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Factors influencing lesion formation due to impact damages in ´Gala Brookfield` and ´Fuji Suprema´ apples

Fatores influenciando a formação da lesão por danos mecânicos de impacto em maçãs ´Gala Brookfield` e ´Fuji Suprema´

Cândida Raquel Scherrer Montero[1]*; Lígia Loss Schwarz[2]; Liege Cunhas dos Santos[2]; Cristiane Salete Andreazza[2]; Renar João Bender[3]

Abstract

Apple bruising due to mechanical damage is of main importance for being responsible for considerable losses that alter the external appearance of the fruit hammering its commercial value. Understanding the factors that affect the formation of bruising is important to attempt to minimize the effects of mechanical damages. The objective of the present work was to identify factors that influence the mechanical damage formation produced by impact in two apple cultivars. Three experiments were conducted to evaluate the effects of fruit size and mass, hydration degree and pulp temperature on the development of fruit bruises. The apples were dropped from a height of 80 cm onto a rigid surface. Bruise diameter and depth were accessed after one week at room temperature. The factors that influence bruise formation are the size and the mass the apples as well as hydration degree of fruit tissues. Greater fruit size and mass result in larger bruise sizes. Highly hydrated tissues at the impact moment also increase the bruise size.
Key words: Bruising, mechanical injury, tissue hydration, *Malus domestica* (Borkh)

Resumo

Machucados em maçãs resultantes de danos mecânicos são de suma importância por serem responsáveis por perdas consideráveis que alteram a aparência externa do fruto prejudicando o seu valor comercial. O entendimento dos fatores que afetam a formação da lesão é importante na tentativa de minimizar os efeitos dos danos mecânicos. O objetivo do presente trabalho foi identificar os fatores que influenciam a formação dos danos mecânicos produzidos por impactos em duas cultivares de maçãs. Três experimentos foram conduzidos para avaliar os efeitos do tamanho e massa dos frutos, grau de hidratação e temperatura da polpa no desenvolvimento de machucados no fruto. As maçãs foram derrubadas sob uma superfície rígida de uma distância de 80 cm de altura. O diâmetro e a profundidade da lesão foram acessados depois de uma semana a temperatura ambiente. Os fatores que influenciam a formação da lesão são o tamanho e a massa das maçãs assim como o grau de hidratação dos tecidos do fruto. Frutos maiores e de maior massa estão mais propensos as lesões de maior tamanho. Tecidos bem hidratados no momento do impacto também aumentam o tamanho da lesão produzida por impactos.
Palavras-chave: Machucado, dano mecânico, hidratação do tecido, *Malus domestica* (Borkh)

[1] Pesquisadora, Drª. em Fitotecnia. Universidade Federal do Rio Grande do Sul, UFRGS. E-mail: candidaraquel@gmail.com
[2] Engª Agrª. Universidade Federal do Rio Grande do Sul, UFRGS. E-mail: ligiaschwarz@gmail.com; liegesantos@ibest.com.br; crisandreazza@hotmail.com
[3] Prof., PhD. Universidade Federal do Rio Grande do Sul, UFRGS. E-mail: rjbe@ufrgs.br
* Autor para correspondência

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Introduction

Apple losses in Brazil are not estimated or not published yet. More general estimates for horticultural products are used to predict losses of fresh produce. According to Vigneault, Bordint and Abrahão (2002) approximately 20 to 25% are wasted after harvest depending on the products sensitivity and damage intensity. Losses are caused by mechanical injuries, inadequate storage, unsuitable handling and transport, and on-display time in the retail market (CEAGESP, 2002). Apples, despite its great storage potencial, have ripeness accelerated by mechanical damages which take place during the classifying process, transport and mainly along the handling chain (STEFFENS et al., 2008).

Apple bruising due to mechanical damage during harvest and handling are of major importance for being the most common type of post harvest mechanical injury (ZEEBROECK et al., 2007), it occurs frequently during harvest, transport, and postharvest handling (BARITELLE; HYDE, 2001). Bruising causes cell destruction and reduces the intercellular air spaces, which are initially filled by the water released from the ruptured cells. As time progresses, the bruised tissue starts to lose moisture and eventually becomes desiccated (LU et al., 2010).

In apples, mechanical damages due to impacts are well studied because they are the source of bruises on the pulp of the fruits which turn into oxidized tissues modifying the epicarp's color and reducing the comercial value of the apples (DE MARTINO et al., 2006; MATTIUZ; DURIGAN, 2001). According to Kader (2002), visual quality responds to 83% of the reasons why a consumer chooses a determined product, and it is extremely affected by the presence of defects.

