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Investigating The Effect of the Type and Thickness of Cushion and Harvesting Time on Apple Bruise Volume Under Impact Test

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ABSTRACT

Fruit bruising is the one of the main quality problem in apple handling and generally caused by impact force and sometimes excessive compressive forces during harvest & postharvest procedures. To reduce damage to fruit, it is necessary to obtain the sensitivity of bruising of fruits. In this study, using a pendulum apparatus and performing impact tests during a factorial experiment in a completely randomized design effect of independent factors digits (Red and Golden delicious), the type of cushion (soft foam and felt industries), thickness of the bumper and three harvest time (15 days before the scheduled harvest date current harvest and 15 days after harvest time) on the amount of bruising apples. Analysis of variance showed that the effect of the type and thickness of the cushion and harvest time was significant. Average bruise volume at 1%. By increasing the thickness of the cushion the rate of bruising was decreased significantly in both varieties. Over time also significantly increased the amount of soreness. As a result, it is necessary to obtain high quality fruit, with regard to the conditions and the consumption of fruits picked the right time to be determined. The greatest amount of bruising of the variety Red Delicious in dealing with industrial felt with the lowest thickness and Golden Delicious least it was in collision with soft foam with maximum thickness. So this indicates the soft foam as the buffer will be more efficient.

Keywords: *Soreness, apple, bumper level, harvest time, hit*

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INTRODUCTION

Apple is a plant belonging to the Rosaceae family, Pomoideae subfamily and Malus genus and is of great importance in terms of nutritional value. The nutrient contents in 100 grams of fresh apple include 84.8% water, 0.2% protein, 0.6% fat and 14.1% carbohydrates. According to the statistics of the Food and Agriculture Organization of the United Nations (FAO), in 2003, the area under apple cultivation in Iran was about 152000 hectares, the production rate was 2358 million tons and its average performance was 1551 tons per hectare (FAO, 1998, 2003). Apple is one of the most susceptible crops to mechanical damages. Extensive researches are carried out in this field and the collected data indicate bruises particularly in the harvest and handling stages. According to the results of the researches, in manual harvesting system, 81% of the produced apples are bruised in the harvest stage, 93% after the handling and 91 to 95% in the packing stage (Altisent, 1990).

Impacts during the harvest, grading and separating occurs due to falling of fruits on different surfaces or collisions with other fruits (Lewis, 2008). One of the factors that could affect the mechanical damage intensity in the crop, is the ripeness of the product. This factor is of great importance from different aspects in the postharvest stages. The product which is harvested in the proper time will have the best quality and the least damage (Afkari et al., 2009).

In the following, to some researches which were carried out in the field of physical and mechanical damages to the crops, particularly apples, in different situations are pointed out.

Shekarbeigi et al. (2001) investigated the effect of temperature and impact surface on the bruise volume of apple. They observed that red delicious cultivar in 0 C° with the impact of galvanized iron and golden delicious in 30 C° with the impact of cardboard had dark brown and light brown bruises, respectively. Also, in the investigation of the effect of the padding surfaces, the least bruise volume was achieved for the impact with cardboard while by increasing the impact force, the bruise volume was increased.

Blahovec and Paprstein (2005) investigated the susceptibilities of different cultivars of pear to bruising. The samples were put between two hard flat surfaces with a constant deformation speed of 0.167 m/s under the pressure test in loading and unloading conditions. The mass and shape of the fruit were effective during the loading.

Afkari et al. (2006) investigated the effects of cultivar, impact energy, and the storage time on the mechanical

losses of apple and its susceptibility to the impact. The result of this research showed that the bruising possibility of apple decreases by increasing the storage time.
Lewis et al. (2007) investigated the bruising due to impact. The golden delicious cultivar was chosen for the experiments. The apples were tested under free fall conditions from heights between 0.1 to 1.2 meters on surface such as Perspex, steel, rubber, wood and cardboard. The results showed that the surface area and the volume of bruise increase with increasing the impact energy and the curvature radius in the impact area. The highest bruising is observed in the flesh of the apple. Also, by increasing the elastic modulus of the padding surfaces, the bruising was increased, such that the lowest bruising was observed on the surfaces of cardboard and wood and the highest bruising was observed on the surfaces of steel and rubber. Finite element method is used for modeling the free fall of the apple on different surfaces.
One factor that could affect the mechanical damage on the products is the ripeness of the crop. This factor is important among the postharvest stages. A crop which is harvested at the proper time will have the best quality and the least damage (Afkari et al. 2009).
Considering the necessity of research and the history of the studies, the aim of this research is to study two key factors in the handling systems of the fruits including the type of padding surface and its thickness which are less attended in the previous researches. Whereas, the effect of the harvest time is also studied for two cultivars of apple.

