (1982), can delineate any type of shape with a closed twodimensional contour. EFDs have been effectively applied to the analysis of various biological shapes in animals (Rohlf and Archie 1984; Ferson et al. 1985; Bierbaum and Ferson, 1986; Diaz et al., 1989; Liu et al. 1996; Laurie et al., 1997) and plants (White et al., 1988; McLellan, 1993; Furuta et al. 1995; Ohsawa et al. 1998; Iwata et al., 1998; Iwata et al., 2000; Toyohara et al., 2000; Iwata et al., 2002; Uga et al., 2003; Iwata et al., 2004a, 2004b; Yoshioka et al., 2005a, 2005b, 2006a, 2006b). Evaluation based on EFDs also gives sufficient resolution¸ in combination with quantitative genetic analysis, to elucidate the inheritance of biological shapes

Compression test

The whole peaches has been compressed between two plates at the constant cross – head velocity 20 mm/min using the TIRA testing machine – see Fig. 5 as an example.



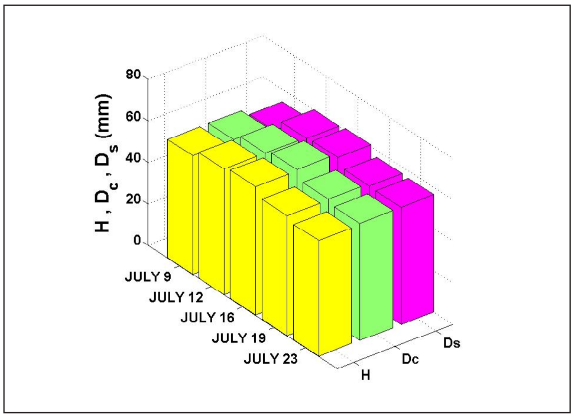
5: *Photo of the compression test*

The peaches have been loaded in the main directions shown in the Fig. 3. Force–deformation curves were recorded by the data acquisition system and the strength properties were measured by these curves.

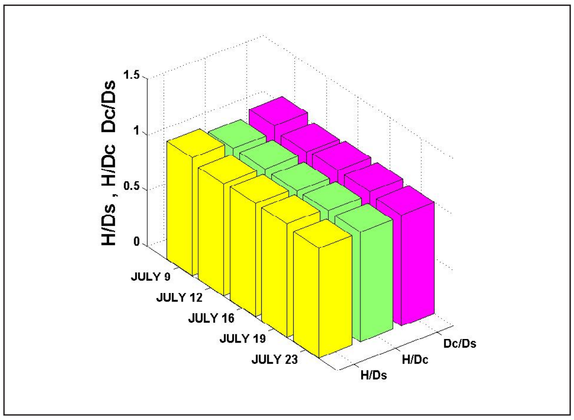
RESULTS AND DISCUSSION

The values of *H*/*D*s, *H*/*D*c and *D*c/*D*s ratios obtained for peaches harvested on the different days are shown in Fig. 6. It is evident that there is no, or nearly no, differences between peaches harvested at the different days. The term of the harvesting exhibits no influence on the peach shape. The shape of the all tested peaches is very close to round one – see Fig. 7. Figs. 8–10 demonstrate that the parameters of the shape are mutually dependent.

