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Determination of Apple Critical Drop Height and its Relation to Bruising

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Abstract. Any effort in reducing agricultural losses could be a way toward a sustainable agriculture. Bruising is one of the most important limitations of agricultural mechanization and a sign of losses in fruits and vegetables. By conducting 360 impact tests, effect of fruit temperature and type of impact surface were investigated on fruit bruising. The results showed that both factors had a significant effect on size of bruised area. By increasing the temperature, the rate of bruising decreased, while increasing the kinetic energy had an inverse effect. The minimum and maximum rates of bruising were related to the use of corrugated fiberboard (0.97%) and galvanized iron (2.26%), respectively. This result may be stated in the form of height of fruit drop, so that, in the Red Delicious cultivar the maximum value of critical drop height was related to corrugated fiberboard at temperature of 30 ℃, equal to 350 mm.

Keywords: Apple, dynamic loading, temperature, impact surface, bruise

1. Introduction

It is important to conserve precious land, water, and energy sources which are required for food production. Kader [1] estimated that worldwide about one third of all fruits and vegetables produced are never consumed by humans. In developing nations, inefficient harvesting and poor infrastructure result in mishandling of agricultural commodities and it results to huge of losses. Food waste introduces more sustainable farming and food handling practices and could increase considerably the request for available food. This is especially critical as the global population is expected to increase in future decades. Bruising is one of the most important limitations of agricultural mechanization and a sign of losses in fruits and vegetables. In this relation, apple is one of the most sensitive fruits to mechanical damage. However, different forms of mechanical stresses apply on fruits during handling and transport [2]. It was observed that dynamic forces cause far more bruising than static forces [3]. Bruise threshold is a drop height at which bruising begins to occur, so it is necessary to consider a minimum height for falling fruit in designing of postharvest handling systems. An extensive research has been done in this relation and it is mainly due to complicated mechanism of bruising and its dependence to several factors [4]. Among these factors, the effects of fruit temperature and type of impact surface have been less studied. While many researchers emphasis on the effect of temperature [5], there are many conflicting reports in this relation. Toivonen [6], showed that different cultivars shows different sensitivity to bruising injury at varying temperature. Indeed, in warm fruits the severity of damage was less than cold fruits. Schoorl and Holt [7] showed that for different varieties resistance to bruising decreases with increasing time of storage, but the temperature will not effect on this phenomenon. According to a Saltveit report [8], for two different apple cultivars, increase of temperature from 0 to 30 degrees Celsius, cause to increase bruise volume. Another research showed that in Golden Delicious cultivar, with increasing temperature, bruised volume decreases [9]. In general, based on literature review the studies should be continuing. At the present research the effect of temperature and type

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of impact surface on bruised area in different levels of impact energy was investigated. And finally, the results were reported in the form of height of drop to be useable in different applications.

2. Materials and Methods

Two common cultivars of apple including Golden Delicious and Red Delicious were obtained directly from a field in Maragheh at north-west of Iran. Apple samples were placed in a temperature control device [10] for 3 hours to create four levels of fruit temperature (0, 10, 20 and 30 ℃). For determination of the relative hardness of impact surfaces (galvanized iron, rubber and corrugated fiberboard) a compressive loading apparatus was used. A spherical probe with 15.8 mm diameter was used and then the slope of the force – deformation curve was computed as criteria for surface hardness. Impact tests were performed by a pendulum impact testing apparatus [11]. Three levels of 300, 600 and 900 mJ kinetic energy were selected for conducting impact tests. After each test the samples were kept at room condition for 72 hours to emergence any bruised spots in the fruits [12]. Then, the main diameters of bruise area were measured for computing the elliptic shape of damage (Eq. 1).

$$A=\pi ab \quad (1)$$

In which, A is bruised area (mm^2), and $2a$ and $2b$ are the major and minor diameters of ellipse (mm), respectively. By considering a threshold of $100mm^2$ as visible bruise [2], critical drop height was determined in all different treatments. To analyze the results using SPSS software (Version 10, SPSS Inc.) a completely randomized design was used in the form of a factorial test with 5 replications.

3. Results and Discussion

The results showed that still small impacts have a significant effect on fruit quality. Damaged tissue, in both cultivars discolored in to bright brown. However, the samples which impacted at zero degrees of Celsius discolored in to dark brown. In addition, in most cases the bruised area was elliptic in shape. According to the results of ANOVA all of double interactions have significant effect on rate of fruit bruising. The result showed that with increasing temperature from 0 to 20 degree of Celsius the bruised area was decreased, but with increasing temperature from 20 to 30 degree the bruised area was increased slightly. These results were coincided with the results of some other researchers [13], [9]. The maximum rate of bruised area was related to Red Delicious at temperature of 0 ℃, equal to 592.5 mm^2 and minimum rate was related to Golden Delicious at temperature of 20 ℃, equal to 370.3 mm^2. This result is acceptable because of the considerable effect of varying temperature on mechanical properties of apple tissue. Indeed we know that the modulus of elasticity decreases with increasing temperature [14] and it means that the fruit tissue become softer (Fig. 1). Horsfield, [15] showed that the stress induced in fruit tissue is proportional to the modulus of elasticity of two colliding bodies. Therefore, due to increasing of fruit stiffness at 0 ℃ the more rate of damage is expected.

