# MECHANICAL PROPERTIES OF SWEET AND SOUR CHERRIES AND THEIR SUSCEPTIBILITY TO MECHANICAL DAMAGE

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A compression test between two plates has been used for testing the mechanical properties of 24 varieties of sweet and sour cherries. Results are compared with organoleptic properties obtained from panel tests and special free fall tests onto thick steel plate. The first part of compression curve, which relates to the force and compression strain, can be described by a power relation. The exponent of this relation has an approximate value 3/2 for firmer cherries (e.g. hard sweet cherries) and higher values for softer cherries (mostly sour cherries). The first ones have higher resistance to skin damage during their impact, and on the other hand the higher resistance to fruit bruising can be expected for the others. Further relation between the observed quantities are briefly discussed.

cherries; mechanical properties; bruising; mechanical damage; skin rupture; compression test

## INTRODUCTION

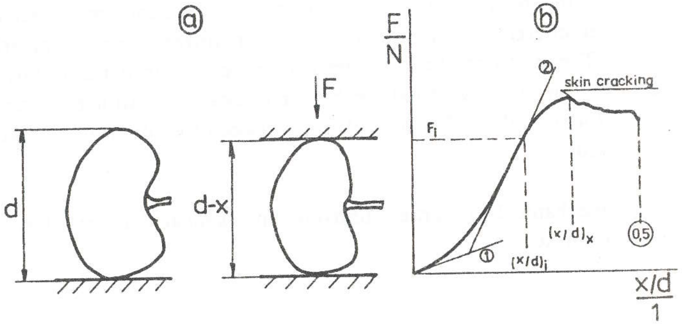
Quality of harvested cherries is considerably dependent on both mechanical and textural properties. This trivial statement has a special meaning in the case of mechanized fruit harvesting where a considerable portion of fruit may be mechanically damaged. Mechanical properties vary with cultivar. Therefore, mechanical properties of cherry fruit of different varieties can be used in selection of those cultivars the most suitable for mechanical harvesting. Mechanical properties of cherries are most often evaluated by compression between two plates (Patten and Patterson, 1985a, b; Blahovec et al., 1991b).

Compression tests between two plates have been also used in the present study to evaluate the fruit of a large group of varieties. Results are compared with those of taste panel test (susceptibility to pressure damage, flesh and skin texture), and the free fall test applied for the determination of fruit resistance to impact damage.

## MATERIALS AND METHODS

Fruits of 24 varieties of sweet and sour cherries were harvested from the experimental orchards of the Research and Breeding Institute of Fruits at Holovousy in a limited experiment in 1989 and repeated in 1990. Fruits were transported in plastic bags to the Prague laboratory of Research Institute of Food Industry on the same day, stored in refrigerator (at approximately 10 °C) and tested within 36 ours. Tab. I summarizes the tested varieties and also gives some of their characteristics.

Sets of 20–30 cherries of each variety were used for compression testing of individual fruits between two plates as is shown in Fig. 1. In all cases, the rate of deformation was always the same, 0.83 $mm.s^{-1}$ and was stopped at the




1. Scheme of fruit compression test between two plates: a) Fruit with initial diameter (*d*) is compressed at constant strain rate by variable compression force *F*. b) So called compression curve, i.e. the plot of force *F* vs. compression strain *x/d*. The experiment is stopped at compression strain 0.5. Point of inflection on the compression curve has coordinates $(x/d)_i$ and $F_i$; the linear approximation of the compression curve is defined by equations $F = a_1 + b_1 x/d$ for *x/d* less than 0.1 and $F = a_2 + b_2 x/d$ for *x/d* higher than $(x/d)_i$ –0.1 and less than $(x/d)_i$

compression strain $x/d = 0.5$. All fruits were compressed without desteming (the stems of fruits were only shortened on a length of approximately 5 mm). Position of the fruit during its testing between two plates is clearly shown in Fig. 1a. A typical compression curve, which is obtained for each compressed fruit as the dependence of compression force *F* and compression strain *x/d*



