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Properties of four local apple varieties from north-west of Iran and bruise damage of them related to drop height

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ABSTRACT

One of the main factors that cause to quality loss for fresh fruit market apples is bruise damage. Amongst the factors that affect apple sensitivity to bruising, major one is drop height and area profile during the impact. In the present study, four Iranian apple varieties consisted of Atirli, Kapak, Kowse and Paiez that were selected and 100 fruits of each variety were picked up, then apples were dropped from three heights and some mechanical properties such as bruise diameter, bruise height, rebound height, bruise energy percent, bruise coefficient of restitution, bruise resistant percent, bruise volume, bruise energy absorb and bruise contact above were tested and measured. The value of all features found to be different from variety to variety. As a result, Paiez variety was firmer than others. The maximum coefficient of static friction for MDF and the minimum was for PVC.

Key words: Bruise, Fruit, Local, Static friction Coefficient.

1- INTRODUCTION

There are more than 7500 known cultivars of apple (Kheiralipour *et al*., 2008). At least 55 million tons of apples grown worldwide in 2005, with a value of about $10 billion. China produced about 35% of this total. In this area the united stated is the second and the Iran is the third one (Anonymous, 2007). Mechanical properties such as failure stress and strain as well as modules of elasticity can also used to evaluate the behavior of fruits mechanically under the static loading. Firmness or hardness is another important attribute of fruits and it often used in the fruit quality assessment (Harker *et al*., 2006). Skin has an important role in maintaining overall shape and integrity of many fruits. It provides a physical barrier against microbial invasion. The mechanical behavior of skin influences the firmness and resistance of fruit top slitting (Blahovec *et al*., 1995) several research (Duprat *et al*., 2000) had shown the feasibility of usual puncture test to study mechanical properties of fruit skin (apple, grap berry). Bruise damage is a major cause of quality loss for fresh fruit market apples. Most bruising occurs because of impacts. Several researchers have shown that bruising linearly related to impact energy (Chen *et al*., 1996) but bruising varies among varieties, and bruising which occurs at a constant value of the impact energy is variable. Several factors have found to influence bruise susceptibility, but often research has obtained conflicting

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results. Klein and Johnson and Dover are shown that bruising increasing from early to late harvest time. Bruise resistance is both qualitative and quantitative characteristics (Brusewitz and Bartsch, 1989). The ability to measure bruise resistance would be of great value in evaluating the readiness to harvest, effect of storage methods, selecting fruit varieties for planting and studying means of reducing fruit bruising during harvest and handling. Now, there is no found out, universally recognized standard technique for measuring bruise resistance. Holt and Schoorl (1977) and Schoorl and Holt (1980) reported a linear relationship between the energy absorbed and bruise volume produced in apples. The resistance measured at 1 kHz. Rotz and Mohsenin (1978) measured electrical resistance of bruised and unbruised tissues in apples. They used two needles inserted into the apple skin and a General Radio Impedance Bridge at 1 kHz. Bruise susceptibility has defined as the change in measured bruise volume matching to the energy absorbed during either mechanically applied compression or resulting from free fall impacts on to a given surface. (Holt and Schood, 1977; Brusewitz and Bartsch, 1989). Some differences in apple bruise susceptibility have found in the literature because of unstandardized impact energy levels and surfaces used for the impacts. In this section, the methods of determining bruise susceptibility in previous research work will discuss. Bruise resistance (bruise energy per unit of bruise volume) is one of the objective indices employed to evaluate apple susceptibility to damaging impact. The other indices include bruising threshold (the drop height at which bruising begins to occur for an apple of giving mass, shape and impact surface). (Bajema and Hyde, 1998) and threshold of material plastic flow (maximum dynamic stress at which no further bruise damages observed). There are many factors affecting apple sensitivity to bruising. The major one proves to be the drop height and area profile during the impact. Still, some post-harvest factors, that is maturity, water potential, storage time, water content, firmness and mass are of importance as well. The objective of this research was to determine bruise. Therefore, this study was carried out to prevent damage in transit.

