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Evaluation of bruise resistance of pears to impact load

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ABSTRACT

The main cause of bruises resulting in loss for fruit growers are dynamic and impact type loads to which fruit is exposed during harvesting, loading and transport. Due to the characteristic shape of the contact plane of the fruit during the impact with the hard surface of e.g., a box or another fruit, there appears a problem of pressure force concentrated in a small area, leading to local exceeding of allowable limits. The authors focused on experimental procedure aimed at quantitative assessment of damage to the 'Clapp's Favorite' pear fruit depending on the changes in surface pressures that occur during impact loads. The study analyzed the influence of impact loads on the bruise resistance by measuring the surface pressures at varying drop heights and a specified number of impacts. The Tekscan® system was applied to determine force impulse values and contact plane areas, which enabled the calculation of surface pressure distribution. A computer analysis of the images of damaged tissue was carried out in order to determine the bruise volume, and a method for evaluating bruise resistance in pears was proposed based on the obtained BRI indicators (bruise resistance index—relationship between contact pressure and bruise volume). Both the analysis of the instantaneous force values, contact planes and surface pressures, as well as verifying analysis of the volume images enabled to determine bruise resistance in the case of the investigated 'Clapp's Favorite' pears at level of 8%. Also the pear bruise threshold was estimated at 46 mm with force impulses of up to 100 N. The presented method allows for the determination of the bruise resistance of fruits with high water content by measuring the surface pressure, accounting for the shape of the fruit's surface, mechanical properties of the flesh, and compression force.

1. Introduction

Increasing consumer demands and substantial competition require growers to increae fruit quality (Sablani et al., 2006). Consumers assess the quality of the fruit on the basis of appearance and they usually prefer fruit that is tasty, firm, juicy and, above all, intact. Therefore, the product supplied to the chain stores should come intact (Commission Implementing Regulation (EU) No 543/2011,Schulte et al., 1991). Pears are among the highly perishable agricultural products. Compared to apples they have a lower storability, and at the same time they are sensitive to inappropriate conditions during harvest, transport and reloading. One of the conditions to ensure high quality of the fruit is, among others, a suitable picking technique and transportation. Mechanical damage is a major cause of loss in the post-harvest processes (Bollen et al., 2001; Mohsenin, 1986; Opara, 2007). For most types of fruit, including pears, bruises are the most common type of mechanical damage. They are generally interpreted as a place of browning tissue under the peel of the fruit (Studman et al., 1997). Excessive loading of a percussive and dynamic nature affects fruit quality by reducing their consumption and nutritional values (Blahovec and Paprštein, 2005). Impacts cause irreversible damage to the external and internal structure, consisting mostly in the mechanical deformation of both the fruit peel and the spatial deformation of flesh cells. The damaging mechanism under the impact load differs significantly from the changes that take place at quasi-static loads. When exposed to impact load the biological material behaves like an elastic material (Holt and Schoorl, 1977; Stopa et al., 2014b; Van Zeebroeck et al., 2004). The sharp increase in the load causes the liquid and the air filling the intercellular spaces within flesh not to move into the other balanced areas where there is more space available, and thus these structures reflect the elastic energy. Therefore, the mechanism of bruising occurrence and the determining of bruising resistance cannot be analyzed using a simple measurement method based solely on the compression test. Understanding the susceptibility or resistance of the product to bruising is important for the development of strategies to reduce this phenomenon (Opara and Pathare, 2014). Therefore, experiments based on impact measurements are often carried out using a pendulum holding a fruit which hits a hard surface while dropped from various heights (Blahovec and Paprštein,

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2005; Ferreira et al., 2008; Kitthawee et al., 2011; ElMasry et al., 2012). Bajema and Hyde (1998) used a technique of repeated drops of fruit from a specified height and recorded the value of the energy absorbed during the subsequent bounce to determine the bruising energy. Rodriguez Sinobas et al. (1991) conducted a study, consisting in dropping pears from different heights, on the basis of which they identified the relationship between the bruising volumes and the results of firmness measurements. This helped them explain the important role of the fruit peel. An important issue in such studies is the difficulty in evaluating the rebound height which is needed to calculate the actual impact energy absorbed by organic products and causing damage.

Currently, the most commonly used parameters necessary to determine the index of susceptibility to bruising are: bruising volume and impact energy. Bruising volume measurement is difficult and time-consuming, while the determining of bruising energy requires complex mathematical and statistical calculations, which do not always have practical application in assessing quality (Opara, 2007; Menesatti and Paglia, 2001). There are several different models which to a greater or lesser extent describe the shape of the bruise, among which the most popular methods include: “bruise thickness”, “full depth”, “enclosed volume”, “unbruised volume removed” or “ellipsoid” (Bollen et al., 1999).

