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Physicochemical Changes of Impacted Tomatoes with Pendulum Mechanical Forces

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ABSTRACT

Tomato is one of the sensitive fruits to mechanical impacts and physical tensions. The most mechanical damages arise from handling which results in reducing tomato quality. in this study, impact energy effect has been studied in 3 different levels 0, 0.14 and 0.25 J by a pendulum impact apparatus, on changes of physicochemical properties of tomato, hybrid variety Shiva F1, including ripening factor, wet content physical properties such as texture resistance versus shearing force , color and shelf life during a period of shelf life for 20 days in Temperature 11±1°C and relative humidity 94±2 percent. It is found that when mechanical energy increase, like something results from increasing shelf life, texture resistance decrease versus shearing force. However increasing impact energy not only reduces firmness texture and wet content in production but also increasing ripening factor and its color during storing time. Results show the least shelf life and most unsuitable changes in 0.25 J samples.

Keyword: Tomato; Impact; Mechanical injury; Storage.

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INTRODUCTION

From production to consumption, horticultural products are prone to the action of static and dynamic forces during the operation and to processing to which they are submitted (Couto *et al*., 2002). Mechanical damage is extremely common during fruit handling (Sanches *et al*., 2008; Arazuri *et al*., 2007).

Tomato (*Lycopersicon esculentum* Mill.) is one of the most important vegetable crops in the world of horticultural economy. Tomato is one of susceptible fruits to mechanical forces. Its Postharvest losses are estimate 30 percent. The major cause of these losses is mechanical damage (bruising) due to impact (Idah *et al*., 2007). Bruising begins when the shear stress reaches a certain value. Because of this the critical shear stress may be defined as the current bruising strength. The bruising mechanism is a result of both physical injury and the subsequent breakdown of the cell wall components by the action of cell wall related proteins (Bennett, 2002; Van Linden & De Baerdemaeker, 2005). The ripeness rate at harvesting has a high influence on the rate of produt losses. The higher the ripeness rate the greater the losses (Macua *et al*., 2003). Studman (1997) mentioned that a loss in cell wall strength will increase the bruise susceptibility of fruit. The cells of riper fruit are less able to withstand external loading and will more easily yield. Sargent *et al*. (1992) observed that tomato fruit at the breaker stage were more susceptible to internal bruising that fruit at the mature-green stage. One of the ways in which tomato quality can be kept is by controlling storage temperature. Temperature greatly influences the rate of respiration of fruits and vegetables, and is undoubtedly one of the most important factors in maintaining post harvest quality of tomato fruits. It was reported that a storage temperature of 10-15°C and 85-95 percent relative humidity could extend the postharvest life of fruits. At these temperatures chilling injury and ripening rate are minimal (Znidarcic *et al*., 2006).

Ball (1997) suggested that a postharvest change in firmness can occur due to the loss of moisture through transpiration, as well as enzymatic changes. In addition, hemicelluloses and pectin become more soluble, which resulted in to disruption and loosening of the cell walls.

Znidarcic *et al*. (2010) were harvested Tomato fruits (cv. Belle) at the middle-red ripe stage and exposed at 5oC and 10oC for up to 28 days. They founded that at both temperatures and at every stage of storage time pericarp firmness decreased as storage time increased. The decrease in firmness was delayed by the lower temperature.

Van linden *et al*. (2006) proposed an appropriate method to evaluate bruise damage and to determine tomato susceptibility to bruises. They used an instrumented pendulum to apply controlled impact energy in a dynamic way. The resulting damage was assessed a few days after impact on a sensory basis. Clearly, the impact energy and its interactions have a substantial effect on the bruise susceptibility of a tomato.

Desmet *et al*. (2003) a pendulum was designed to evaluate the puncture injury susceptibility of tomato cultivars in an objective way. This methodology was applied to two cultivars with different susceptibilities to puncture injury, 'Tradiro' (less susceptible) and 'Blitz' (very susceptible). Their susceptibilities to puncture injury were measured as a function of storage time and colour stage. It was found that: (i) tomatoes at harvest were less susceptible to puncture injury than after storage for several days; and (ii) colour at harvest had no effect on the susceptibility for puncture injury.

Mechanical forces are effective on physicochemical properties. The main modification resulted from impact on the fruit, were losses of citric acid and soluble solids, which increased the solid: acid ratio, that this ratio is ripening factor (Montero *et al*., 2009). As well as, In tomato a decrease of 17 percent in vitamin C was determined in injured fruit (Moretti *et al*., 1999). Nagy (1980) reported most of the ascorbic acid is lost after harvest due to aerobic reaction. Tomato skin (a*) and flesh colour (b*) greatly affect bruise susceptibility. A change in *a* value indicates fruit ripening. The colour evaluation in fruits corresponds to a fall in chlorophyll and an increase in carotenoid accumulation, reflecting the transformation of chloroplasts to chromoplasts. The colour development rate of fruits increased with increasing maturation (Znidarcic *et al*., 2006).