I. Basic characteristics of tested fruits

| Sort and variety | DR | Mean fruit dimension | | |
|---|---|---|---|---|
| | | diameter in mm | mass in grams | |
| | | | total | flesh |
| SWEET CHERRIES (*Prunus avium* L.) | | | | |
| Heart (var. *juliana* L.) | | | | |
| Karešova | 2 | 20.0 | 6.21 | 5.74 |
| | *2 | 19.2 | 5.98 | 5.52 |
| Kaštánka | 2 | 18.2 | 4.38 | 4.04 |
| Semihard (var. *duracina* L. x var. *juliana* L.) | | | | |
| Burlat | 2 | 20.1 | 6.71 | 6.31 |
| Büttner | 5 | 18.3 | 3.86 | 3.49 |
| Frühe Rote Meckenheimer | 2 | 20.9 | 7.10 | 6.63 |
| Lambert | 6 | 20.2 | 5.62 | 5.08 |
| Moreau | *2 | 21.2 | 5.95 | 5.38 |
| Hard (var. *duracina* L.) | | | | |
| Granát | 4 | 18.3 | 4.99 | 4.65 |
| Kordia | 6 | 19.5 | 5.65 | 5.23 |
| | *6 | 21.1 | 6.41 | 5.94 |
| Napoleonova | 5 | 18.5 | 4.83 | 4.43 |
| | *5 | 21.1 | 6.44 | 5.98 |
| Starking Hardy Giant | 5/6 | 21.3 | 5.02 | 4.51 |
| Schneiderova (Thurn–Taxis) | 6 | 21.5 | 7.42 | 6.90 |
| Sam | 5 | 19.4 | 5.47 | 5.00 |
| Stella | *5/6 | 23.1 | 8.70 | 8.16 |
| Stella Compact | 6 | 21.7 | 6.46 | 6.03 |
| Těchlovická | *5/6 | 20.5 | 6.50 | 6.05 |
| Van | 5 | 19.8 | 5.28 | 4.93 |
| SOUR CHERRIES (*Prunus Cerasus* L. subsp. *eucerasus* A. GR., var. *austera* L.) | | | | |
| Érdi bötermö | 6 | 19.4 | 5.15 | 4.69 |
| Fanal | 7 | 18.3 | 4.74 | 4.20 |
| Körösi | 7 | 19.2 | 4.34 | 3.81 |
| Montmorency | *5/6 | 19.6 | 5.35 | |
| Morellenfeuer | 8 | 16.2 | 3.98 | 3.60 |
| North Star | 7 | 16.4 | 4.22 | 3.87 |
| | *7 | 16.0 | 3.42 | |
| Záhoračka | 5 | 17.5 | 3.70 | 3.24 |
| | *5 | 17.4 | 3.16 | |

DR – date of ripening in cherry weeks for 1990 and 1989 (*)

(as a ratio of the actual deformation of the fruit and its initial diameter), is plotted in Fig. 1b. Compression curves have three important points, i.e. initial point, point of inflexion, which is denoted by index *i*, and point of skin rupture or cracking, denoted by index *x*. Evaluation procedures for compression curves are given in Fig. 1b and these are described in its legend. Values of compression strain corresponding to skin rupture point were also evaluated by observation of the fruit surface during fruit compression. Detailed examination of fruit surface after deformation revealed which parts of the skin were damaged. A substantional portion of the compression curve, from the beginning nearly to the point of inflexion, can be described by the following relationship (B l a h o v e c et al., 1991b):

$$F = a_3\,(x/d)^k \qquad (1)$$

where $a_3$ and $k$ are parameters determined for each compression curve using the least square method. Parameter $a_3$ can be understood as compression force corresponding to hypothetic full compression of the fruit (for $x/d = 1$). Parameter $k$ is an exponent, its increasing value (for $k$ higher than 1) indicates increasing curvature of the corresponding deformation curve.

Thirty fruits of each variety were used for the so-called „free fall test", which consists of dropping individual destemed fruits from the height of 2 m onto a thick steel plate. Damage to each fruit was categorized as follows: criteria undamaged fruit exhibits no macroscopic crack; in the skin slightly damaged fruit exhibits ruptured skin but without fruit juice flowing out; in heavily damaged fruits juice flows through the ruptured skin.