Damage to the delicate tissue of biological material that is subjected to dynamic loads during post-harvest processes points to undertake research toward the designation of contact pressures. It becomes necessary, from the viewpoint of experiments conducted on whole fruits, to measure pressure distribution on the contact plane of the fruit during the application of loads in different directions. Wu et al. (2012) and Sun et al. (2014) measured the impact pressure and bruising of pears ‘Korla’ (Lu et al. (2010) for apples) dropped from different heights and on different surfaces using adhesive film technique. The technique and the obtained regression models based on the impact force helped assess and predict the bruising of apples and the influence of impact loads that occur during transport. Literature reports indicate a small number of research studies documenting the fruit surface pressures.

Lewis et al. (2008) studied apple contact areas and stresses under static loading in bulk storage bins during harvesting using a novel ultrasonic technique. References to the studies on fruit surface pressures can be sourced from (Herold et al., 1996; Stopa et al., 2014a; Van Zeebroeck et al., 2007), who tested Tekscan® sensors for static and dynamic measurements.

Dan et al. (2004, 2005, 2006, 2007) applied pressure sensors to analyze stress distribution in cross sections of different varieties of cucumbers, and they also analyzed images of texture and determined the course of the cracking process in brittle and crunchy foods.

The usefulness of this technique to accurately determine the mechanical resistance and the formation of the fruit damage was assessed higher than the conventional methods which used force sensors and were based on the point measurements.

According to the authors of this study for determining the resistance of fruit to mechanical damage preferred may be the analysis of contact loads defined as the operation of a destructive force focused on a small contact plane. The assessment of the resistance of the biological material to bruising can be based on the surface pressure impulses taken at the moment of impact and referred to the bruising volume. The method would help determine the limit values of contact pressures, bruise height thresholds that cause no further deformation of tissues and an assessment of the degree of bruise resistance for pears.

The main aim of the study was to define a parameter which would allow for the determination of the bruise resistance of ‘Clapp’s Favorite’ pear. Surface pressure, which depends on the shape and the load of the fruit, as well as on its mechanical properties, is such a parameter. As demonstrated by the preliminary study, the change in the distribution and values of surface pressure can be attributed to the change in bruise volume, which significantly affects the bruise resistance of fruits.

Bruise resistance is associated with the concept of the bruise threshold, which was defined on the basis of changes in the contact surface of the pear with the bearing surface, obtained during the measurement of the distribution and contours of surface pressure.

2. Materials and methods

2.1. Material

The material used in the research consisted of ‘Clapp’s Favorite’ pears from Poland. The study used 70 fruits of pears. The fruit

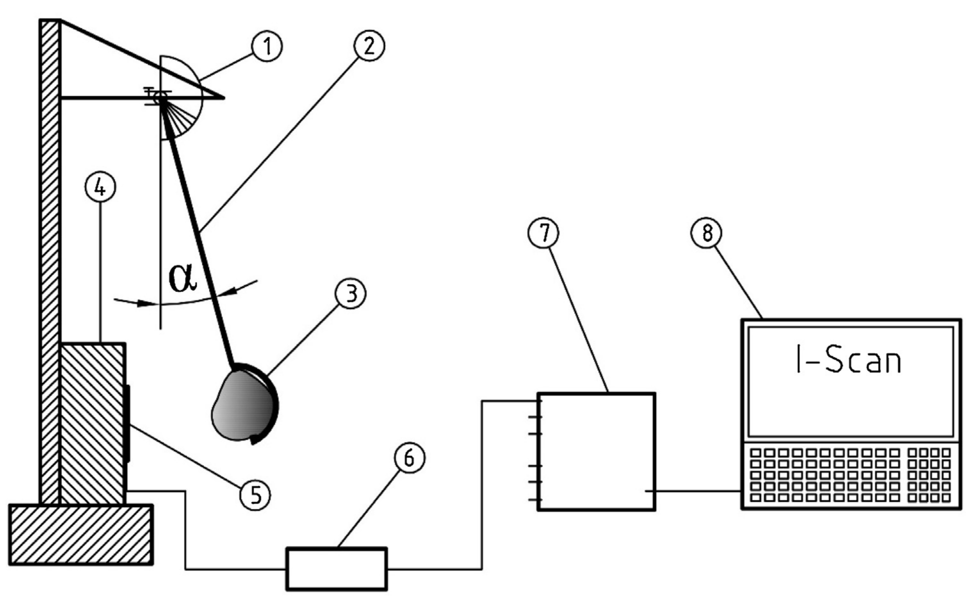

Fig. 1. Diagram of the impact measuring instrument: 1—protractor, 2—pendulum pull cable, 3—fruit holder, 4—static bumper plate, 5—ultra thin pressure sensor, 6—sensor holder, 7—multichannel signal splitter, 8—PC.