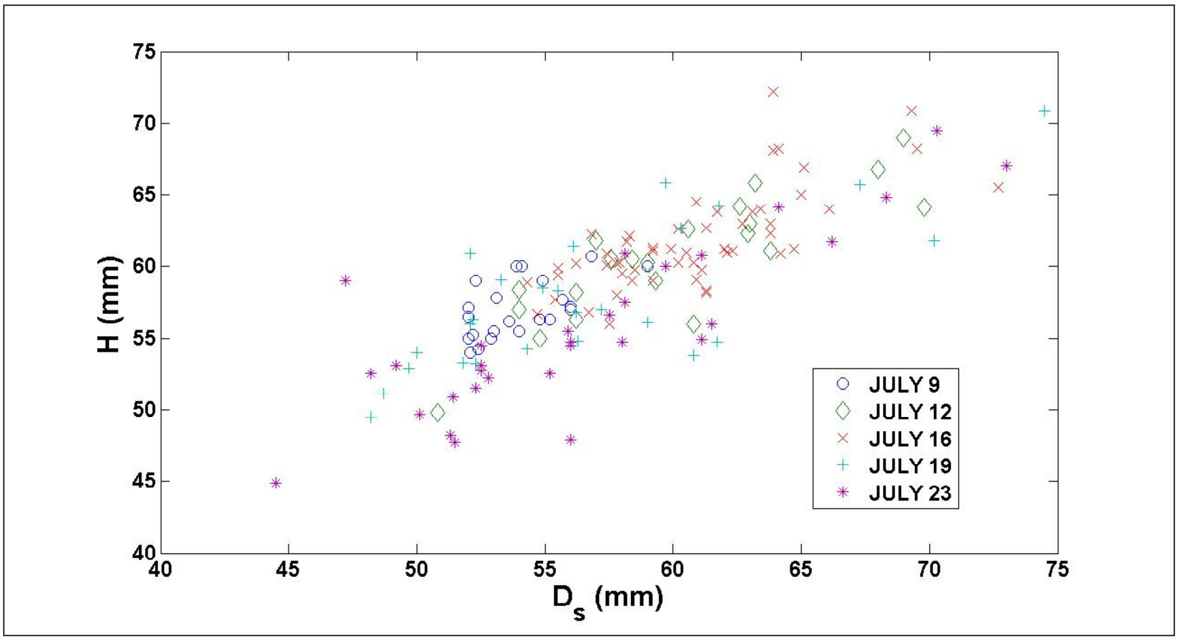
We established a similar global linear relationship for peaches harvested on different days between the dimensions taken in pairs (Fig. 8–10). Slopes of these relationships were not significantly different from 1.



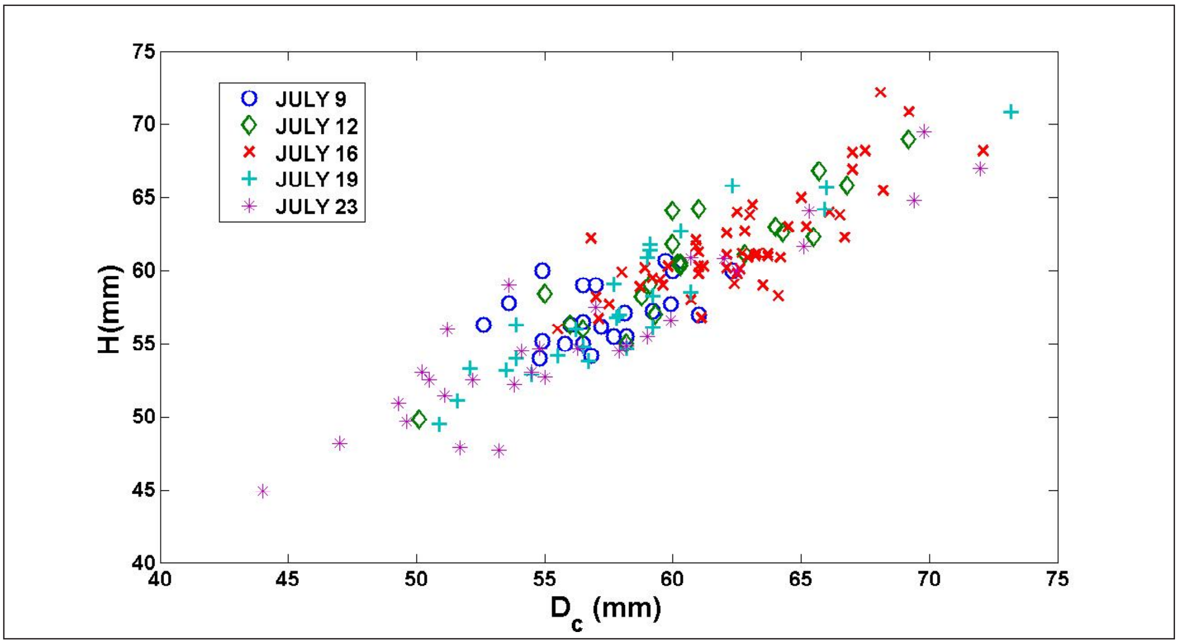
6: *The average values of the parameters describing the peach shape*