## RESULTS

Basic fruit characteristics of tested cultivars are presented in Tab. I. Tab. II contains the mean values obtained by evaluation of the compression curves for different fruit varieties. Coefficients of variation of these values usually do not exceed 20%. Data concerning localization of skin damage and prevailing damage are summarized in Tab. III: type (1) near the fruit stem, type (2) at the fruit tip, type (3) on the fruit side. The prevailing form of damage in each variety was classified according to the type when more than 50% of the damaged fruits in a set had the same type of injury. In a few varieties, where the damage could not be classified unambiguously, a zero was recorded. Most fruit cracks that appear during fruit compression between two plates are cracks of type 1. Type 3 (on the side of the fruits) were least frequent but they were more common among sour cherries than among sweet cherries.

Mean values of parameters $a_3$ and $k$ obtained from the regression relationship (1) are given in Tab. IV. The coefficient of variation of exponent $k$



II. Data obtained by compression fruits between two plates at constant strain rate. Characteristic deformations, i.e. inflexion strain and rupture strain, are dimensionless (Fig. 1)

| Variety | Slope of the curve in Newtons | | Inflex force (N) | Inflex strain | Rupture strain |
|---|---|---|---|---|---|
| | initial | inflex. | | | |
| SWEET CHERRIES | | | | | |
| Karešova | 26.2 | 62.0 | 8.0 | 0.198 | 0.440 |
| * | | | 6.5 | 0.200 | |
| Kaštánka | 19.1 | 39.5 | 5.5 | 0.212 | 0.458 |
| Burlat | 34.5 | 105.1 | 12.5 | 0.208 | 0.403 |
| Büttner | 36.6 | 54.9 | 6.1 | 0.134 | 0.475 |
| Frühe Rote Mecken. | 23.3 | 55.4 | 7.4 | 0.212 | 0.425 |
| Lambert | 39.7 | 90.8 | 13.1 | 0.198 | 0.359 |
| Granát | 29.8 | 62.7 | 8.2 | 0.187 | 0.429 |
| Kordia | 47.7 | 111.2 | 17.2 | 0.198 | 0.435 |
| * | 43.6 | 98.6 | 12.4 | 0.177 | 0.409 |
| Napoleonova | 28.6 | 82.6 | 13.0 | 0.242 | 0.448 |
| * | 34.8 | 63.9 | 8.6 | 0.180 | 0.469 |
| Starking Hardy Giant | 43.8 | 87.2 | 11.7 | 0.171 | 0.364 |
| Schneiderova | 38.5 | 111.6 | 17.4 | 0.243 | 0.369 |
| Sam | 37.6 | 68.0 | 6.6 | 0.132 | 0.443 |
| * Stella | 37.9 | 82.6 | 10.0 | 0.177 | 0.405 |
| Stella Compact | 36.1 | 102.3 | 15.0 | 0.224 | 0.402 |
| * Těchlovická | 28.2 | 64.1 | 9.0 | 0.204 | 0.405 |
| Van | 38.0 | 83.3 | 10.2 | 0.172 | 0.429 |
| SOUR CHERRIES | | | | | |
| Érdi Bötermö | 14.4 | 34.2 | 4.5 | 0.273 | 0.428 |
| Fanal | 13.7 | 41.8 | 5.3 | 0.289 | 0.484 |
| Körösi | 15.0 | 43.6 | 5.5 | 0.264 | 0.467 |
| * Montmorency | 8.4 | 30.2 | 3.8 | 0.272 | 0.434 |
| Morellenfeuer | 12.5 | 30.0 | 4.7 | 0.268 | 0.468 |
| North Star | 17.4 | 38.4 | 5.5 | 0.230 | 0.429 |
| * | 7.8 | 28.1 | 3.8 | 0.281 | 0.470 |
| Záhoračka | 14.0 | 46.3 | 6.8 | 0.304 | 0.487 |
| * | 9.4 | 50.3 | 7.1 | 0.336 | 0.405 |