Kays (1991) stated that mechanical and geometrical properties of tomato tissue and tissue structure are important factors determining differences in damage susceptibility. The objective of this research project was Study the effects of pendulum mechanical forces on the quantitative and qualitative characteristics of tomato.

MATERIAL AND METHODS

Tomato fruits

160 tomatoes (*Lycopersicon esculentum* Mill.) cultivar Shiva F1 were purchased free from disease and injury and uniform in shape and size at the day of harvest, from growers situated in the Chaharbagh region of Karaj. Tomatoes were harvested at red ripeness. Measurements were carried out at harvest day (day 0) and after 5, 10, 15 and 20 days of storage at 11±1°C and 85 percent RH. For each treatment 3 replications were utilized.

Pendulum

In order to objectively determine the susceptibility of tomatoes to mechanical injury, a pendulum was chosen as an instrument to simulate impacts and apply controlled impact on tomatoes (Desmet *et al*., 2002; Van linden *et al*., 2006).160 tomatoes were impacted after harvest at three levels of impact energies by releasing the arm of the pendulum from several impact angles 0◦, 15◦, 30◦ (table 1). Impactor weight of pendulum was 955g and length of its wire was 100 cm.

Table 1: Different impacts levels and their mean values used in the experiments

Level Energy	Drop Height (mm)	Impac Energy (N)
Level 1	180	70
Level 2	300	125

The energy at impact (E) is the potential energy of the pendulum (Mohsenin, 1986):

$$E = m \times g \times L\ (1-\cos\theta) \quad (1)$$

Where m is the mass of the pendulum, g is the acceleration due to earth´s gravity (9.81 m / s²), L is length of the pendulum wire and θ is the pendulum angle.

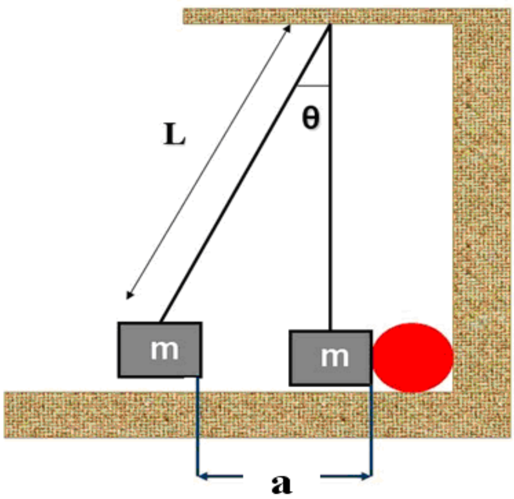

Fig.1: simple pendulum

For more accuracy in practice, pendulum angle changed by following formulation to length (Fig. 1):

$\sin^2\theta + \cos^2\theta = 1$

$$\cos\theta = \sqrt{1-\sin^2\theta} \qquad (2)$$

$$E = m \times g \times L\,(1-\sqrt{1-\sin^2\theta}) \qquad (3)$$

Because of sin is the rib in front of chord, therefore :

$$E = m \times g \times l\,(1-\sqrt{1-(a/l)^2}) \qquad (4)$$

Where a is pendulum displacement.

Analytical methods

Ripening Factor

Ripening factor is solid: acid ratio (Montero *et al.*, 2009).

Rf = T.S.S / Acidity

Moisture Content

The moisture contents of the tomatoes were determined by keeping the samples in a thermostatically controlled electric oven at 96°C for five hour (AOAC, 1976).

Texture

Texture was measured using a Texture Analyzer (HOUNSFIELD-H5K5) with 6.4mm penetration probe and was determined as: (Mohsenin, 1986).

$$SS = F / \pi \,.d\,.\,l$$

SS= texture resistance (N/mm²), F= impact force (N), d= diameter of prob (mm), l= tomato thickness in zone of applying maximom force(mm).

Color

Color measurements were conducted using a colorimeter HUNTERLAB-D25-9000 to obtain CIElab values (L (illuminance), a (red-green index), b (yellow-blue index)). The decrease of parameter L* and the increase of a* were considered as browning indices (Riva *et al.*, 2005).

Statistical Analysis

The experiment was conducted according to a completely randomised design. Data were evaluated by analysis of variance (ANOVA) and Duncan test, using SPSS16 software version 16.0.

