Impact induced mechanical damage of Agria potato tubers

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ABSTRACT: Potato variety Agria was cultivated in different fertilisation and/or irrigation regimes. Tuber damage after impact was studied two months after the harvest with aim to find some relation between the regime of cultivation and impact test tuber damage. It was found that tuber cracking and/or crushing belongs to the most frequent mechanisms of damage masking usual bruising in many cases. Most severe tuber cracking was observed for cultivation with irrigation and classical methods of fertilisation. On the other hand, bruising was most frequent in case without any irrigation and fertilisation and in cases used for fertilisation the pig slurry. In every cultivation regime the bruising was more pronounced in narrower tuber side in comparison to the wider flat side.

Keywords: potato; density; stem; bud; cultivation regime; impact; bruising; cracking; crushing; irrigation; fertilisation

Fruit and/or tuber bruising is one of the most important factors limiting the mechanisation and automation in harvesting, sorting and transport of soft fruits and vegetables, including potatoes. Dark spots appearing near the product surface are due to previous forceful mechanical contacts of the products with other bodies. Bruise extent is usually described in terms of bruise volume, which is closely related to product quality. The bruise spots belong to the whole scale of potato mechanical damage leading to yield losses expressing in tens of percent (Baritelle et al. 1999). The most important bruise factor in every case is the loading extent, which is usually expressed in the terms of loading energy or absorbed energy (Holt, Schoorl 1977).

Bruise spots are usually classified as a special type of mechanical damage (Baritelle et al. 1999) termed also as black-spots that: "…have no visible cell wall or cell debonding damage although the cells are often damaged. Typically, recent bruises are blue black and in perimedulary tissue rather than in cortex. Discoloration appears within 48 hours at 10–20°C. Black-spots occur in warmer more flaccid tubers, especially if potassium is deficient; and are associated with lower damaging drop heights (lower impact velocities)." These conclusions are in agreement with Molema's study (1999) on variety Bintje. The susceptibility of a potato sample to bruising is usually assessed by frequency of black-spot forming (Baritelle et al. 1999), dimensions of the black spots to be formed (Noble 1985) and/or black spot volume (Molema 1999). No successful relation of bruising sensitivity of potato tuber to any physical property has been observed. The bruising mechanism is frequently masked by the other damage mechanisms taking part in the mechanically induced potato tubers, mainly cracking, crushing and the other mechanisms leading to "separation" of the tuber tissue.

It was shown previously (Blahovec et al. 2003, 2004; Blahovec, Židová 2004) that the shape of the bruise spot depends either on the tested product and/or the object shape, which was in contact with the product before forming the spot. The simplest way of description the bruise spot shape is relation of its thickness (depth) to its maximum diameter. This ratio was termed bruise spot ratio (BSR – see Blahovec, Židová 2004). Moreover, there were observed bruise spots with the maximum spot diameter not located just under the tuber surface as is usual in other products (apples, cherries, pears – Blahovec et al. 2003, 2004) in agreement with the theoretical studies (e.g. Johnson 1987). In most cases the maximum diameter of the bruise spot is located close to the tuber vascular ring.

The aim of this paper is to analyse the main differences between damage mechanisms taking part in the impacted Agria tubers that were cultivated under different conditions.

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MATERIALS AND METHODS

The variety Agria cultivated in six different regimes was tested two months after harvest. The regimes of the potato cultivation are given in Table 1. Whole field experiment was organised on the experimental station Valečov (Research Potato Institute) close to Havlíčkův Brod in the Eastern Bohemia. The tubers were cold stored in an air ventilated room at temperature 6–10°C. After the transport the tubers were stored in a refrigerator for few days at temperature (7 ± 1)°C. The day prior testing the tubers were washed in cold water and then 50 defect free tubers of mediate size (5 to 8 cm in dimension) were selected for the test. After determining the density of the individual tubers (method of two weightings: in air and in water) at room temperature the surface water was dried laying the tubers for about one hour on the table in laboratory conditions. The tubers were then put into the refrigerator (at temperature about 7 ± 1°C) for about 20 hours.