2- MATERIALS AND METHODS

The North-West Iranian apple varieties consisted of *Atirli, Kapak, Kowse and Paiez (not ripen on the tree) were* obtained from orchard located in Maku, Iran (260 km far from Urmia in Western Azerbaijan Province) in July 2012. The 100 fruits of each variety were picked up and properties were tested in the biophysical laboratory of University of Tabriz, Tabriz, Iran. The mechanical properties of apples such as bruise volume, static friction coefficient were measured. Apples were dropped from three heights (30, 20 and 10 cm) on a firm surface. The sound was recorded and then was analyzed by Paar software. The time between first and after a rebound compact calculated and by the following equation parameters determined:

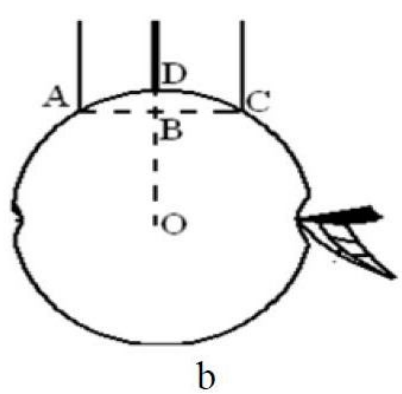

Fig 1-1. Radius parameters

Radius of apple calculated from (Mohsenin 1986):

$$C_r = \frac{AC}{8BD} + \frac{BD}{2} \quad (1)$$

Where the parameter is shown in fig 1-1.

Mohsenin (1986) define the bruise volume (V_b, mm^3) with the assumption the shape of the bruise is spherical:

$$V_b = \frac{\pi d}{24}(3D^2 + 4d^2) \quad (2)$$

Where d is the depth of a bruise at the center and D is the surface diameter of the bruise (mm). Holt and Schoorl (1977) assumed the shape of the bruise is spherical above and below the contact plane. The X is the height of the bruise above the contact plane can calculate by the following equation:

$$X = R - \sqrt{R^2 - D^2/4} \quad (3)$$

Where the R is the radius of apple and D is the bruise diameter.

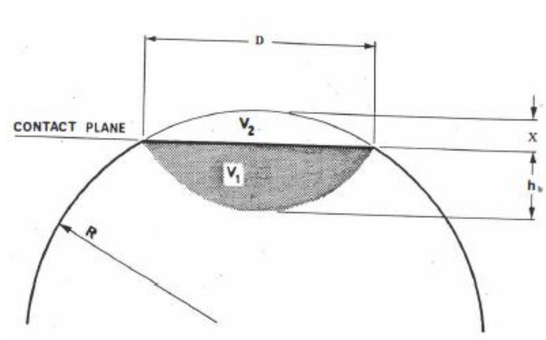

Fig1-2. Bruise above the contact plane

While there is not a standard method for determining bruise susceptibility, Schoorl and Holt (1980) suggested the use of a bruise resistance coefficient defined as the ratio of the bruise volume to the energy absorbed in the impact. This method based on an assumed linear relationship between bruise volume and energy absorbed in an impact. The energy absorbed during an impact can obtained by dropping a single apple on to a solid surface and recording drop and rebound heights. The energy absorbed given by:

$$E = mg\,(H - Hr) \tag{4}$$

And

$$Eb = \left(1 - \frac{Hr}{H}\right)\% \tag{5}$$

Where E is the energy absorbed (J), m is the mass of the apple (kg), g is the gravitational constant (9.81 m/s^2), H and H_r are drop height and rebound height respectively (m). Eb is the percent of energy absorbed). The bruise resistant percent was calculated by following equation:

$$BR\% = \frac{\%E}{V} \tag{6}$$

Where: E is bruise energy percent and V is the bruise volume.

Rebound height determined following equation:

$$Hr = \left(\frac{S}{2}\right)^2 \times \frac{9.81}{2} \tag{7}$$

Where: S is time between the first and second compact.