MATERIALS AND METHODS

For conducting the experiments, two common cultivars of apples called golden delicious and red delicious are used. 25 kilograms of each cultivar were supplied from a garden in Maragheh County in coordination with the agricultural research center of Maragheh. Then, 120 samples of each cultivar were collected for the experiments. However, this number of apple are supplied in three time with intervals of 15 days which almost lasted from the fourth week of September to the end of October. The samples were kept in a cold environment with a temperature below 4 C^{o}. Several hours before conducting each test, the samples were brought out of the refrigerator and their weights were measured with a digital scale with an accuracy of 0.001 gram and their dimensions were measured with a caliper with an accuracy of 0.01 millimeter. The three geometrical dimensions of the fruit including the large, medium and small diameters are measured. An impact test apparatus is used for generating vertical impacts on the crops.

In this experimental research, fruit samples is connected to a ball bearing in a height of 1.5 meter using a metal wire. The position of the connection point to the bearing is adjustable in the horizontal and vertical directions. In the upper part of the apparatus, a scale with an accuracy of 1 degree is used as the indicator of measuring the angle of the pendulum. The tested sample is at the end of the pendulum and it falls from a certain height in which, L is the length of the wire of the pendulum from the rotating position to the end of the arm and α is the pendulum release angle. The amount of potential energy in height h could be assumed to be equal to the kinetic energy at the time of impact. The velocity of the weight at the time of impact to the padding surface is equal to $V = \sqrt{2gh}$ at the lowest point of the swing point. In this case, the kinetic energy resulted from the impact is equal to:

$$E = \frac{1}{2}mv^2 \quad (1)$$

Which E is the kinetic energy in (J), m is the mass of the sample in (kg) and v is the velocity of the pendulum before the impact in (m/s).
For determining the hardness of the padding surfaces, an uniaxial compressive loading apparatus designed by SANTAM Company is used. This machine has a 20-kilonewton load cell and the samples were loaded between two flat plates. In penetrating test, a spherical probe with diameter 15.80 mm is used while the loading speed was chosen equal to be 20 mm/min. The padding surfaces are under a continuous load on a fixed jaw and the force-deformation curve is obtained to be in the elastic region. As the thickness of the padding surfaces are different, similar strains of 0.15 are used for both surfaces to compare their hardness.
To investigate the effect of padding surfaces, soft foam and industrial felt are used which are common materials. At first, the surfaces were glued to the galvanized iron surface. After measuring the weight of the apple from equation 2-2, the height of the fall was determined for which the impact energy was assumed to be 900 millijoule.

$$E = mgh \quad (2)$$

Then, the release angle of the pendulum was calculated from the equation $h = l - l\cos\alpha$. Each sample was released after locating it inside the clamp. Before the test, some flour was sprinkled on the padding surface to locate the exact impact position on the sample for the approximation of the bruise volume and surface. In this research, the effects of two cultivars, two padding surfaces and three harvest time levels are calculated in 4 repetitions on the apple bruise volume and a total of 240 impact tests were conducted.

RESULTS AND DISCUSSION

The results showed that even small impacts on apple fruit cause considerable effects on the quality of the product, such that in most cases, the bruises are clear through the skin and the damaged texture turns into light brown color in both cultivars. These findings are in good agreement with the results previously obtained by Shekarbeigi (2009). This color change occurs for the energy level of 900 mill joule and the least thickness of the padding surface after at least two hours. But, in some samples, for the energy level of 900 millijoule and the highest thickness of the padding surface and the harvest time of 15 days before the assumed harvest time, the bruises were not recognizable on the skin. Based on the observations, dark brown color is observed in the damaged tissue in red delicious due to impact with the thinnest surface of the felt and foam and in golden delicious light brown colors are observed due to impact with soft foam with the highest thickness. Also, the bruise surfaces were mainly in oval shapes.
The results from the variance analysis of the data associated with the measurement of the volume of bruise in red delicious and golden delicious cultivars implies that all the independent variables and their double and triple correlations meaningfully affect the bruise volume. The coefficient of variation of the data (CV) for red delicious and golden delicious is 27.31% and 31.06%, respectively which make sense considering the number of different treatments and tests (mechanical test).
Duncan's multiple range test is used for comparing the means of different groups in the probability level of 5%. According to the tests, the hardness of the soft foam and