7: *The difference between round and real shape*



8: *The relation between parameters describing peach shape*

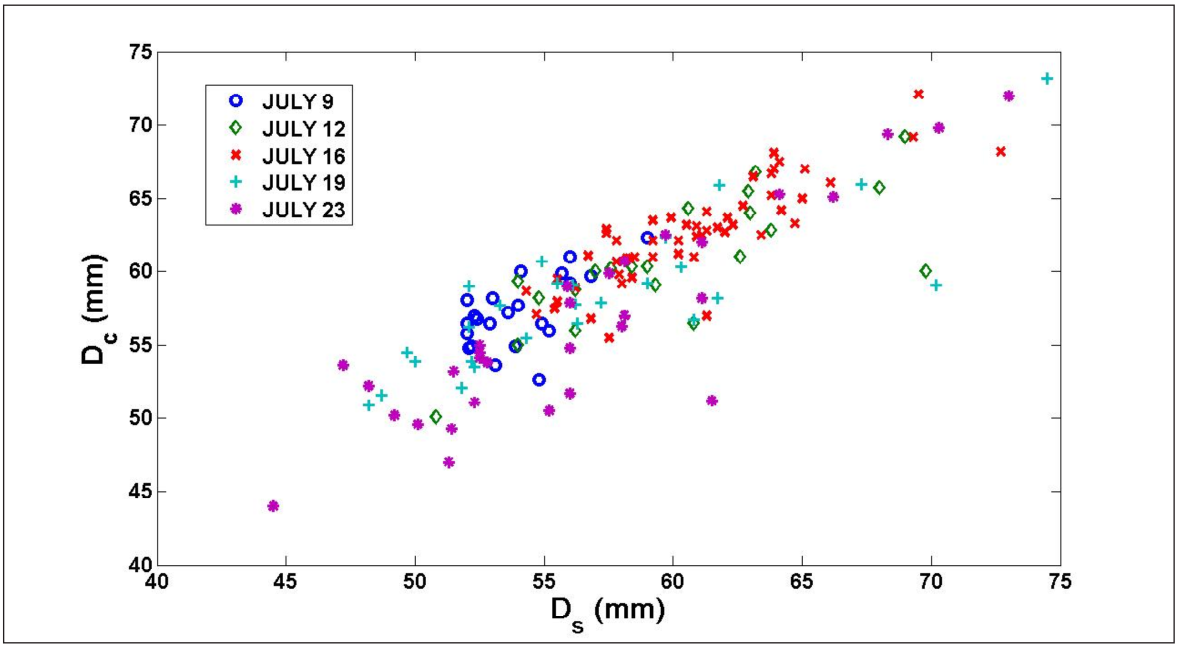


9: *The relation between parameters describing peach shape*

The analysis of the digital image by the method mentioned above enables to obtain a description of the peach countour in the form:

$$x(\varphi) = r \cos \varphi, y(\varphi) = r \sin \varphi,$$

where r is the radius and φ the polar angle. The knowledge of this description can be used for the evaluation of the radius of the curvature R. The knowledge of this parameter is than very useful e.g. for the evaluation of the results of the compression test.