Coefficient of restitution

The coefficient of restitution varied in a non-linear manner with impact energy, decreasing as impact energy increased. The value of the coefficient of restitution (e) depended on the magnitude of the impact. Since e related to the elasticity of an impact, a low value implies that significant non-elastic are occurring. For a fully elastic impact e = 1, while for fully plastic impact there is no rebound and e = 0. This confirmed by the low occurrence of measured bruising when the value of e was above 0.7 and determined from following equation:

$$e = \left(\frac{Hr}{H}\right)^{0.5} \tag{8}$$

Where: Hr is rebound height and H is the release height.

3- RESULT AND DISCUSSION

Summary of the mechanical properties of north-west of Iran cultivars shown in Table 1, 2, 3, 4 and 5.

Result for apples when dropped from 30 cm height

The bruise diameter was 14.76, 8.95, 5.51 and 9.55 mm for Ko, At, Pa and Ka apples, respectively. According to the results of the bruise height of four apple cultivars, for Ko variety the mean was 3.77 whereas the similar values for the At, Pa and Ka varieties were 2.61, 3.04 and 2.7 mm. The rebound height was 8.2, 9.51, 9.78 and 8.83 cm for Ko, At, Pa and Ka apples, respectively. According to the results of the bruise coefficient of restitution of four apple cultivars, for Ko variety the mean was 0.52 whereas the similar values for the At, Pa and Ka varieties were 0.56, 0.57 and 0.54. The bruise energy absorbed percent were 72.67, 68.30, 67.39 and 70.56 percent for Ko, At, Pa and Ka apples, respectively. According to the results of the bruise energy absorbed of four apple cultivars, for Ko variety the mean was 0.14 whereas the similar values for the At, Pa and Ka varieties were 0.06, 0.09 and 0.08 J. The bruise resistant percent were 0.22, 0.91, 1.1 and 0.65 for Ko, At, Pa and Ka apples, respectively. According to the results of the bruise volume of four apple cultivars, for Ko variety the mean was 480.47 whereas the corresponding values for the At, Pa and Ka varieties were 118, 60.14 and 132.97 mm^3. The bruises above the contact plane were 3.57, 1.22, 1.31 and 1.63 for Ko, At, Pa and Ka apples, respectively.
The highest bruise diameter related to Ko variety and lowest related to Pa variety (Fig. 2).
The highest bruise height related to Ko variety and lowest related to At variety (Fig. 3).
The highest bruise energy absorbed related to Ko variety and lowest related to At variety.
The highest bruise energy absorbed percent related to Ko variety and lowest related to Pa variety.
The highest bruise volume related to Ko variety and lowest related to Pa variety (Fig. 4).
The highest bruise above the contact plane related to Ko variety and lowest related to At variety (Fig. 5).
The highest bruise resistant percent related to Pa variety and lowest related to the Ko variety (Fig. 6).
The highest bruise coefficient of restitution related to Pa variety and lowest related to the Ko variety (Fig. 7).

Result for apples when dropped from 20 cm height

The bruise diameter was 15.08, 8.53, 5.26 and 8.77 mm for Ko, At, Pa and Ka apples, respectively. According to the results of the bruise height of four apple cultivars, for Ko Variety the mean was 3.85 whereas the similar values for the At, Pa and Ka varieties were 3.17, 2.63 and 2.46 mm. The rebound height 5.90, 6.75, 6.52 and 6.84 cm for Ko, At, Pa and Ka apples, respectively. According to the results of the bruise coefficient of restitution of four apple cultivars, for Ko Variety the mean was 0.54 whereas the corresponding values for the At, Pa and Ka varieties were 0.58, 0.57 and 0.58.
The bruise energy absorbed percent were 70.49, 66.24, 67.40 and 65.82 percent for Ko, At, Pa and Ka apples, respectively. According to the results of the bruise energy absorbed of four apple cultivars, for Ko Variety the mean was 0.09 whereas the similar values for the At, Pa and Ka varieties were 0.04, 0.06 and 0.05 J. The bruise resistant percent were 0.17, 1.08, 1.23 and 0.79 percent for Ko, At, Pa and Ka apples, respectively. According to the results of the bruise volume of four apple cultivars, for Ko Variety the mean was 458.93 whereas the corresponding values for the At, Pa and Ka varieties were 150.97, 46.46 and 98.43 mm^3. The bruise above the contact plane was 3.59, 1.12, 0.41 and 1.36 for Ko, At, Pa and Ka apples, respectively.

