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The Effect of Temperature and Type of Impact Surface on Critical Drop Height of Apple

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Abstract

Fruit bruising is one of the most important factors which are limiting the mechanization and automation in harvesting, handling and transport of fruits and vegetables, including apple. Because of importance of dynamic loads in handling systems, it is useful to identify the conditions that cause in reducing the rate of bruising under impact loads. According to the results of this research, factors of temperature, type of impact surface and kinetic energy are affected on rate of bruised surface area ($P<0.01$). By increasing temperature of fruit tissue, the rate of bruise decreased, while the kinetic energy had the inverse effect. In addition, by increasing the hardness of impact surface the rate of bruise was increased, so that the minimum and maximum rate of bruise were related to corrugated carton (0.97%) and galvanized iron (2.26%), respectively. This result may be stated in the form of drop height, so that, in Red Delicious variety, the maximum value of critical drop height was related to corrugated carton and temperature of 10 °C, equal to 130 mm, while the minimum value was related to galvanized iron and 0 °C, equal to 26 mm. However, the results showed that Golden Delicious apple had more resistance to bruising than the Red Delicious.

Keywords: Apple, impact, drop height, fruit temperature, bruise.

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Introduction

Mechanical damage is the major source of losses in perishable agricultural products. According to FAO (3), 130 thousand hectares of land in Iran is under apple cultivation which yielding around 1.66 million tons of product each year. The high production of apple versus little exports of it is due to high amounts of losses and inability to obtaining the necessary standards of fruit quality. During fruit handling, from orchard to the market, fruits may experience a number of different types of loading that may lead to damage and bruising. The dynamic loads may be due to single impacts, which may occur during picking or sorting as the apples are dropped into storage bins, collecting pan of harvesting machines. The major contributing factor to such losses is bruising. This is defined as damage to, and discoloration of apple flesh, usually with no breach of the skin (6). Any rupture in cellular level of product cause contact of Enzymes and intercellular liquids with out of tissue agents and these phenomena bring about production of ethylene. In addition, discoloration of tissue, due to production of melanin, is another undesired result of mechanical damages. This condition results in increasing weight losses during storage, decreasing product quality and increasing post-processing costs.

The results showed that the bruised surface area and volume increase with increase of fruit radius of curvature, drop height and impact energy. It should be noticed that there are many contradictory results from previous studies about the effect of temperature on apple bruise..While, according to the other studies, increase of temperature cause to decrease of bruised volume in Golden Delicious apple (5). However, understanding the effect of temperature and type of impact surface on rate of bruise could be useful in decreasing mechanical losses in apple. Therefore, it seems that there are needed further researches in this area and especially in common varieties. Accordingly, the main objectives of this research were to determining the effect of temperature and type of impact surface on apple bruised area and determining the critical drop height.

Materials and Methods

360 samples of apple from two varieties of Red Delicious and Golden Delicious were selected randomly from an orchard in city *Maragheh* located in *East-Azerbaijan* province in Iran. The samples were kept at 4 °C until beginning of the tests. By means of an automatic conditioner, temperature of samples were kept for 3 hours to reach four levels of temperatures (0, 10, 20 and 30 °C) prior to impact tests. For determining the hardness of impact surfaces (galvanized iron, rubber and corrugated carton), each surface was pressed by a steel sphere (with 16 mm diameter) and a loading speed of 20 mm/min by a compression-tensile apparatus. Because of difference in thickness of surfaces the 0.15 strain was considered as a base for calculating tangent modulus from force/deformation curve. A pendulum impact apparatus (1), specifically designed for testing agricultural material, was used in the tests. The values of drop height were calculated from equation (1):

$$E=m.\ g.\ h \quad (1)$$

in which: *E*, *m*, *g* and *h* are kinetic energy (J), apple mass (kg), gravitational acceleration (m/s^2) and drop height (m), respectively. According to three energy levels of 300, 600 and 900 mJ and the length of pendulum wire (L= 0.5 m), each individual fruit released from a calculated height based on equation (2):

$$h=L-L\cos\alpha \quad (2)$$

in which α is the angle of release in degree. By considering the bruised surface area (*A*) as an ellipsoid, equation (3) was used for calculating its area, based on ellipse major (*a*) and minor (*b*) diameters.