* denotes 1989 results

III. Localization of skin damage to fruit following compression (strain about 50%) between two plates; cracks were classified as types: 1 – near fruit stem, 2 – near fruit tip, 3 – on the sides of the fruit; zero was used when the prevailing type of fruits damage cannot be determined

| Variety | Percentage | | | Prevailing type |
|---|---|---|---|---|
| | type 1 | type 2 | type 3 | |
| SWEET CHERRIES | | | | |
| Karešova | 63.9 | 13.9 | 22.2 | 1 |
| Kaštánka | 27.8 | 58.3 | 13.9 | 2 |
| Burlat | 21.7 | 26.7 | 51.6 | 3 |
| Büttner | 69.0 | 17.2 | 13.8 | 1 |
| Frühe Rote Mecken. | 62.0 | 20.0 | 18.0 | 1 |
| Lambert | 40.4 | 8.5 | 51.1 | 3 |
| * Moreau | 80.0 | 0.0 | 20.0 | 1 |
| Granát | 36.4 | 60.6 | 3.0 | 2 |
| Kordia | 93.8 | 0.0 | 6.2 | 1 |
| * | 71.1 | 2.6 | 26.5 | 1 |
| Napoleonova | 30.6 | 52.8 | 16.6 | 2 |
| * | 67.6 | 17.6 | 14.8 | 1 |
| Starking Hardy Giant | 61.4 | 29.5 | 9.1 | 1 |
| Schneiderova | 67.6 | 5.9 | 26.5 | 1 |
| Sam | 76.5 | 14.7 | 8.8 | 1 |
| * Stella | 42.6 | 18.5 | 38.9 | 0 |
| Stella Compact | 35.4 | 14.6 | 50.0 | 3 |
| * Těchlovická | 17.9 | 76.9 | 5.2 | 2 |
| Van | 51.4 | 48.6 | 0.0 | 1 |
| SOUR CHERRIES | | | | |
| Érdi Bötermö | 0.0 | 47.6 | 52.4 | 3 |
| Fanal | 33.3 | 31.1 | 35.6 | 0 |
| Körösi | 16.7 | 63.9 | 19.4 | 2 |
| * Montmorency | 17.8 | 44.4 | 37.8 | 0 |
| Morellenfeuer | 2.9 | 40.0 | 57.1 | 3 |
| North Star | 0.0 | 84.4 | 15.6 | 2 |
| * | 17.8 | 44.4 | 37.8 | 0 |
| Záhoračka | 15.8 | 23.7 | 60.5 | 3 |
| * | 6.6 | 31.7 | 61.7 | 3 |

* denotes 1989 results



IV. Mean values of parameters in the power relationship (1) obtained by the regression analysis of the initial parts of compression curves; $F_{0.1}$ is compression force calculated from Eq. (1) for compression strain $x/d = 0.1$ and parameters $a_3$ and $k$ given in this table

| Variety | Regression parameters of Eq. (1) | | $F_{0.1}$ in Newtons |
|---|---|---|---|
| | $a_3$ in Newtons | $k$ | |
| SWEET CHERRIES | | | |
| Karešova | 125.3 | 1.69 | 2.56 |
| Kaštánka | 78.7 | 1.71 | 1.54 |
| Burlat | 275.3 | 1.95 | 3.09 |
| Büttner | 82.8 | 1.28 | 4.35 |
| Frühe Rote Mecken. | 117.6 | 1.75 | 2.09 |
| Lambert | 147.9 | 1.49 | 4.79 |
| Granát | 118.6 | 1.58 | 3.12 |
| Kordia | 170.4 | 1.42 | 6.48 |
| * | 181.6 | 1.53 | 5.35 |
| Napoleonova | 140.7 | 1.67 | 3.01 |
| * | 107.0 | 1.46 | 3.71 |
| Starking Hardy Giant | 140.1 | 1.40 | 5.58 |
| Schneiderova | 199.0 | 1.72 | 3.79 |
| Sam | 132.8 | 1.47 | 4.50 |
| * Stella | 113.4 | 1.59 | 3.97 |
| Stella Compact | 189.8 | 1.69 | 3.87 |
| * Těchlovická | 113.4 | 1.59 | 2.91 |
| Van | 160.2 | 1.56 | 4.41 |
| SOUR CHERRIES | | | |
| Érdi Bötermö | 104.7 | 2.39 | 0.43 |
| Fanal | 161.6 | 2.72 | 0.31 |
| Körösi | 141.8 | 2.42 | 0.54 |
| * Montmorency | 103.3 | 2.52 | 0.31 |
| Morellenfeuer | 63.9 | 1.94 | 0.73 |
| North Star | 81.4 | 1.82 | 1.23 |
| * | 81.7 | 2.38 | 0.34 |
| Záhoračka | 134.8 | 2.47 | 0.46 |
| * | 156.2 | 2.82 | 0.24 |