The highest bruise diameter related to Ko variety and lowest related to Pa variety (Fig. 2).
The highest bruise height related to Ko variety and lowest related to the Ka variety (Fig. 3).
The highest bruise energy absorbed related to Ko variety and lowest related to At variety.
The highest bruise energy absorbed percent to Ko variety and lowest related to Ka variety.
The highest bruise volume related to Ko variety and lowest related to Pa variety (Fig. 4).
The highest bruise above the contact plane related to Ko variety and lowest related to Pa variety (Fig. 5).
The highest bruise resistant related to Pa variety and lowest related to Ko variety (Fig. 6).
The highest bruise coefficient of restitution related to At and Ka varieties and lowest related to Ko variety (Fig. 7).

Result for apples when dropped from 10 cm height

The bruise diameter was 12.39, 5.97, 3.37 and 5.92 mm for Ko, At, Pa and Ka apples, respectively. According to the results of the bruise height of four apple cultivars, for Ko variety the mean was 3.32 whereas the similar values for the At, Pa and Ka varieties were 4.96, 1.27 and 1.98 mm. The rebound height 3.46, 4.07, 4.15 and 2.93 cm for Ko, At, Pa and Ka apples, respectively. According to the results of the bruise coefficient of restitution of four apple cultivars, for Ko variety the mean was 0.59 whereas the corresponding values for the At, Pa and Ka varieties were 0.63, 0.63 and 0.54.
The bruise energy absorbed percent were 65.42, 59.29, 58.48 and 70.74 percent for Ko, At, Pa and Ka apples, respectively. According to the results of the bruise energy absorbed of four apple cultivars, for Ko variety the mean was 0.04 whereas the similar values for the At, Pa and Ka varieties were 0.02, 0.03 and 0.03 J. The bruise resistant percent were 0.38, 1.74, 4.05 and 0.04 percent for Ko, At, Pa and Ka apples, respectively. According to the results of the bruise volume of four apple cultivars, for Ko variety the mean was 276.82 whereas the similar values for the At, Pa and Ka varieties were 74.96, 11.53 and 54.56mm^3. The bruise above the contact plane was 2.27, 0.76, 0.19 and 0.67 mm for Ko, At, Pa and Ka apples, respectively.

The highest bruise diameter related to Ko variety and lowest related to Pa variety (Fig. 2).
The highest bruise height related to At variety and lowest related to Pa variety (Fig. 3).
The highest bruise energy absorbed related to Ko variety and lowest related to At variety.
The highest bruise energy absorbed percent to Ka variety and lowest related to Pa variety.
The highest bruise volume related to Ko variety and lowest related to Pa variety (Fig. 4).
The highest bruise above the contact plane related to Ko variety and lowest related to Pa variety (Fig. 5).
The highest bruise resistant related to Pa variety and lowest related to Ka variety (Fig. 6).
The highest bruise coefficient of restitution related to At and Pa varieties and lowest related to Ka variety (Fig. 7).

4- CONCLUSION

Some mechanical properties of Iran north-west local apple varieties presented in this study. These parameters, which may be useful in designing many of the equipments used for harvesting, post harvest and sorting. From this study it can conclude that:
1. The value of all features was different from variety to variety.
2. The Pa variety was much firmer than others.
3. The Maximum coefficient of static friction for MDF and the minimum was for PVC.