Literature data suggest that pulp temperature and turgidity influence bruise formation, but there are controversial data related to this matter, especially concerning temperature. Besides, size and fruit form are characteristics which, as well, could predispose the apples to particular mechanical damages. Thus, the objective of the present work was to identify characteristics that influence the mechanical damage formation by impacts on fruit of two apple cultivars.

Material and Methods

'Gala Brookfield' and 'Fuji Suprema' apples were harvested from private groves and transported on the same day by car to the postharvest laboratory at the Departamento de Horticultura in Porto Alegre, Rio Grande do Sul, the southernmost state in Brazil. The harvested apples were dropped twice from a 80 cm height on a rigid ceramic surface. This height was pre-defined in previous experiments because it set off visible bruises on the fruit. Diameter and depth of the bruises were measured with a digital calliper.

Three experiments were conducted. In the first experiment 'Gala Brookfield' and 'Fuji Suprema' apples of similar size and mass were separated in three groups: big sized apples (average mass of 185.4 g and a 79.7 mm diameter = caliber 98), medium sized apples (average mass of 137.9 g and a 67.9 mm diameter = caliber 130) and small sized apples (average mass of 100.4 g and a 60,56 mm diameter = caliber 180). After the experimental units had been divided up the apples were, one by one, submitted to the impacts. The experiments were conducted with three treatments with three replicates and six fruit per replicate.

The second experiment consisted of two treatments: more hydrated apples and less hydrated apples. The third experiment evaluated the effects of pulp temperatures: 18ºC or 0ºC. In both experiments only 'Fuji Suprema' apples were used, also in a completely randomized design with three replicates of six fruit each replicate.

To hydrate fruit tissues the apples were placed at a temperature of 25°C for seven days in not sealed polyethylene plastic bags enclosing, as well, wet cotton balls. To ensure less hydrated apples, a set of fruit were maintained unprotected for the same period of time and temperature. After seven days, the experimental units had its mass losses calculated: the hydrated fruit tissues yielded average weight gains of 0,5% while the less hydrated tissues had an average weight loss of 1%.

For the pulp temperature treatments the apples were separated into two sets of fruits. One set was maintained at a room temperature of 20°C for six hours. The second set of apples was transferred to a cold room at 0°C for the same time. Both sets had been placed in polyethylene bags to avoid weight losses. After the six hour period and before the impact treatments were applied pulp temperature at 2 cm depth was determined. Cold stored apples reached pulp temperature of 0ºC whereas room temperature apples were at 18ºC.

The diameter and depht of the bruises consequence of impact treatments were determined with digital calliper one week after treatment application. Bruise dimension data were submitted to analysis of variance and the averages compared by Duncan's multiple range test at $p<0.05$.

Results and Discussion

Bruise dimensions varied with apple size in both cultivars: 'Gala Brookfield' and 'Fuji Suprema' (Tables 1 and 2). Amongst the tested apple fruit sizes the biggest apples had bruises of greatest diameter and depth. In contrast, the smallest apples presented the smallest values for diameter and depth of the bruises resulting from the impact treatments.

Table 1. Bruise size after seven days at room temperature on 'Gala Brookfield' apples deriving from an 80 cm drop onto a rigid ceramic surface.

Treatment	Bruise diameter (mm)	Bruise depht (mm)
Big sized apples	35,4 a*	12,6 a
Médium sized apples	30,6 b	11,9 a
Small sized apples	23,9 c	9,9 b
Variation coefficient (%)	6,4	5,6

*Averages followed by the same letter in columns are not statistically different by Duncan's multiple range test ($p<0,05$).

Table 2. Bruise size after seven days at room temperature on 'Fuji Suprema' apples deriving from an 80 cm drop onto a rigid ceramic surface.

Treatment	Bruise diameter (mm)	Bruise depth (mm)
Big sized apples	32,32 a*	14,59 a
Médium sized apples	27,32 b	13,05 b
Small sized apples	23,37 c	10,99 c
Variation coefficient (%)	5,17	2,98

*Averages followed by the same letter in columns are not statistically different by Duncan's multiple range test ($p<0,05$).

There is significant correlation between all variables studied on both apple cultivars, and greater correlations occur between mass and diameter of the fruit and the bruise diameter (Tables 3 e 4). Correlations are positive indicating that with the increase of the mass or diameter of the apple there is an increase in bruise diameter. Correlation was also positive and significant for bruise depth and the variables of the fruits mass and diameter, nevertheless, values were lower indicating that bruise diameter is more influenced by the characteristics of mass and diameter of the apples than bruise depth.