* denotes 1989 results

is usually less than 10% while values of parameter $a_3$ are mostly in region of 10–20%. The quantity $F_{0.1}$ in Tab. IV represents the value of force $F$ which was calculated from expression (1) using the empirically determined parameters $a_3$ and $k$ for compression strain $x/d = 0.1$. Consequently, it is the mean value of force required for compression of the fruit between two plates by 10%.

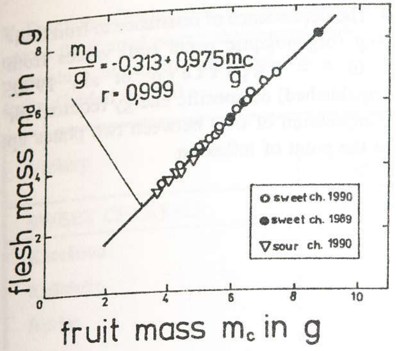
## DISCUSSION

Relationships between measured quantities are very complex. There are very close and logical relationships between fruit diameter, fruit mass and flesh mass (mass of fruit minus mass of seed). These relationships are increasing functions with positive correlation coefficients. This type of relationship is graphically expressed in the exemplary plot of flesh mass vs. fruit mass in Fig. 2. The value –0.313 in the regression relationship between both quantities indicates slightly lower values of the flesh to fruit mass ratio for smaller fruits.

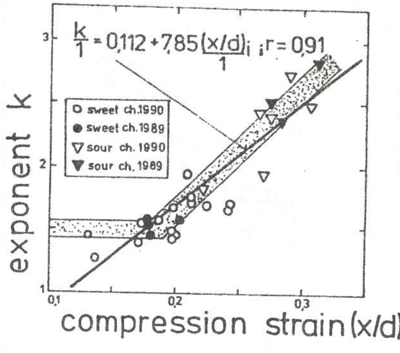
Quantities given in Tabs. II–IV can be divided into two groups according to the signs of the mutual correlation coefficients: those comprising compression strains at point of inflexion $(x/d)_i$ and at skin rupture point $(x/d)_x$, exponent $k$ and relative representations of skin cracks at the tip and on the side of fruit, on one side and the other quantities on the other side. A characteristic feature of the values included in both of these groups is the sign of correlation coefficient which corresponds to the relationship between quantities in one group and quantities belonging to different groups. All correlation coefficients of relationships between quantities inside one group are positive, regarding the statistically significant relationships, whereas, the relationships between quantities belonging to different groups are characterized by a negative correlation coefficient. This means that virtually all relationships between quantities inside one group are increasing functions, while relationships between quantities belonging to different groups are decreasing functions. This means, among other things, that an increase in fruit size causes an increase in slope of the compression curve, in force corresponding to the point of inflexion, and in force at constant compression strain ($F_{0.1}$). However, under the same conditions, compression strain at point of inflexion as well as compression strain at point of skin rupture decreases. Increasing fruit diameter leads to a greater frequency of cracks on fruit side as opposed to cracks near the stem insertion (see B l a h o v e c et al., 1991a).