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Table 1. Mechanical bruise analysis for Kowse (Ko) Variety

D=Bruise Diameter (mm); H=Bruise height (mm); Hr= Rebound height (cm); Eb=Bruise Energy percent; e= Bruise coefficient of restitution; BR=Bruise resistant percent; V=Volume (mm^3); E=bruise Energy Absorb (J); X= Bruise contact above (mm)

	MAX	MIN	AVE	S.D	S.V	MAX	MIN	AVE	S.D	S.V	MAX	MIN	AVE	S.D	S.V
Height	**30**	**30**	**30**	**30**	**30**	**20**	**20**	**20**	**20**	**20**	**10**	**10**	**10**	**10**	**10**
D	20.40	11.76	14.86	2.83	0.19	18.57	10.06	15.08	2.06	0.14	14.62	5.65	12.39	2.24	0.18
H	5.46	1.56	3.77	1.12	0.30	5.75	2.76	3.85	0.81	0.21	9.56	1.40	3.32	1.90	0.57
Hr	8.74	7.60	8.20	0.36	0.04	6.95	5.15	5.90	0.50	0.09	4.33	2.69	3.46	0.46	0.13
Eb,	74.66%	70.86%	72.67%	1.18%	1.63%	74.23%	65.27%	70.49%	2.52%	3.57%	73.14%	56.66%	65.42%	4.58%	6.99%
e	0.54	0.50	0.52	0.01	0.02	0.59	0.51	0.54	0.02	0.04	0.66	0.52	0.59	0.04	0.07
BR	0.61%	0.07%	0.22%	0.15%	66.70%	0.28%	0.10%	0.17%	0.05%	30.63%	1.76%	0.08%	0.38%	0.41%	108.06%
V	987.14	118.21	480.47	293.56	0.61	707.54	257.53	458.93	133.89	0.29	716.01	34.77	276.82	158.75	0.57
E	0.18	0.11	0.14	0.02	0.15	0.11	0.07	0.09	0.01	0.13	0.05	0.03	0.04	0.01	0.14
X	6.03	1.23	3.57	1.67	0.47	5.94	0.95	3.59	1.37	0.38	4.46	0.34	2.27	1.02	0.45

Table 2. Mechanical bruise analysis for Atirli (At) Variety

	MAX	MIN	AVE	S.D	S.V	MAX	MIN	AVE	S.D	S.V	MAX	MIN	AVE	S.D	S.V
Height	**30**	**30**	**30**	**30**	**30**	**20**	**20**	**20**	**20**	**20**	**10**	**10**	**10**	**10**	**10**
D	12.61	3.89	8.95	2.45	0.27	12.43	4.75	8.53	2.47	0.29	11.10	1.71	5.97	3.04	0.51
H	3.97	1.56	2.61	0.63	0.24	5.01	0.97	3.17	1.22	0.38	11.53	0.97	4.96	3.62	0.73
Hr	11.04	8.29	9.51	0.79	0.08	8.10	5.00	6.75	0.79	0.12	5.36	1.71	4.07	1.05	0.26
Eb	72.37%	63.21%	68.30%	2.62%	3.84%	74.98%	59.50%	66.24%	3.93%	5.93%	82.93%	46.44%	59.29%	10.50%	17.71%
e	0.61	0.53	0.56	0.02	0.04	0.64	0.50	0.58	0.03	0.06	0.73	0.41	0.63	0.09	0.14
BR-	3.98%	0.25%	0.91%	0.91%	100.03%	5.90%	0.17%	1.08%	1.45%	134.35%	7.16%	0.30%	1.74%	1.93%	111.03%
V	288.95	17.51	118.00	71.00	0.60	382.65	11.46	150.97	127.88	0.85	205.13	11.57	74.96	58.36	0.78
E	0.07	0.05	0.06	0.01	0.12	0.05	0.03	0.04	0.01	0.14	0.03	0.01	0.02	0.00	0.21
X	2.32	0.27	1.22	0.53	0.43	2.29	0.34	1.12	0.56	0.50	2.39	0.03	0.76	0.76	1.01

D=Bruise Diameter (mm); H=Bruise height (mm); Hr= Rebound height (cm); Eb=Bruise Energy percent; e= Bruise coefficient of restitution; BR=Bruise resistant percent; V=Volume (mm^3); E=bruise Energy Absorb (J); X= Bruise contact above (mm)