The tubers of were removed sequentially from the refrigerator and tested dynamically by impact pendulum (Blahovec et al. 2004). The pendulum had a 30 cm long arm with removable weight and changeable impactors with flat and/or spherical heads of diameter 15 mm. The impactor with spherical head was used in our test, basic parameters of the pendulum for this case are given in Table 2. The impact test were performed on the tuber "equator" in the direction perpendicular to a tuber axis (connection of the bud and stem parts). The tested tubers were fixed in a special jig and pre-stressed by the spring of a micrometer screw. Two pendulum impacts by the spherical impactor were done into the same place on a tested tuber: the preparing (initial arm angle 30°) followed by the initiating one (initial arm angle 75°). This procedure was reproduced onto two places at the side of every tuber (in direction of the maximal tuber thickness – B1 and in direction of the minimal tuber thickness – B2). The pendulum arm was then fixed in the corresponding initial position and dropped on the tuber. After rebounding of the arm into the highest position, the arm was caught by hand. The initial (α_1) and rebounding (α_2) angles were detected by a special optical sensor connected with the pendulum axis. The measurements were computer controlled and the resulting hysteresis losses of the individual impact were calculated directly under the formula (Blahovec et al. 2004):

Table 2. The basic parameters of the pendulum with spherical indentor and additional weight

Angle	Load energy (J)	Impact velocity (m/s)
30	0.123	0.787
45	0.269	1.164
60	0.460	1.521
75	0.682	1.851

$$HL = \frac{\cos \alpha_2 - \cos \alpha_1}{1 - \cos \alpha_1} \quad (1)$$

The quantity $CE = 1 - HL$ represents the part of the impact energy that were conserved during the impact; we will term it relative conserved energy. After test the tubers were left on the table in a laboratory at room temperature (20–22°C) for about 24–72 hours. During this interval the colour of the bruised parts of the tuber flesh changed from the original to dark grey (Baritelle et al. 1999). Then the impacted parts of tubers were sliced by a calibrated peeler into planar 1.4 mm thick slices parallel to the tuber surface (Molema 1999). The slices were visually inspected to detect the presence of "black spots". Mean diameters of the discoloured tissue were measured manually (Molema 1999). The set of measured diameters gave information on volume profile of the black spot in the case that it was initiated by the impact.

Table 1. Cultivation regimes

Regime	1	2	3	4	5	6
Mineral N (kg/ha)	0	120	60 + 60*	60 + 30*	60 + 30*	0
Animal manure (t/ha)	0	30	30	37	37	0
Application		autumn	autumn	spring	spring	
Form		manure**	manure**	slurry***	slurry***	
Irrigation	0	0	full	full	saving	full

*organic N added to irrigation, **pig farmyard manure, ***pig slurry

The tested tissue was characterised by two values of *HL*, the first obtained from the first, so called preparing impact (initial angle 30°), HL_{30}, and the second from the second, so called initiating impact (initial angle 75°), HL_{75}. The first value can be understood as an information on the rebound properties of the undamaged tuber tissue, the second value then informs on rebound properties of the damaged tuber tissue.

RESULTS AND DISCUSSION

Tuber density

There were not observed significant differences between density values corresponding to different cultivation regimes (Blahovec 2005). The obtained mean values lay in very narrow range from 1,086 to 1,095 kg/m^3.

Impact parameters

The hysteresis losses as well as the relative conserved energy (*CE*) are the basic parameters characterising the impact process. The *CE*-value of the preparing impact is usually higher than 0.28. The variability of this value is very low (with CV lower that 10%). No such a conclusion can be made for the second impact to the tuber. Such a potato was turgid enough that it was mechanically damaged in many cases and *CE* is then lower (up to 0.20). The same process is a source of increasing variability with CV increasing up to values higher than 0.20 (Blahovec, Židová 2004).

The obtained results are displayed in Fig. 1. The figure shows that the obtained relative conserved energy in the second impact (RCV2) can serve as an indicator for division of the tested samples into two groups: the first one with RCV2 higher than 0.2 and the second one with RCV2 lower than 0.2. The first group is formed by the potatoes cultivated without fertiliser and irrigation (regime 1) and potatoes cultivated with the slurry fertilising (regimes 4, 5). This indicates that samples of this group were less damaged during the second impact.

Bruise volume

Study of bruising was complicated by the other mechanisms of mechanical damage (Fig. 2). Both the external and internal cracks accompanied the process of impact. They took part mainly in the tuber samples in which lower values of RCV2 were observed – the second group of classification given in the previous paragraph, the cultivation regimes 2, 6, and 3 (Fig. 2, Table 1). In samples of the second group (cultivation regimes 1, 4, 5) the combination of cracking and bruising was more frequent. The simple bruising was observed mainly for cultivation regimes 2, 4, and 5, but also in these cases the occurrence of the pure bruising represented less than 40% of all the tested tubers.