industrial felt surfaces (with thicknesses of 3.2 to 3.8 millimeter) are obtained to be 63.38 and 87.72 newton per millimeter. In other words, the soft foam was 28% softer than the industrial felt based on the slope of the force-deformation curve. The results show that increasing the surface hardness, meaningfully increases the bruise volume in each cultivar. This result is in good agreement with the results obtained by Lewis et al. (2007), Gahari et al. (2006) and Shekarbeigi (2009). Bemedsen (1986) has used sponge materials and has obtained similar results. The highest average bruise volume of 4729.15 mm^3 is obtained for the impact with industrial felt padding surface and the lowest value of 2232.06 mm^3 is obtained for the impact with soft foam padding surface.
The average of the highest bruise volume occurs for the impact with industrial felt with the lowest thickness. Soft surfaces such as soft foam absorb the highest impact energy with the highest thickness. Consequently, the least bruises are occurred for the impacts with this surface.

Accordingly, the results show that increasing the thickness of the padding surface for each surface type, the bruise volume decreases. The results of Duncan's test show also show meaningful effect of the padding surface thickness on the bruise volume. The obtained results show that the effect of harvest time is meaningful on the bruise volume of both apple cultivars. This result is in good agreement with the results obtained by Zeebroek and Van linden (2007).

The results of the comparison of the average correlation of the padding surface in thickness show that for each cultivar, the bruise volume is increased by increasing the thickness such that the highest average bruise volume in both surfaces have occurred in the lowest thickness. This difference is due to the reduction of hardness of the surfaces by increasing the thickness both surface types. Consequently, the energy absorption is increased by increasing the thickness leading to the decrease in bruise.

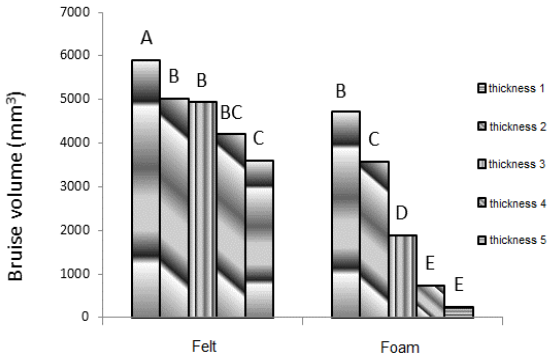

Figure 3 the results of comparing the correlation of the type of padding surface and padding surface thickness on the bruise volume of red delicious cultivar, LSD=771.0

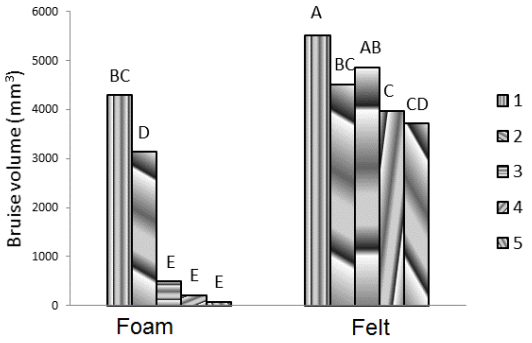

Figure 4 the results of comparing the correlation of the type of padding surface and padding surface thickness on the bruise volume of golden delicious cultivar, LSD=775.0

The results of comparing the averages presented in figure 5 indicate that the damages increase with the treatment time. The highest average bruise volume of 5893.186 mm^3 is calculated for red delicious apple is for felt surface and 15 days after the harvest time and the least bruise volume is 1159.175 mm^3 for golden delicious for soft foam and 15 days before the harvest time. The best harvest time in terms of quality and marketability is the very harvest time and considering the obtained values, the padding surface of the soft foam type is the best choice between the two studied cases.

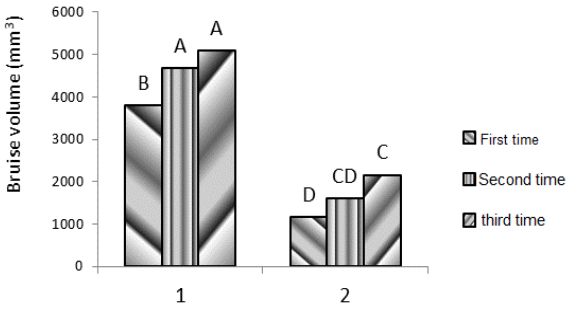

Figure 5 the results of comparing the effects of average correlation of harvest time and padding surface type on the bruise volume of golden delicious cultivar, LSD=600.3

According to figure 6, it is observed that 15 days after the harvest time, increasing the thickness causes the bruise volume to decrease. But, for harvest time, planned harvest time and 15 days before the planned harvest time, increasing the thickness does not cause the average bruise volume to decrease monotonically which could be due to the fact that at these times, the fruits do not have the same treatment quality. The highest average bruise volume is for red delicious cultivar with the least thickness of padding surface at the harvest time, 15 days after the planned time (7043.513 mm^3) and the least average bruise volume is for red delicious with the highest padding surface thickness at the harvest time, 15 days before the planned time (1547.030 mm^3).