Table 3. Mechanical bruise analysis for Paiez (Pa) Variety

	MAX	MIN	AVE	S.D	S.V	MAX	MIN	AVE	S.D	S.V	MAX	MIN	AVE	S.D	S.V
Height	30	30	30	30	30	20	20	20	20	20	10	10	10	10	10
D	7.16	0	5.51	2.02	0.37	6.89	0	5.26	1.96	0.37	5.71	0	3.37	1.94	0.57
H	4.94	0	3.04	1.47	0.49	4.05	0	2.63	1.11	0.42	2.39	0	1.27	0.88	0.69
Hr	14.18	7.36	9.78	1.84	0.19	7.30	6.04	6.52	0.41	0.06	9.61	2.58	4.15	2.02	0.49
Eb,	75.46%	52.75%	67.39%	6.13%	9.09%	69.78%	63.50%	67.40%	2.07%	3.08%	74.22%	3.86%	58.48%	20.25%	34.62%
e	0.69	0.50	0.57	0.05	0.09	0.60	0.55	0.57	0.02	0.03	0.98	0.51	0.63	0.13	0.21
BR	3.12%	0.00%	1.10%	0.81%	73.41%	2.21%	0.00%	1.23%	0.55%	44.47%	8.83%	0.00%	4.05%	3.52%	86.92%
V	132.60	0	60.14	34.71	0.58	69.71	0	46.46	19.14	0.41	27.18	-0	11.53	8.61	0.75
E	0.14	0.08	0.09	0.02	0.20	0.08	0.05	0.06	0.01	0.15	0.04	0.00	0.03	0.01	0.40
X	9.24	0	1.31	2.79	2.13	0.65	0	0.41	0.19	0.47	0.49	0	0.19	0.14	0.76

D=Bruise Diameter (mm); H=Bruise height (mm); Hr= Rebound height (cm); Eb=Bruise Energy percent; e= Bruise coefficient of restitution; BR=Bruise resistant percent; V=Volume (mm^3); E=bruise Energy Absorb (J); X= Bruise contact above (mm)

Table 4. Mechanical bruise analysis for Kapak (KA) Variety

	MAX	MIN	AVE	C.V.%	S.D	MAX	MIN	AVE	C.V.%	S.D	MAX	MIN	AVE	C.V.%	S.D
Height	30	30	30	30	30	20	20	20	20	20	10	10	10	10	10
D	11.07	8.43	9.55	11.64	1.11	10.15	7.26	8.77	12.306	1.08	8.11	3.47	5.92	34.48	2.04
H	4.33	1.57	2.70	37.89	1.02	3.83	1.43	2.46	41.089	1.01	3.49	0.05	1.98	80.24	1.59
Hr	9.61	8.04	8.83	7.54	0.67	7.97	6.10	6.84	11.400	0.78	3.42	2.44	2.93	13.04	0.38
Eb	73.21%	67.95%	70.56%	3.15	2.22%	69.51%	60.13%	65.82%	5.92	3.90%	75.62%	65.80%	70.74%	5.39	3.82%
e	0.57	0.52	0.54	3.77	0.02	0.63	0.55	0.58	5.653	0.03	0.58	0.49	0.54	6.54	0.04
BR	1.12%	0.37%	0.65%	51.35	0.33%	1.22%	0.42%	0.79%	43.73	0.34%	6.96%	2.20%	0.04%	2.09%	64.22
V	199.90	61.08	132.97	45.26	60.17	156.00	56.68	98.43	43.925	43.23	120.19	0.60	54.56	108.31	59.09
E	0.09	0.06	0.08	18.48	0.01	0.06	0.04	0.05	20.571	0.01	0.03	0.02	0.03	19.50	0.01
X	2.09	1.37	1.63	18.59	0.30	1.71	1.00	1.36	22.802	0.31	1.28	0.18	0.67	70.64	0.47

D=Bruise Diameter (mm); H=Bruise height (mm); Hr= Rebound height (cm); Eb=Bruise Energy per cent; e= Bruise coefficient of restitution; BR=Bruise resistant percent; V=Volume (mm^3); E=bruise Energy Absorb (J); X= Bruise contact above (mm)