$$A=\pi ab \quad (3)$$

A visible bruise threshold of 100mm^2 is a typical value used in industry for determining which apples should be discarded due to damage (2). By considering this threshold, the critical drop height of apple was defined for different levels of temperature and on different types of impact surfaces. The results were analyzed by a factorial experiment and based on a completely randomized design. The data extracted from the tests were analyzed by MSTAT-C statistical software and presented as graphs and charts by Microsoft Office Excel.

Results and Discussion

Effect of fruit temperature

In corroboration with Van Lancker (11) and Hyde (5), by increasing temperature from 0 to 20 °C mean values of bruised surface area were decreased, while variation of temperature from 20 to 30 °C the bruised surface area was increased, however the later was not statistically significant (Fig. 1). Maximum quantity of bruised surface area equal to 592.5 mm^2, was related to temperature of 0 °C and in Red Delicious variety while, the minimum rate was related to Golden Delicious and temperature of 20 °C. Temperature might be expected to influence the mechanical properties of apples and therefore bruising, but existing literature data are conflicting. (12).

Also, It should be noticed that increasing temperature cause decreasing modulus of elasticity of fruit tissue (11) and vice versa. On the other hand, Horsfield (4), showed that the stress induced in fruit tissue, due to impact, is proportional to elastic modulus of two contacting bodies. So, at a constant drop height and for a constant hardness value of impact surface, by increasing elastic modulus of fruit tissue impact stress increase which cause in increasing rate of bruise. Therefore, it would be expected to have the maximum damage at 0 °C (Fig.1). This result may be confirmed as we know that the viscosity of the cell walls will increase with decreasing temperature and the cell walls might become more brittle. In figures 1 to 3, different letters indicate significant difference between mean values according to Duncan multi range test.