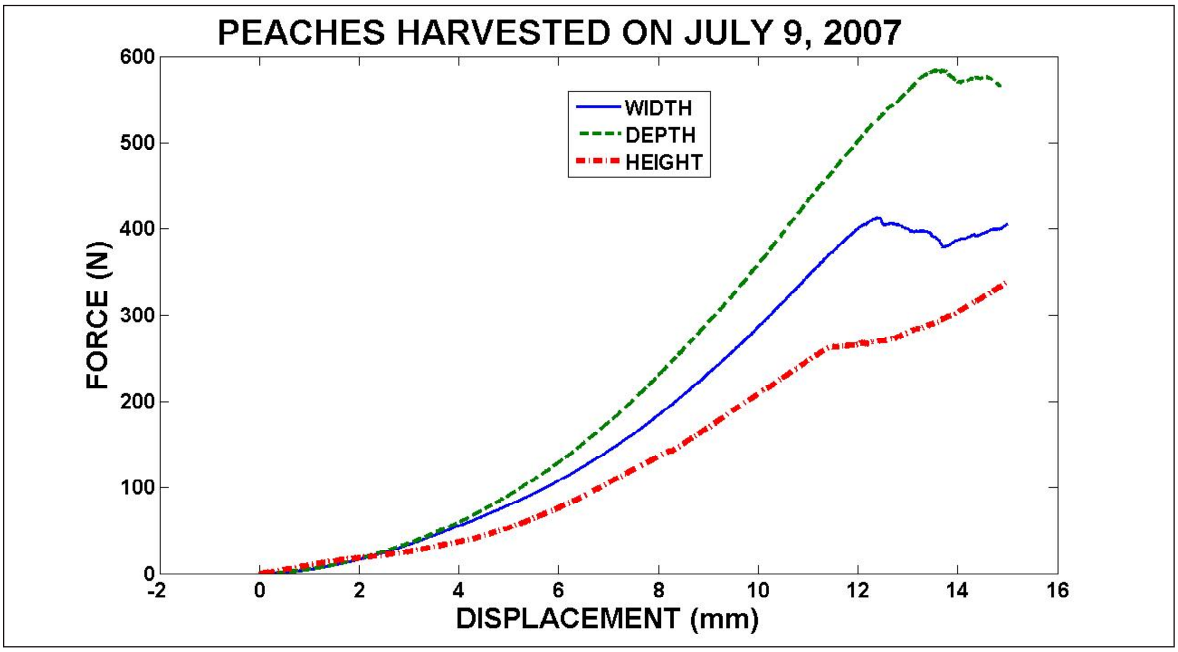
10: *The relation between parameters describing peach shape*

Compression test

Examples of the force-displacement curves are shown in the Fig. 11.

The curves are characterised by certain monotonic increase and the point where force exhibits a drop. This point is usually termed as the bioyield. Before the bioyield point the dependence of the force F on the displacement x is well fitted by the non-linear function:

$$F(N) = ax^3 + bx^2 + cx.$$



11: *The depence force – displacement*

At the bioyield the bruise of the peach starts. The next parameter is the apparent modulus of elasticity, which can be evaluated as the tangent elastic modulus mid–way along the force deformation curve between the origin and the yield point from the following equation:

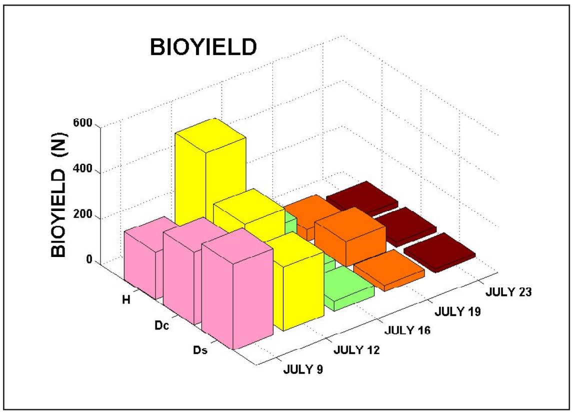
$$E = \frac{0.338 K_u^{\frac{3}{2}} F \left(1 - \nu^2\right)}{x^{\frac{3}{2}}} \left(\frac{1}{R} + \frac{1}{R'}\right),$$

where E is the apparent modulus of elasticity in Pa, F is the applied compressive force in N, μ is Poisson´s ratio (dimensionless), x is the displacement under compression in m, K_u is the constant, R is the minimum radius of curvature of the sample at the point of contact in m, $R´$ is the maximum radius of curvature in m.