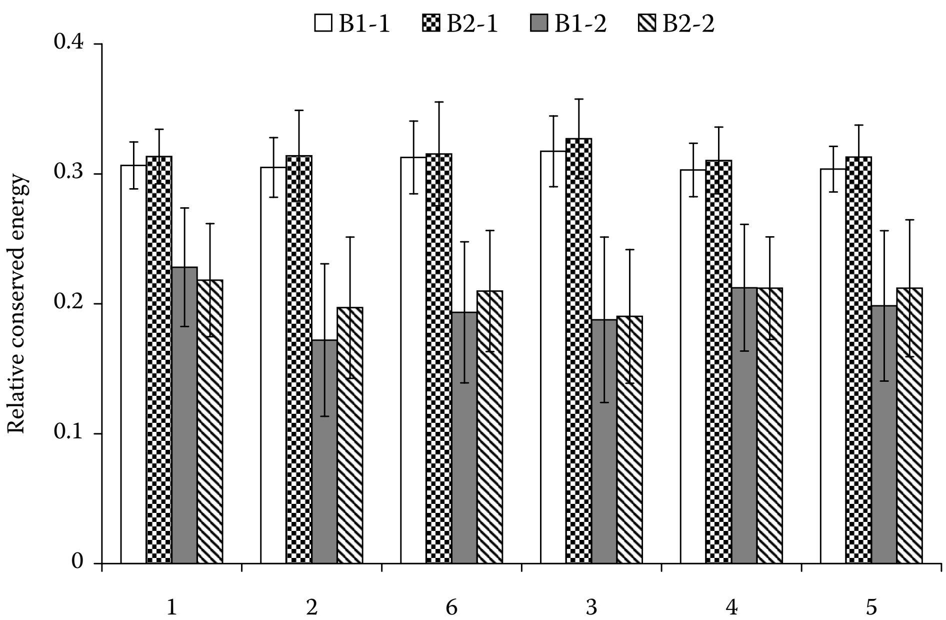

Fig. 1. Relative conserved energy obtained for different cultivation regimes (1–6) and different impact positions on the tuber side (B1 and B2 – for details see text). Additional numbers (1 and 2) at the symbol (e.g. B1 – 1) denotes the first and second impact into the same place (see text). The bars denote the corresponding standard deviations

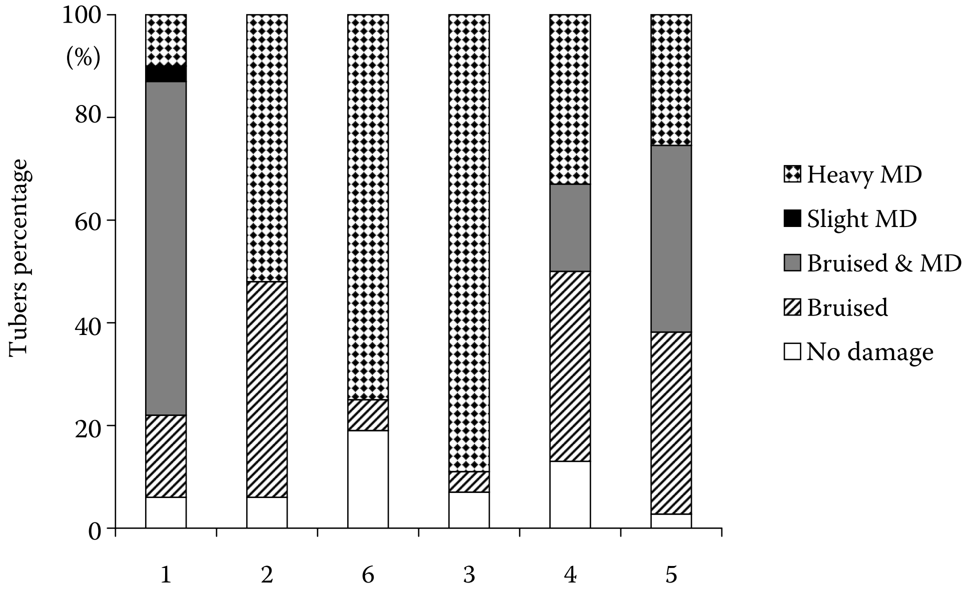

Fig. 2. The percentage of different damage modes taking part in the tested tubers. The results obtained at both the side locations (B1 and B2) were unified into one resulting set of data for a cultivation regime

The bruise volume of the individual bruise spots varied from 36 to 1,500 mm^3 with the total mean value 384 mm^3. Even if there were observed differences in the mean bruise spot volumes among the different cultivation regimes (207 to 609 mm^3) the main difference among the samples is given by number of the observed bruise spots transformed than into the total bruise spot volume of an individual sample (Fig. 3). Fig. 3 gave the similar information as Figs. 1 and 2: well irrigated potatoes,

