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IDENTIFICATION OF APPLE BRUISING AFFECTED TRANSPORT, SORTING AND STORAGE CONDITION

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Bruising of apple at harvest and transport affected final quality of fruit during storage and self-life. Transport and unloading of fruits are the production stages when the apple is most exposed to damage. The fruit resistance to damage is related to variety and maturity, harvest date, type of packing and means used at transport and loading operations, as well as, road surface and transport speed. Non adequate firmness of apples of immature or overripe fruit at delayed harvest may affect the extent of damage in transport.

On the other hand, damage of fruit is strongly related to the container properties. It depends on the container type, designing and material used, capacity, and height. Design and special foam coating reduced the level of damage in transport by 35-40%. An important indicator of the suitability of a packing container for fruit transport is the ratio of the area and number of fruit contact with the walls of the container.

Mechanical damage of apple is strongly related to the reaction of vehicle suspension and feedback to road surface. Vibrations and shocks caused by road roughness are transmitted through the suspension of the vehicle onto its frame and then, through the packing bins or boxes to the fruit.

To define the factors that affect the character and extent of damage to fruit, the mechanical properties of fruit tissue and skin for numerous varieties were tested in a previous study [2]. Estimating the mechanical strength of fruits of 10 varieties of apple, three classes of skin resistance and three classes of flesh resistance to destructive damage were defined. The mechanical tests relating to the firmness at harvest ripeness indicate that the values of apple firmness of the Shampion and Idared varieties are 70.2-74.8 and 84.2-89.3 N, respectively. In terms of tissue strength, Idared variety was classified in Class I (resistant fruits), and Shampion was classified in Class II (medium resistant fruits).

More extensive damage is caused by vibrations with higher acceleration values, even is their duration is relatively short. It has been observed that when the combination of amplitude and frequency in the surface layers of fruits is sufficient to generate vibrations close to 1 g (g – gravitational acceleration), the fruits in those layers can move freely as they receive sufficient energy from the lower layers.

According to Brown et al. [1] even sporadic occurrence of strong vibrations in the load, with acceleration values of up to 7.0 g, can generate load forces that create a hazard for the middle and bottom layers of fruits. Soft suspension dissipates more energy generated by bumps on road surface irregularities, which reduced apple damage by 40% compared to hard suspension.

Damage to apples was assessed on Shampion and Idared apples, that it based on different resistance to mechanical damage (Shampion is susceptible to damage, and Idared is more resistant. Both varieties played strong role on Polish and EU market. In 2015/2016, European production of Idared apples reached 1 129 thousand tons, while Shampion exceeded 513 thousand tons. Most of them are produced in Poland more than 800 thousand tons and 400 thousand tons, respectively.

Studding the effect of transport condition on apple damage were in two ways:

1) practice - the apples in bins were placed on vehicle and were transported on gravel and tarmac at various speed, and

2) laboratory - the apples were loaded using machine dedicated to fatigue test - Instron model 8872, that it allows to simulate transport condition at different amplitude and frequency on individual fruit.

According to the first way, harvested fruits were collected in metal bins with removable canvas bottoms, and immediately were transported to the storage facility. To determine the response of the transport vehicles to the road surface, in all transport trips the values of acceleration or vibrations frequency are collected.

The apples came from the orchard to the storage facility at three different speeds in accordance to the following assumptions:

- $V_1 = 3.87$ m s^{-1} (13.9 km h^{-1}) – all vehicle speed reach on gravel in the orchard, no vibrating fruit observed,
- $V_2 = 5.49$ m s^{-1} (19.8 km h^{-1}) – average speed on gravel and tarmac, that single

fruits vibrating on top layer of bin,

- V_3 = 7.27 m s^{-1} (26.2 km h^{-1}) – all vehicle speed reach on tarmac between orchard and storage facility, that most of fruits on top layer vibrating.

According to the second way the apples after storage were loaded using Instron machine and were kept till 15 days at self-life condition to estimate bruise color. The color was determined three times: at the day when the fruits were removed from the storage, after 7 days, and 15 days of shelf-life. During shelf-life, the fruits were bruised twice: on the both side of fruit; on the blush and on the opposite side of ground color. The color of apples were tested each day, during the first week and then after 9, 13, and 17 days at shelf-life.

The measurements were performed with the Braive Instruments 6016 supercolor™ colorimeter according to the L*a*b* system. The L*a*b* color system, recommended by CIE as a way of more closely representing perceived color and color difference. In this system, L* is the lightness factor; a* and b* are the chromaticity coordinates (Good, 2002).

- L* (lightness) axis – 0 is black; 100 is white.
- a* (red-green) axis – positive values are red; negative values are green; 0 is neutral.
- b* (yellow-blue) axis – positive values are yellow; negative are blue; 0 is neutral.

The color coordinates of Shampion apples during the shelf period kept up to 17 days at the same conditions, however, bruising caused darkening of the fruit skin. All changes of color at shelf-life are well describe by linear regression, while the multiplicative model indicates more closely bruising. The high color of blush consists of more intensive components, which is the reason why bruising is invisible on this area. More distinct differences are visible on the skin of the ground area. The lightness coordinate L* of the ground color is stable during shelf-life. Darkening of apple increases each day, especially during the first five days after bruising when L* rapidly decrease from 72.4 to 55.2. Keeping bruised apples for a long time at this condition involve further darkening and large differentiation in lightness.

After bruising, the red color represented by chromaticity parameter a* increases for ground area from 3.27 to 18.3, while slightly increases from 0.39 to 4.78 at shelf-life. Shampion apples, having no red in ground color, gave a* values very near to zero, while at that time bruising caused browning of tissue, which appearing intensity of red color component on the skin and increase of the index a*. One day after bruising, the skin of this area becomes statistically different to the ground color of Shampion apples, being stable during further period of shelf-life from 4 to 17 days. It is easy to conclude, that only the bright side of fruit changes its color significantly ($R = -0.82$ and $R = 0.86$) for L* and a* respectively. It easy to conclude, that red component of bruising is similar to the color of blush, being invisible on this area, while, the bruising appears on the ground area, just after 2 days of shelf-life, affecting not satisfactory quality estimation.

The increase of yellow color co-ordinates b* of Shampion apples, is similar to results presented previously for Idared apples over the range of shelf-life. Positive linear regression ($b^* = 47.76 + 0.59\ d$), slope, and correlation coefficient ($R = 0.63$)

indicates similar influence of shelf-life on the coordinate b* for Shampion apples. On the ground color of Shampion apples the bruising was statistically different after four days. The shelf-life caused further decrease of coordinate b*, however, the values covering larger differentiation in the range from 28.3 to 42.4.

Lightness L* describing intensity of skin color indicating freshness of product. The change of this parameter as a result of storage or shelf-life depends on storage conditions or bruising and low value of L* indicates dark skin. More distinct differences are visible on the ground color area. Darkness of apple increases each day, especially during five days after bruising when L* rapidly decrease. Keeping bruised apples for a long time at this condition involve further darkening and large differentiation of lightness.

Estimation of fruit quality based on L*a*b* system describing coordinates of color could be useful in connection with marketing, for monitoring consumer preferences and assessing the products quality and bruising after storage and at shelf-life. This system, if properly integrated into a marketing plan, could improve appearance of fruits, making consumers more aware of true quality factors.

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