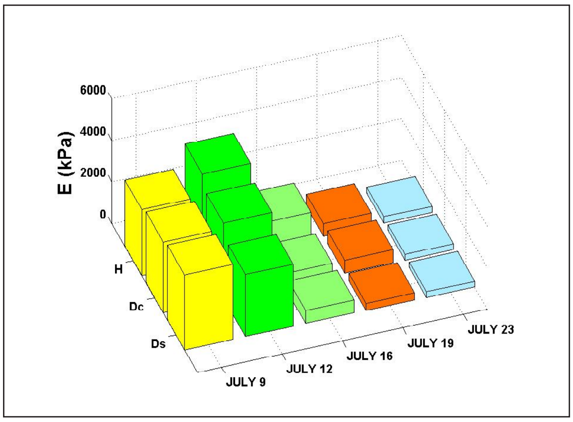
The values of of the bioyield are displayed in Fig.12.

It is evident that the bioyield significantly decreases with the date of the harvesting. This fact is valid since certain days. There is no evidence of the dependence of this parameter on the direction of loading.

The same result is approximatively valid also for the apparent modulus of elasticity E – see Fig. 13.



12: *Bioyield of the peaches – an average value from about 5 measurements*



13: *Apparent modulus of elasticity of the peaches – an average value from about 5 measurements*

SUMMARY

Shape of the peaches of the *Red Haven* variety has been characterized by calculating the *H*/*D*s, *H*/*D*c and *D*c/*D*s ratios. Detailed description of the peach shape has been based on the Elliptic Fourier analysis (EFDs) of the digital photos. Compression tests have been also perforemd – the whole peaches have been compressed between two plates at the constant cross–head velocity 20 mm/min.

The results suggest that the peach shape appeared stable and round. The day of the harvesting plays no or only minor role in the development of the main parameters which describe the peach shape. Because the fruit shape is determined by mesocarp growth in the various directions of the fruit, one can conclude that this growth is different in the different directions in the peach. This conclusion follows from the shape of the stone. The more detailed examination of this effect will be subject of the forthcoming papers.

It was found that the peaches exhibited superior strength properties at the beginning of the harvest, and that after about 7 days they softened rapidly. Therefore, it is advisable to do most handling, such as packing and transportation, within about 7 days after beginning of the harvest.

SOUHRN

Hodnocení tvarů a mechanických vlastností broskví *Red Haven* v různých stadiích zralosti

V rámci této práce byly hodnoceny tvary a mechanické vlastnosti broskví odrůdy *Red Haven* sklízených v různých fázích zralosti v červenci 2007. Tvar plodů a pecek byl popsán vypočtenými poměrovými parametry *H*/*D*s, *H*/*D*c a *D*c/*D*s. Je zřejmé, že neexistuje zřejmý kvantifikovatelný rozdíl v tvarech broskví sklízených v různých termínech (stadiích zralosti). Tvar téměř všech broskví sledovaných v rámci tohoto výzkumu byl téměř kulový. Detailnější rozbor tvaru broskví byl založen na obrazové analýze digitálních snímků plodů. Použita byla tzv. Eliptická Fourierova analýza (EFD). Analýza vedla k výpočtu poloměrů křivosti. Tento parametr byl dále využit při hodnocení mechanických vlastností broskví. Celé plody byly stlačovány ve všech hlavních směrech mezi dvěma deskami (hlavicemi) zkušebního stroje rychlostí 20 mm/min. Byly získány křivky závislostí síla–posunutí, které byly následně modelovány pomocí nelineárních modelů. Křivky vykazovaly počáteční lineární region nárůstu. Za tímto regionem následoval ve všech případech bod, kdy nastal pokles síly. Tento bod je obvykle nazýván „bioyield". Od fáze „bioyield" začínají na plodech vznikat otlaky. Je zřejmé, že poloha bodu „bioyield" je závislá na datu sklizně – jeho hodnota se výrazně snižuje s datem. Tento závěr je platný až od určitého stupně zralosti. Nebyla zaznamenána závislost tohoto parametru na směru zatěžování. Obdobný závěr je možno vyvodit i pro vypočtený zdánlivý modul elasticity. Z výsledků měření vyplývá, že broskve vykazují výborné mechanické pevnostní charakteristiky během první sedmi dnů sklizňové sezony. V dalších dnech se tyto vlastnosti výrazně zhoršují. Proto je doporučováno, aby byla většina manipulačních operací (balení, transport apod.) prováděna na začátku sklizně.

broskev, mechanické vlastnosti, analýza tvaru, zralost

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