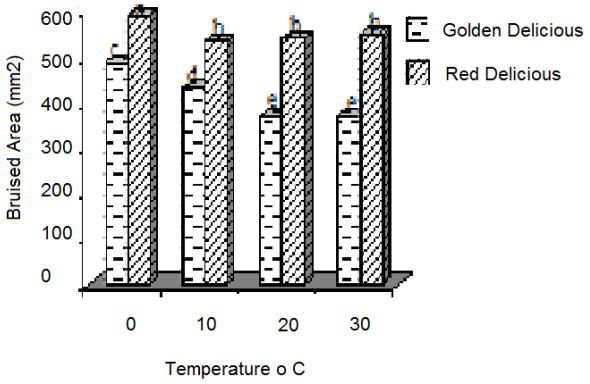

Fig. 1: Effect of temperature on bruised area in both cultivars

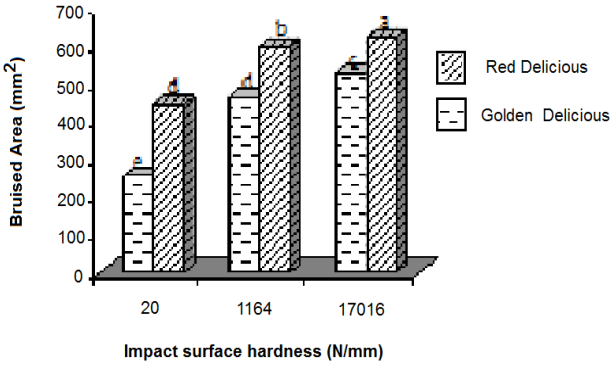

Fig. 2: Effect of type of impact surface on bruised area in both cultivars

Resistance of Golden Delicious cultivar to bruising is more than Red Delicious in different types of impact surfaces, and as expected, different rate of bruised area was observed (Fig. 2). This may be due to the difference in mechanical properties of two cultivars [16]. Indeed, the Golden Delicious cultivar was less

sensitive to impact forces, and hence, its damaged area was less. The results showed that galvanized iron produced more mechanical injury on apple samples than corrugated fiberboard. In fact, a portion of kinetic energy is absorbed by fiberboard due to its corrugated shape and also its visco-elastic nature. These results were coincided with the results of Lewis [2]. The highest level of bruised area, equal to 620.9 mm^2, was related to Red Delicious cultivar and was created due to collision with galvanized iron, while the minimum rate, equal to 253.8 mm^2, was related to Golden Delicious and was created due to collision with a corrugated fiberboard surface.

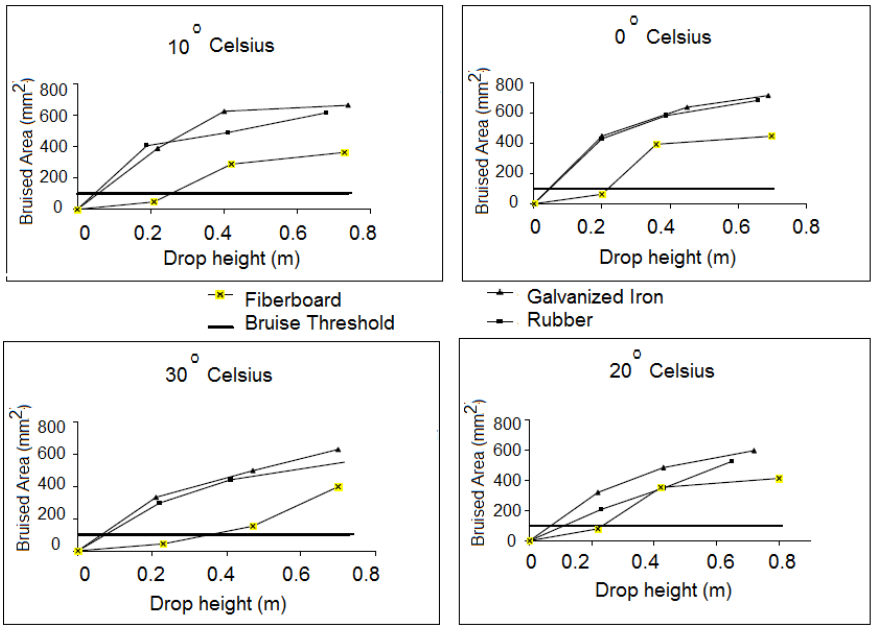

Fig. 3: Bruised area vs. drop height in Golden Delicious cultivar

Rate of bruised area versus drop height, in Golden Delicious cultivar, for different impact surfaces and in different apple temperature are shown in Fig. 3. The critical drop height was determined from intersection of a fixed threshold (100 mm^2) with the curves in different treatments. It is observed that fruit temperature and type of impact surface have considerable effect on critical drop heights in both two cultivars. According to the results, this height for corrugate fiberboard is 3 times more than galvanized iron. According to the results, the minimum rate of critical drop height was related to Red Delicious apple, due to collision with galvanized iron and at 0 ℃, equal to 26 mm. However, the maximum rate was related to Golden Delicious apple, due to collision with corrugated fiberboard surface and at 30 ℃, equal to 350 mm.

4. Acknowledgements

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