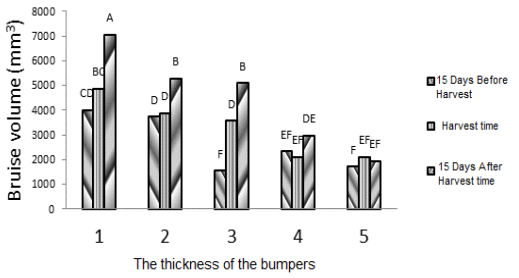

Figure 6 the results of comparing the effects of correlation of harvest time and padding surface thickness on the bruise volume for red delicious cultivar, LSD=944.3

The bruise percentage for each cultivar affected by padding surface thickness, padding surface type and harvest time factors is calculated. Table 3 shows that the highest bruise percentage is for red delicious apple for the least padding surface thickness with a value of 0.428 percent. According to table 4, the lowest bruise percentage is for golden delicious for impact with soft foam with a value of 0.137 percent. Also, according to table 3, the highest bruise percentage has occurred for red delicious cultivar, 15 days after the planned harvest time with a value of 0.375 percent of the total volume of apples.

Table 3 the results of comparing the effect of the thickness of padding surface on the bruise percentage in the studied cultivars, LSD=0.4789

Cultivar		Padding surface thickness
Red delicious	Golden delicious	
0.408A	0.428A	First thickness
0.345B	0.351B	Second thickness
0.215C	0.308B	Third thickness
0.183C	0.184C	Fourth thickness
0.175C	0.147C	Fifth thickness

Table 4 the results of comparing the effect of correlation of harvest time-cultivar in the studied cultivars, LSD=0.03717

Cultivar		Harvest time
Red delicious	Golden delicious	
0.231B	0.222A	15 days before the planned harvest time
0.245B	0.290A	Planned harvest time
0.375A	0.283B	15 days after the planned harvest time

Table 5 the results of comparing the effect of double correlation of padding surface-cultivar in the studied cultivars

Cultivar		Padding surface type
Red delicious	Golden delicious	
0.383	0.393	Industrial felt
0.184	0.137	Soft foam

The results of calculating the permissible falling height for each cultivar is presented in table 6. According to this table, the highest permissible falling height for red delicious cultivar is 620 millimeter which is obtained for the impact with soft foam at harvest time of 15 days before the planned time. The lease falling height which is 540 millimeter is obtained for the impact with soft foam in the planned harvest time. Also, for golden delicious cultivar, the lease value is for the soft foam surface and harvest time of 15 days after the planned time and its value is 600 millimeter and the highest value is for soft foam at the planned harvest time with a value of 740 millimeter. As observed from the diagram, the industrial felt surface does not cross the bruise threshold curve. Therefore, no points is determined as the permissible falling height. This could be due to the fact that the kinetic energy that we assumed was high and consequently an acceptable level of bruise was not obtained and was higher than the permissible value. It is suggested that in the future studies, the effectiveness of this surface is examined by using it with lower energy levels.

Table 6 Permissible falling height

Permissible falling height (mm)		Padding surfaces	Harvest time
Red delicious	golden delicious		
-	-	Felt	15 days before the planned time
720	620	Foam	
-	-	Felt	Planned time
740	540	Foam	
-	-	Felt	15 days after the planned time
600	580	Foam	

CONCLUSION

- The results observed show that even small impacts on apple leads to considerable effects on the quality of the product such that in most of the time, it is observable from the skin.
- The results of variance analysis showed that the effects of cultivar, padding surface, thickness of the padding surface and harvest time are meaningful in a probability level of 1%.
- The type and hardness of the padding surfaces are related to the bruise volume of apple cultivars. The highest average bruise volume was obtained for the impact with felt with hardness 87.71 and the lowest bruise volume was obtained for the impact with foam surface with hardness 63.37. Soft padding surfaces absorb some of the impact energy and less bruises have occurred for these surfaces.
- The thickness of the padding surface does not affect the bruise volume significantly. As illustrated by the results, increasing the thickness caused the average bruise volume to decrease significantly which showing that the thickness of the padding surface should be noticed while choosing its type.
- The harvest time, also known as crop treatment is related to the bruise volume, too. On way to produce high-quality fruits is to postpone the harvest time. But, doing so leads to overripe and soft and more susceptible fruits to impacts and spoilage. Based on the results, the highest bruise volume has occurred 15 days after the planned harvest time.

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