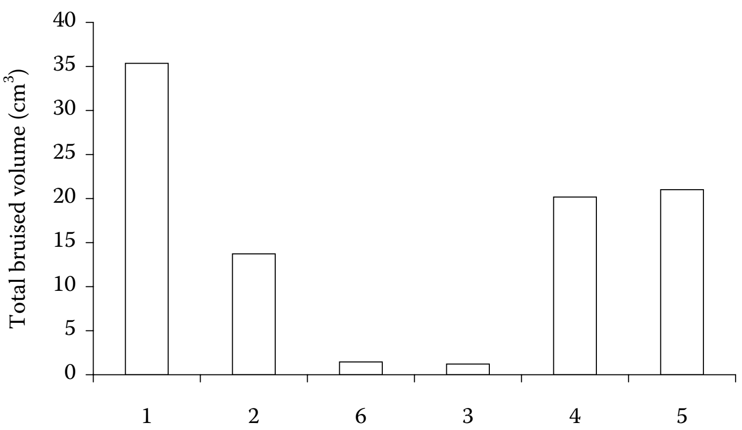

Fig. 3. Total bruise volume determined for all the tested tubers in a cultivation regime (the results at B1 and B2 were unified similarly as in Fig. 2)

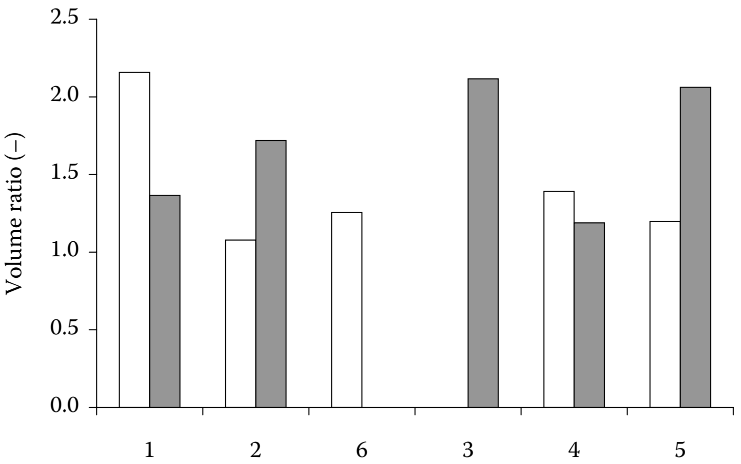

Fig. 4. Mean values ratio of bruise volumes obtained at B1 and B2 (white columns). The same data obtained in previous year (Blahovec, Židová 2004) are plotted by the grey columns

fertilised and/or unfertilised were bruised only sporadically with total bruise volume, including that accompanying the other forms of mechanical damage, represented in those cases volume less than 1.5 cm^3 for the whole sample (50 tubers).

The bruise spots observed for B1-orientation were usually bigger than for B2-orientation. The ratio of mean bruise volumes for both the orientations is plotted in Fig. 4. Similar trend was observed also in previous experiments even if agreement of the obtained results for individual cultivation regimes in 2003 and 2004 seasons is not perfect.

CONCLUSIONS

The soft impact properties (*CE*) only slightly depend on the cultivation regime. The higher differences in *CE*-values obtained for different cultivation regimes were observed at more energetic impacts. The lower *CE*-values accompany the impacts with heavier potato damage e.g. with cracking or crushing, the processes masking the main studied process – bruising. The bruise spot suppressing is stronger for the cultivation modes with irrigation and classical method of fertilising.

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Mechanické poškození hlíz brambor odrůdy Agria po nárazu

ABSTRAKT: Brambory odrůdy Agria byly pěstovány s různým režimem hnojení a zavlažování. Bylo studováno poškození hlíz po nárazu jednorázově dva měsíce po jejich sklizni. Cílem bylo hledat souvislosti mezi rozsahem a typem poškození a režimem pěstování brambor. Bylo zjištěno, že praskání a zhmoždění hlíz je velmi časté a v mnoha případech maskuje obvyklé šednutí dužniny. Nejvyšší rozsah praskání hlíz byl pozorován pro hlízy pěstované se závlahou a s klasickým způsobem hnojení. Naopak šednutí bylo nejčastější u pěstování bez závlahy nebo v případech přihnojování porostu prasečí kejdou. Při každém způsobu pěstování šednutí dužniny bylo výraznější na užší části boku hlízy ve srovnání s její širší plochou stranou.

Klíčová slova: brambory; hustota; pupek; korunka; režim pěstování; úder; šednutí; praskání; zhmoždění; zavlažování; hnojení

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