Table 5. Radiuses of apples

	Ko					At				
	Max	**Min**	**Ave**	**S.D**	**S.V**	**MAX**	**MIN**	**AVE**	**S.D.**	**C.V.**
Cr	35.12	13.44	22.62	5.33	0.24	29.78	13.77	18.11	3.78	0.21
	Pa					**KA**				
	Max	**Min**	**Ave**	**S.D**	**S.V**	**MAX**	**MIN**	**AVE**	**S.D.**	**C.V.**
Cr	24.68	15.34	20.37	2.10	0.10	19.28	14.00	16.35	1.38	8.45

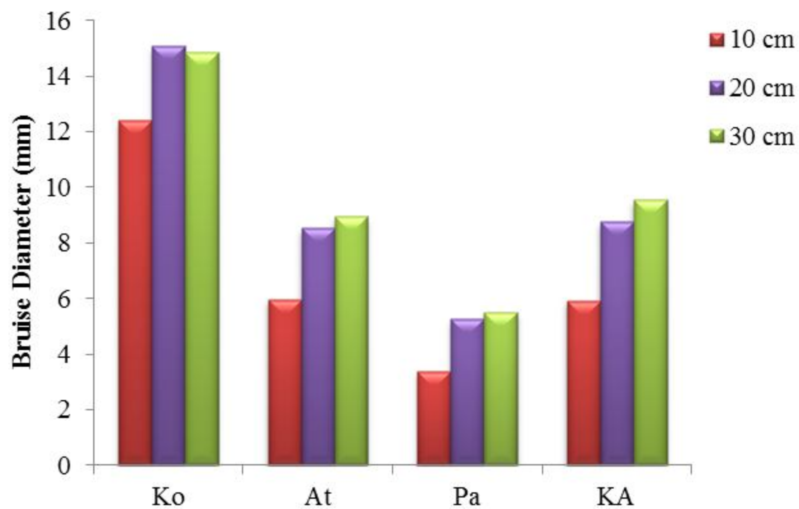

Fig 2 - Average of Bruise Diameter for four Apple cultivars