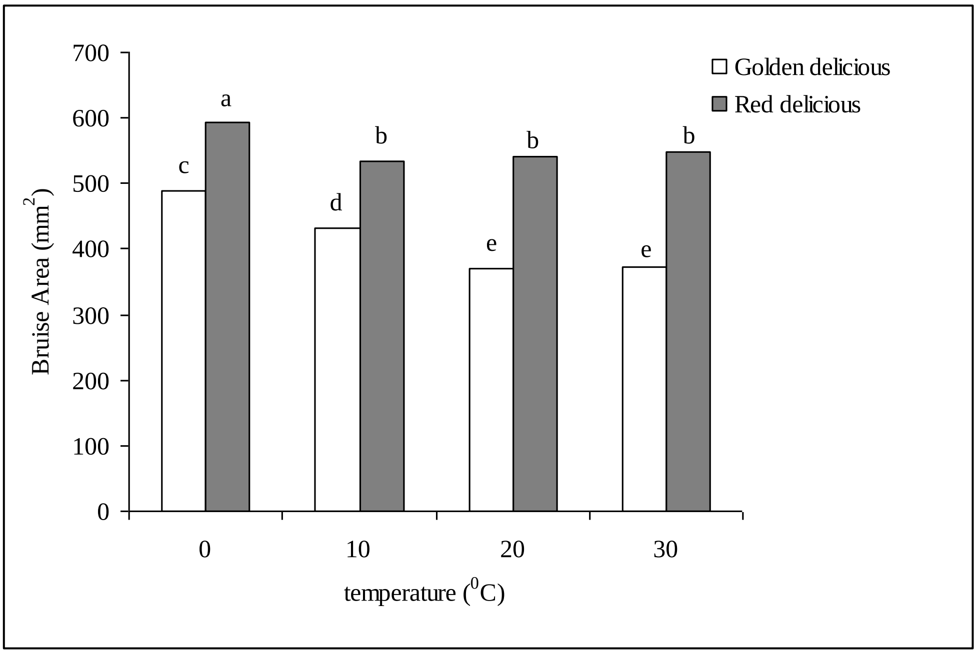

Figure 1: Effect of temperature on rate of bruise area in both varieties

Effect of impact surface

As figure 2 shows, Golden Delicious variety has more strength than Red Delicious and this lead to less damage in impacting to every three types of surface. This result has been confirmed by other researches (13). Obviously, this result is due to significant difference between two varieties in their mechanical properties, such as: rupture stress, strain, energy and firmness (7, 5). Table 1, shows the hardness value of different impact surfaces. According to it, there is a relationship between surface hardness and rate of fruit damage that is related to rate of stress induced in to fruit tissue. Corrugated carton, due its softness and also corrugated structure, absorb a great portion of impact energy and so show the minimum rate of damage in fruit as bruised area (Fig. 2).

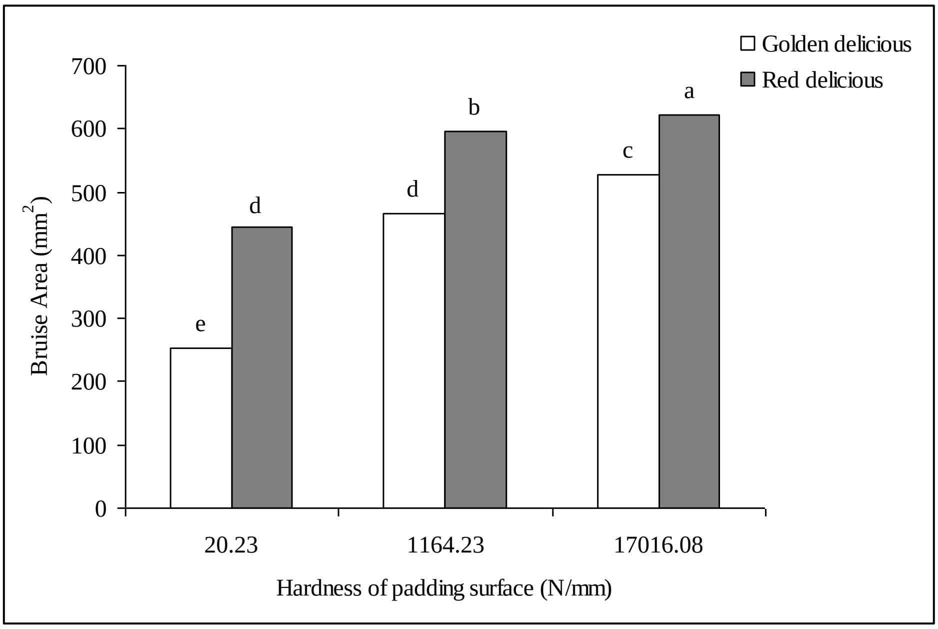

Figure 2: Effect of impact surface (based on hardness) on rate of bruise in both varieties

Table 1: Hardness of different impact surface and their thickness

	Galvanized Iron	Rubber	Carton
Hardness (N/mm)	17016.1	1164.2	20.2
Thickness (mm)	4.5	5.6	4.1

Effect of kinetic energy

As it was expected, effect of kinetic energy was significant on rate of bruise and its highest value was related to highest level of impact energy (Fig. 3). According to analysis of variance, there are significant differences in main and interaction effects of temperature, type of impact surface, kinetic energy and variety on bruised surface area in 1% level of statistical probability.