Fig. 3 presents the relationship between the exponent $k$ and compression strain at the point of inflexion $(x/d)_i$. It turns out that the quantity $k$ is for






2. Relationship between flesh mass and total mass of fruit




3. The dependence of exponent $k$ in the relationship (1) on the compression strain at point of inflection; regression function – solid line, expected values – hatched field

$(x/d)_i$ lower than 0.2 almost constant and equal approximately to 3/2. For $(x/d)_i$ higher than 0.2 $k$ increases with increasing value of $(x/d)_i$. The value 3/2 of the exponent $k$ is a theoretical value for the Hertz theory of contact of round homogeneous elastic bodies (J o h n s o n , 1985). It seems that the compression of fruits characterized by $(x/d)_i$ higher than 0.2 is described by non-Hertzian relationship (1) with values of $k$ higher than 1.5 and lower than 4.2, i.e. value calculated for compression of spherical membrane filled with a liquid (B l a h o v e c , 1991). This behaviour is typical for smaller and softer fruits, e.g. sour cherries.

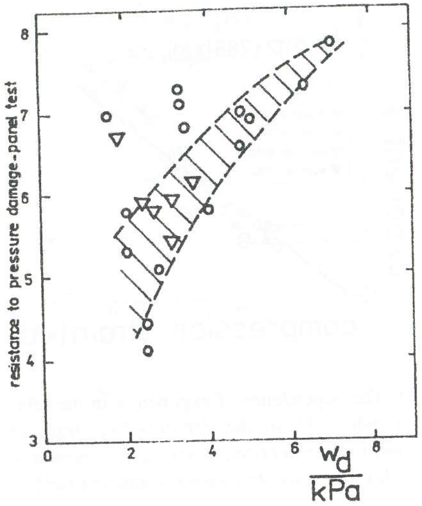
Specific deformation energy required for the compression of fruits up to the point of inflection seems to be an acceptable parameter to describe fruit resistance to impact and pressure damage. This quantity is mathematically defined as:

$$W_d = \frac{1}{V} \int_0^{x_i} F \, dx \tag{2}$$

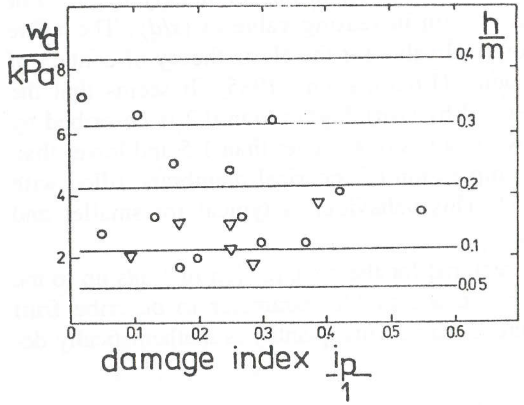
where $V$ is the fruit volume. We suppose, that the fruit is pressure damaged (or in other words is bruised) when it is compressed up to the point of inflection. Simple calculations based on simple premises (the fruit is ball with diameter $d$) lead to the expression for the above quantity:

$$W_d = 6 \, F_i \, (x/d)_i / [\pi \, (1 + k) \, d^2] \tag{3}$$

where $F_i$, $(x/d)_i$ and $k$ are the measured values and $d$ is the initial fruit diameter. The quantity defined in such way strongly agrees with resistance




4. The dependence of resistance to fruit bruising (organoleptic panel test, values from 1 to 9 – P a p r š t e i n et al., 1990, unpublished) on specific energy required for compression of fruit between two plates up to the point of inflexion




5. Specific energy required for compression of fruit between two plates up to the point of inflection plotted against the damage index $i_p$. Horizontal lines identified with numbers showing the heights of fruit free fall at which kinetic energy corresponding to the value $w_d$ (for density 1 100 kg.m$^{-3}$) is attained

to mechanical damage, determined by the panel test (Fig. 4). Some deviations outside the hatched field may be explained in terms of the different definitions of the both quantities plotted in Fig. 4. The quantity $w_d$ is actually defined with respect to the dynamic loading (it is normalized to the fruit volume, whereas the kinetic energy of fruit increases with its increasing volume before the impact at free fall from the same height). On the contrary, panel resistance to pressure damage is determined with respect to static load.