RESULTS AND DISCUSSION

Ripening Factor

Ripening factor is solid:acid ratio (Montero *et al*., 2009). As shown in Figure 2 during time of storage countinously increased the solid: acid ratio, because acids are a great energy source for the oxidation process in the Krebs cycle. Organic acids are usually reduced with maturation due to respiration and are converted into suger (Mattiuz *et al*., 2003). Soluble solids content increases with fruit maturity through biosynthesis process or degradation of polysaccharides (Salunkhe *et al*., 1974) resulted increase ripening factor with the increase in impact energies (Table 2).

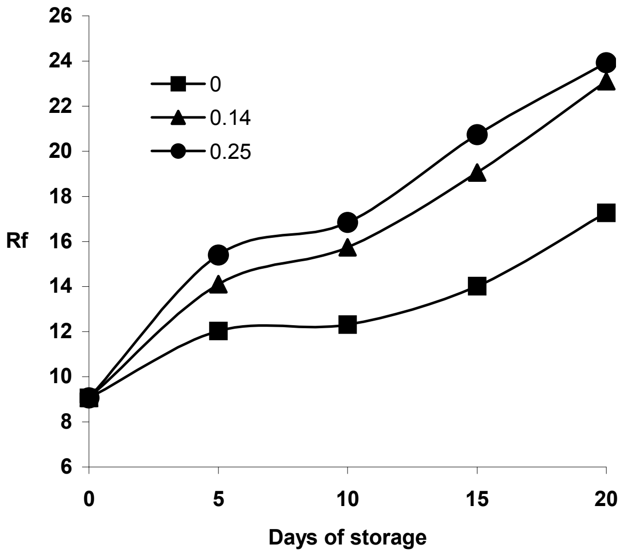

Fig.2: **Effect impact energy and time of storage on Rf in tomato cv. Shiva F1.**

Table 2: Chemical and physical propertiese of tomatoes

Impact Energy	Storge	Rf	M.C	SS	a
0	0	9.06	93.6	0.111	31.63
0	5	12.027	93.61	0.089	32.937
0	10	12.31	93.42	0.084	37.477
0	15	14.013	93.267	0.064	38.353
0	20	17.27	92.8	0.057	39.34
0.14	0	9.06	93.65	0.111	31.63
0.14	5	14.1	93.547	0.086	37.283
0.14	10	15.737	93.323	0.07	38.807
0.14	15	19.06	92.353	0.054	39.247
0.14	20	23.1	91.15	0.048	40.05
0.25	0	9.06	93.65	0.111	31.63
0.25	5	15.397	93.13	0.065	38.487
0.25	10	16.85	92.303	0.056	39.317
0.25	15	20.733	92.167	0.04	39.85
0.25	20	23.923	91.06	0.037	40.17

Moisture Content

The evolution of moisture content is presented in Figure 3. The initial level of moisture content was about 93.6. The moisture content change was negatively related to the period of storage (Table 2). It is also noticeable that moisture content reduced with increasing impact energy. Moisture content are reduced due to the loss of moisture through transpiration. Storage and impact energy contributed to a significant reduction of moisture amount found in our study. However, higher impact energy increased the rate of moisture loss compared to the lower impact energy. It was suggested by Ball (1997) that increasing storage period causes a decrease of moisture content in fruits and vegetables.

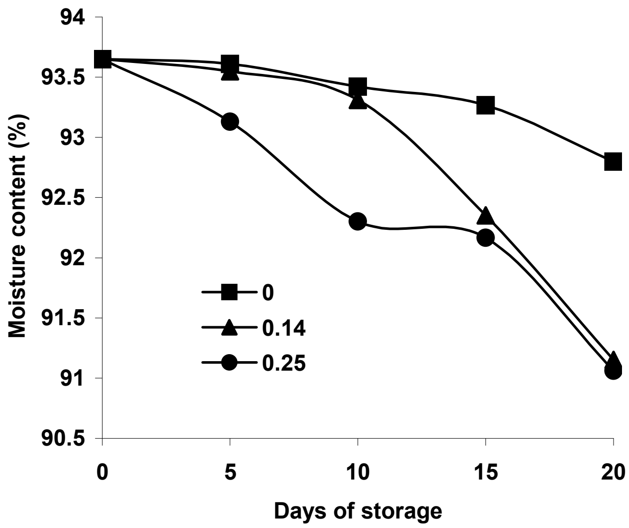

Fig.3: Effect impact energy and time of storage on moisture content in tomato cv. Shiva F1.