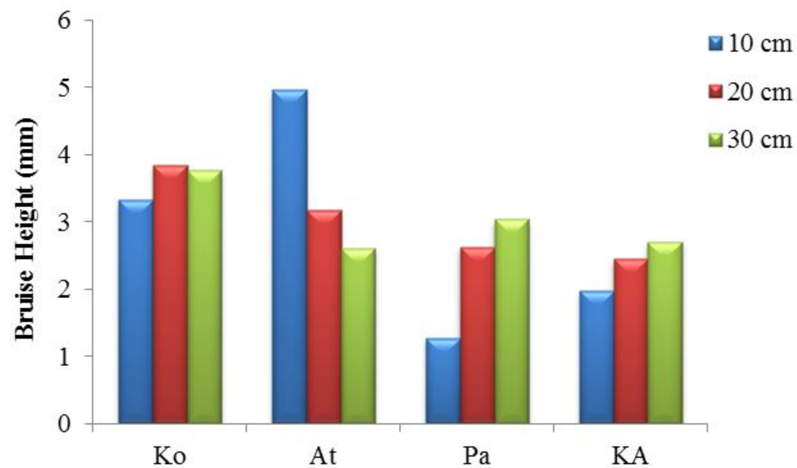

Fig 3 - Average of Bruise Height for four Apple cultivars

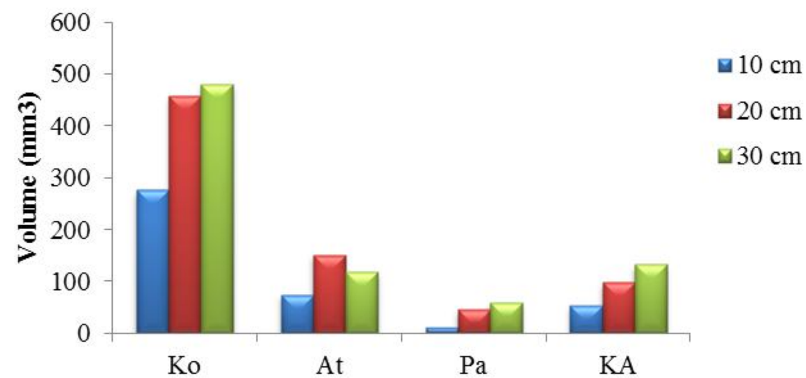

Fig 4 - Average of volume

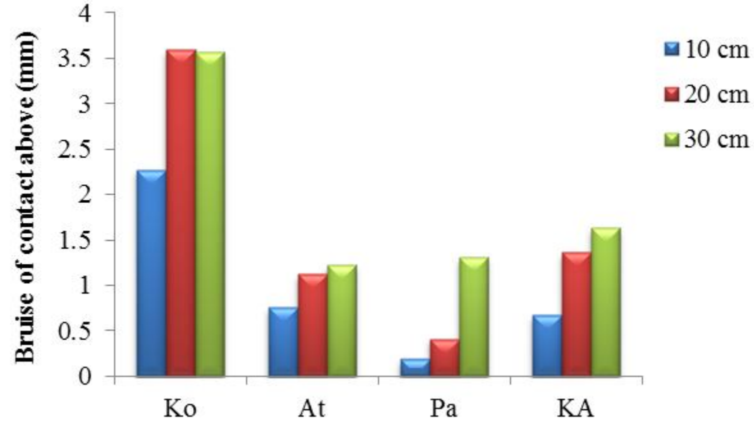

Fig 5- Average of Bruise contact above

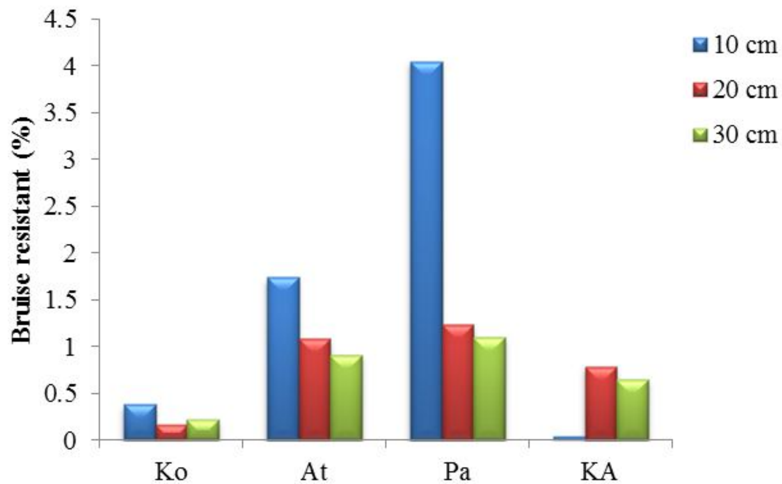

Fig 6- Average of Bruise resistant percent for four Apple cultivars

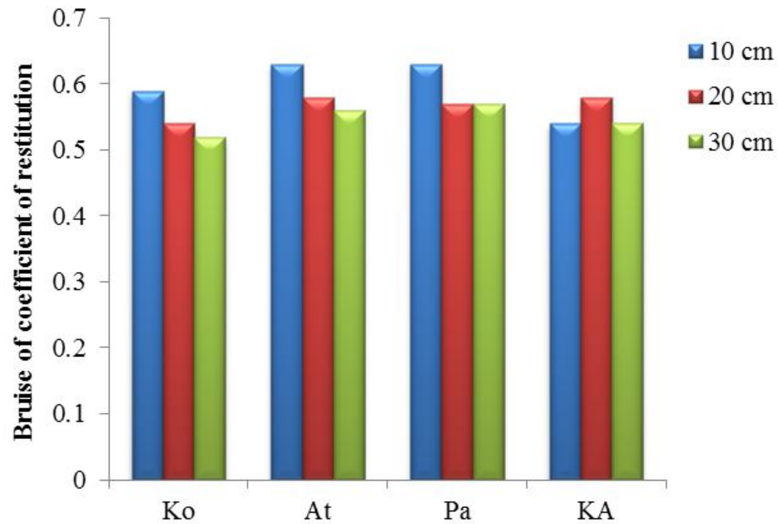

Fig 7- Average of Bruise coefficient of restitution