V. Fraction of fruits with the defined extent of skin damage in fall test (free fall from 2 m height onto a thick steel plate); the damage index $i_p$ is determined as a sum of two values: there is the percentage of slightly-damaged fruits divided by 200 and the percentage of heavily-damaged fruits divided by 100

| Variety | Percentage of fruits | | $i_p$ |
|---|---|---|---|
| | undamaged | slightly damaged | |
| SWEET CHERRIES | | | |
| Karešova | 90.0 | 10.0 | 0.050 |
| Kaštánka | 60.0 | 20.0 | 0.300 |
| Burlat | 20.0 | 76.7 | 0.417 |
| Büttner | 73.4 | 13.3 | 0.200 |
| Frühe Rote Mecken. | 36.7 | 53.3 | 0.366 |
| Lambert | 63.3 | 23.3 | 0.251 |
| Granát | 76.7 | 20.0 | 0.133 |
| Kordia | 96.7 | 3.3 | 0.017 |
| Napoleonova | 90.0 | 0.0 | 0.100 |
| Starking Hardy Giant | 40.0 | 10.0 | 0.550 |
| Schneiderova | 53.3 | 30.0 | 0.317 |
| Sam | 80.0 | 6.7 | 0.167 |
| Stella Compact | 71.0 | 25.8 | 0.161 |
| Van | 70.0 | 3.3 | 0.267 |
| Mean value - sweet cherries | | | 0.235 |
| SOUR CHERRIES | | | |
| Érdi Bötermö | 70.0 | 3.3 | 0.284 |
| Fanal | 70.0 | 10.0 | 0.250 |
| Körösi | 87.6 | 6.2 | 0.093 |
| Morellenfeuer | 70.0 | 10.0 | 0.250 |
| North Star | 83.3 | 0.0 | 0.167 |
| Záhoračka | 53.3 | 16.7 | 0.384 |
| Mean value - sour cherries | | | 0.238 |

All quantities characterizing the rate of force increase in the first part of compression curve, i.e. its slopes and force values at point of inflection and at compression strain 0.1 etc., may serve also as a measure of the resistance of the fruit to bruising (B l a h o v e c et al., 1991a).

Susceptibility of fruits to surface damage by impact, particularly skin damage, is defined in Tab. V by means of damage index $i_p$. This quantity encompasses values from 0 (when no fruit is damaged in free fall test) to 1 (when all tested fruits are heavily damaged). Damage index is not connected, in an important way, with the texture values of the both flesh and skin, that were determined by panel organoleptic tests (P a p r š t e i n et al., unpublished results). Fig. 5 shows that no important correlation was observed between the damage index and the quantity $w_d$. Lines that in Fig. 5 belong to the constant values of $w_d$ correspond to heights of the fruit free fall, during which the fruit acquires kinetic energy needed for the compression strain at the point of inflection in course of impact. This figure shows that in many cases this stage of impact compression appears at heights about 0.1 m and only in three cases this height is higher than 0.3 m. It means that impact bruising could be observed on fruits after their falling onto some hard body from the heights few tens of cm.

For the tested fruits, mean value of the damage index $i_p$ is about 0.236 and no difference between sweet and sour cherries has been observed (Tab. V). But when the different types of sweet cherries are analyzed, it is clear, that hard sweet cherries have usually lower values of damage index than the other types of sweet cherries. For five of eight studied hard cherry varieties (Tab. V) significantly lower values of damage index were observed than the mean value for sweet cherries (0.235). It seems that some additional source of firmness has to exist for explaining these results which cannot be explained only by differences in quasi-static parameters obtained from compression curves.