Firmness of texture

The development of pericarp firmness, i.e. the softening of the fruits, was significantly affected by storage time (Figure 4). Firmness decreased notably at during the storage period. In contrast, firmness decreased sharply the first 5 days of storage (Table 2).It was suggested by Ball (1997) that a postharvest change in firmness can occur due to the loss of moisture through transpiration, as well as enzymatic changes. In addition, hemicelluloses and pectin become more soluble, which resulted in to disruption and loosening of the cell walls (Paul,1999). Time had significant effect on fruit firmness. Fruits softened during the storage period. A close relationship between the softening of the fruits, extension of storage time was described by Gomez and Camelom (2002).

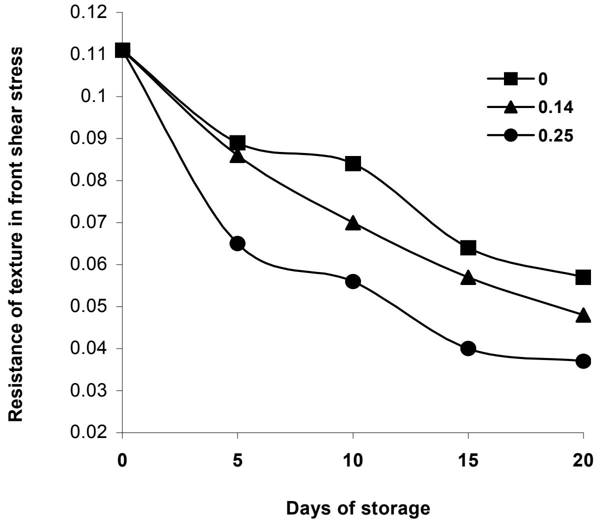

Fig.4: Effect impact energy and time of storage on Firmness of texture in tomato cv. Shiva F1.

Colour of Pericarp

Fig. 5shows the changes of colour in tomato skin as illustrated by the *a* value. A change in *a* value indicates fruit ripening. The initial fruit colour was 32.1 (*a* value). The *a* value increased with fruit maturity. Ripe tomato colour continued to increase clearly by 35.9 (at 0 J), by 37.8 (at 0.14 J) and by 38.8 (at 0.25 J) (Table.2).Carotenes and xanthophylls, especially lycopene, oxidized during the storage and gradually changed the colour from bright red to dark brown. However, after 20 days fruits reached their minimum of *b* value (data not shown). The tomatoes reached the full red stage at day 20 of storage. The findings of Znidarcic *et al*. (2006) supported our results. The colour evaluation in fruits corresponds to a fall in chlorophyll and an increase in carotenoid accumulation, reflecting the transformation of chloroplasts to chromoplasts(Pretel *et al*., 1995). The colour development rate of fruits increased with increasing maturation (Batu, 1998).

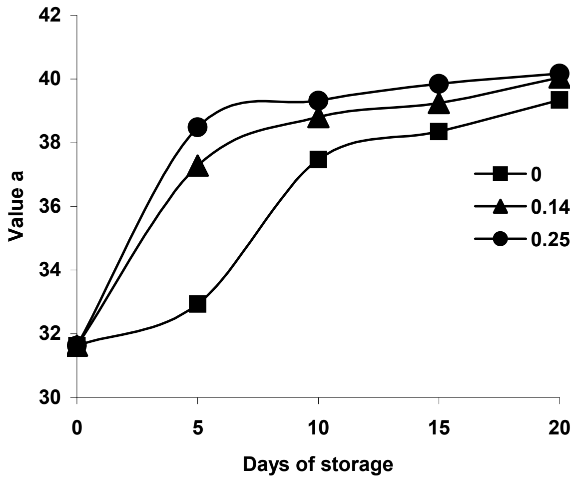

Fig. 5: Effect impact energy and time of storage on value a in tomato cv. Shiva F1

CONCLUSION

Studies have been done in this case display the fact, that increasing impact energy decreasing shelf life. it results from stimulating reactions which are related to ripening , increasing respiration enhancing enzyme activities specially pectin esterase and poly galactronase .wet content of product decreased by increasing impact energy applied to it, because this leads to crack and little gap in product which accelerate wet exiting. Increasing impact energy applied to product ,as a reason of destroying effect and mechanical damage to cell walls, cause to a loss of quality through texture softening ,following by decreasing texture firmness of tomato and producing more red color arising from ripening process, as a result of impact applied to product and rapid accumulation of lycopene .

All results show that impact energy 0.25J was more than tolerance threshold of texture, the most mechanical damages and the least shelf life has been after 20 days of chilling.

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