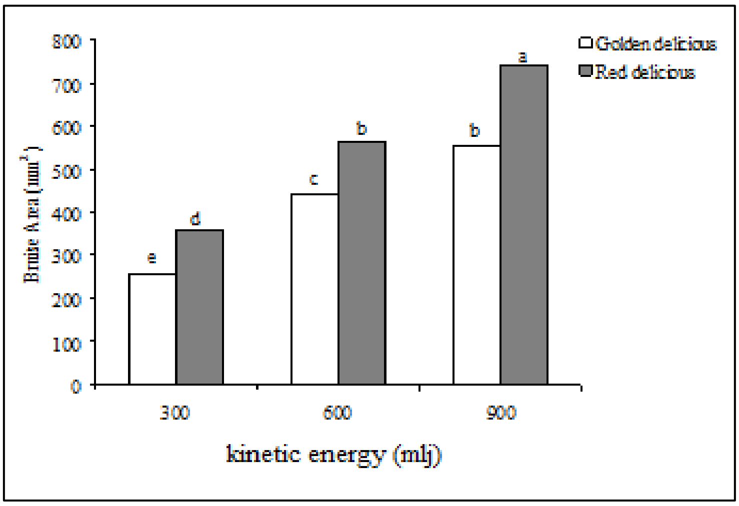

Figure 3: Effect of kinetic energy on rate of bruise in both varieties

3.4. Critical drop height

According to Figure 4, which shows the relationship between bruised surface area and drop height, critical drop height could be determined from intersect of a horizontal line at bruised threshold of 100 mm^2 with the curves. As it has shown, type of impact surface affect on critical drop height significantly. In this relation, the critical drop height of fruits on corrugated carton is 3 to 4 times of galvanized iron.

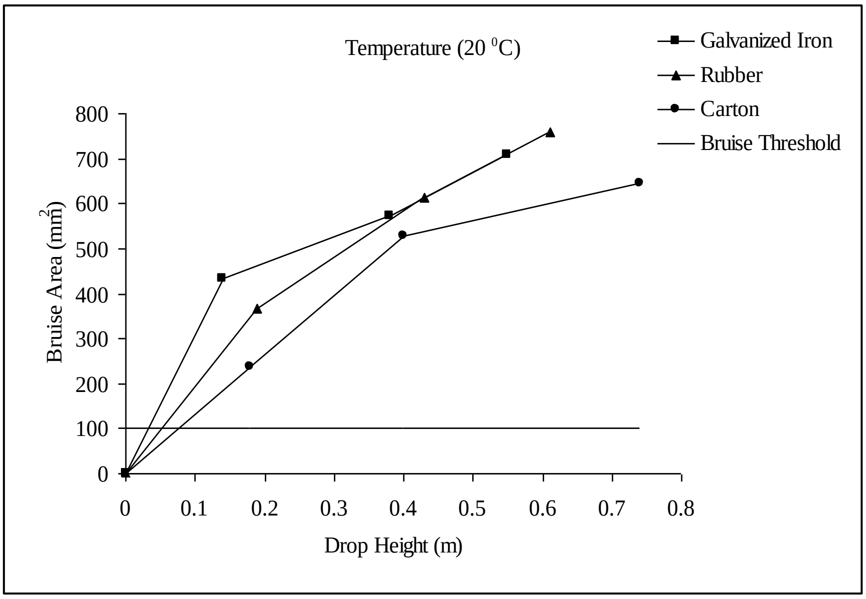

Figure 4:Bruised surface area versus drop height (Golden Delicious Var.)

Conclusion

The results showed that the impacts, even with small rate of energy, had a considerable effect on apple quality. Color of the damaged tissues changed to light brown in both varieties. However, according to visual observation, the color of tissue of the samples in temperature of 0 °C tended to dark brown. In all samples, also, the bruised surface area was in form of an ellipse. Based on the results, the maximum rate of bruise, equal to 2.18% (percent of bruised surface area) was related to samples of Red Delicious and temperature of 30 °C. While, the minimum rate of bruise was related to Golden Delicious and when impacted by corrugate carton, equal to 0.63%.According to maximum level of bruised surface area at 0 °C, it is recommended to increase the temperature of apple tissue to 20-30 °C in the chain of fruit handling. In addition, it is necessary to consider the drop heights in mechanized handling systems and it is preferred to use covering surfaces with low hardness and especially padding structure such as corrugated cartons for reducing impact energy. Due to effect of variety on the rate of bruise, it is proposed to consider the variety according to its mechanical strength in engineering design of handling systems and machines. In this relation, separating of apple fruits according to variety in prior to post-harvest handling may be lead to reduction of mechanical damage.

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