## CONCLUSIONS

Several parameters which characterize force increase in the first part of the compression curve (compression between two plates) can be used as a measure of fruit resistance to pressure damage (fruit bruising). Higher resistances of this type have been observed with fruits that exhibit lower values of the coefficient k in Eq. (1), lower values of compression strain at point of inflexion, and mainly higher values of specific deformation energy required for compression of a fruit to point of inflexion. Resistance of fruit to skin damage during the fruit impact is not related in simple way to the quantities characterizing the initial stages of compression curves obtained in quasi-static compression of a fruit between two plates. In this case, direct analysis of the problem using simulated damage of fruit is best found, e.g. damage obtained from free fall test. No systematic difference in resistance to skin damage has been observed for sweet and sour cherries, but it seems that the majority of hard-type sweet cherries are more resistant to skin damage than the other types of sweet cherries.



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**Mechanické vlastnosti třešní a višní a jejich odolnost proti mechanickému poškození.**

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Pro testování mechanických vlastností 24 odrůd třešní a višní v období jejich sklizně (přehled je uveden v tab. I) byl použit stlačovací test mezi dvěma deskami. Neodstopkované plody byly sklízeny z pokusných sadů Výzkumného a šlechtitelského ústavu ovocnářského v Holovousích, dopraveny do laboratoře Výzkumného ústavu potravinářského v Praze a do 36 hodin po sklizni testovány podle této metodiky: Celkem 20 až 30 plodů neodstopkovaných plodů bylo použito ke stlačovacímu testu mezi dvěma deskami (obr. 1) stálou rychlostí deformace 0,83 mm.s$^{-1}$ až do stlačení 50 %. Vyhodnocovány byly především směrnice stlačovací křivky v okolí počátku (1 - obr. 1b) a inflexního bodu (2 - obr. 1b), hodnota stlačovací síly $F_i$ v inflexním bodě stlačovací křivky a poměrné stlačení v inflexním bodě – $(x/d)_i$ a v okamžiku prasknutí slupky – $(x/d)_x$. Stlačovací křivka mezi počátkem a inflexním bodem byla navíc popsána parametry mocninné funkce. Dalších 30 plodů bylo odstopkováno a testováno pádem ze 2 m na silnou ocelovou desku. Plody, jejichž slupka nebyla pádem poškozena, se považují za plody nepoškozené. Plody s poškozenou slupkou se dále dělí na plody slabě a silně poškozené, přičemž u silně poškozených plodů dochází oproti slabě poškozeným navíc k výtoku buněčné tekutiny.

Výsledky testů jsou uvedeny v tab. II (stlačovací test – charakteristické veličiny), tab. III (stlačovací test – charakter poškození slupky), tab. IV (parametry charakterizující průběh stlačovací křivky mezi počátkem a inflexním bodem) a tab. V (pádový test). Pro všechny sledované odrůdy třešní a višní byly pozorovány velmi těsné vztahy mezi hmotnostmi jednotlivých částí plodů a jejich rozměrů (lineární vztah mezi hmotností plodu a jeho dužniny na obr. 2). Pro exponent $k$ mocninného vztahu (1) použitý k popisu prvé části stlačovací křivky byly experimentálně nalezeny hodnoty cca 1,5 (pro tužší plody zejména chrupek) až 3 (pro měkčí plody zejména višní). Experimentální hodnoty a jejich jednoduché statistické zpracování jsou uvedeny na obr. 2. Tuhost plodů souvisí s tuhostí dužniny, která pak významnou měrou ovlivňuje síly potřebné k jejímu vnitřnímu poškození a vzniku otlaků. Odolnost proti otlačení lze velmi dobře popsat energií potřebnou ke stlačení plodu do inflexního bodu a vztaženou na jednotkový objem plodu – tato veličina je vyjádřena vztahy (2) a (3). Vztah mezi touto veličinou a příslušným organoleptickým údajem ukazuje obr. 4. Odolnost plodu proti mechanickému poškození v pádovém testu nesouvisí jednoduchým způsobem s odolností plodů proti otlačení (obr. 5) a výrazný rozdíl v odolnosti proti mechanickému poškození není pozorován ani mezi třešněmi a višněmi.

třešně; mechanické vlastnosti; otlačení; mechanické poškození; puknutí slupky; stlačovací test

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