Table 3. Correlations between fruit variables and bruise parameters of ‘Gala Brookfield’ apples resulting from 80 cm height drops onto a rigid surface.

	Fruit diameter	**Bruise depth**	**Bruise diameter**
Fruit mass	0.97 (p<.0001)	0.46 (p=0.0010)	0.74*(p<.0001)
Fruit diameter		0.48 (p=0.0006)	0.70 (p<.0001)
Bruise depth			0.39 (p=0.0074)

* n = 48.

Table 4. Correlations between fruit variables and bruise parameters of ‘Fuji Suprema’ apples resulting from 80 cm height drops onto a rigid surface.

	Fruit diameter	**Bruise depth**	**Bruise diameter**
Fruit mass	0.95*(p<.0001)	0.73 (p<.0001)	0.85 (p <.0001)
Fruit diameter		0.70 (p <.0001)	0.75 (p <.0001)
Bruise depth			0.67 (p <.0001)

*n=53.

Apple tissue hydration degree influenced the bruise development (Table 5). Well hydrated apple tissues resulted in greater values for bruise diameter when compared to the less hydrated tissues. As for bruise depth, there are no differences amongst well hydrated and less hydrated apple tissues. The hydration degree of the tissue is important on bruise formation. The determined values demonstrate that a greater hydration degree of the tissue increases the bruised area, probably because the more turgid cells are more prone to cellular rupture in comparison cells with lower water contents. Similar results were obtained by Garcia, Ruiz-Altisent and Barreiro (1995) using Golden Delicius apples and pears. According to the authors, fruits under different air relative humidity conditions for hours preceding damage tests presented differences in their physical properties and bruise susceptibility. Fruits with high tissue turgidity were more susceptible to bruising.

Table 5. Bruise diameter and depth after seven days at room temperature of well hydrated and less hydrated ‘Fuji Suprema’ apples dropped from an 80 cm height onto a rigid ceramic surface.

Treatments	**Diameter (mm)**	**Depth (mm)**
Hydrated	27,89a*	12,59a
Not hydrated	24,36b	11,57a
Variation coefficient (%)	5,95	4,09

*Averages followed by the same letter on the column do not differ significantly by Duncan (p<0,05).

Lin and Pitt (1986) demonstrated that when cell rupture is the predominant mechanism of failure, as with potato tissues under compression forces, high turgor pressure has lead to a decrease in tissue strength and rigidity, *i.e.*, less force and energy are required to induce failure of the prestressed cells. Kokkoras (1995) measured changes in residual strains and stresses due to changes in temperature and water status of carrot tissue in view to explain the effects of temperature and water status on the sensitivity of carrot tissue to mechanical damage. The authors concluded that the higher the water status, the greater the residual stresses and strains, and the lower the temperature, the higher the residual stresses. The authors also regarded water status as having a more marked effect than the temperature within the range of tested compression forces.

The physical loads which fruit experience have their primary consequences on membrane systems of individual cells (LEWIS et al., 2008). More intense cellular rupture favors cellular decompartmentalization leading to oxidative processes and ending up with the typical browning of damaged tissues. Since the membranes keep cellular constituents compartmentalized, when plant parts are submitted to physical injury membranes are damaged and are no longer able to maintain tissue integrity. As a result, damage can allow the mixing of enzymes from the cytoplasm with molecules (called phenolics) from the vacuole and the resulting reaction causes the brown coloration associated with a bruise (LEWIS et al., 2008).

Pulp temperatures of 0°C or 18°C did not result in significant differences for bruise diameter and depth (Table 6). Pang et al. (1996) suggested that apples with lower pulp temperature are more susceptible to bruise occurrence than when the pulp temperature is more elevated or close to ambient temperature. The authors evaluated the incidence of damages on Gala, Granny Smith, Braeburn and Fuji apples and concluded that part of the observed results effects could be ascribed to the storage temperature. One of the factors that could influence the response to temperature, according to Pang and coworkers (1996) could be related to the hydration degree of the apple tissues when stored, as has been determined in the present work with 'Brookfield Gala' and 'Fuji Suprema' apples.

Table 6. Bruise diameter and depth after seven days at room temperature of chilled and not chilled 'Fuji Suprema' apples dropped from an 80 cm height onto a rigid ceramic surface.

Treatments	Diameter (mm)	Depth (mm)
Pulp temperature at 0°C	27,12 [ns]	12,75 [ns]
Pulp temperature at 18°C	26,77	12,12
Variation coefficient (%)	5,54	4,95

[ns] Not statistically different by Duncan's multiple range test ($p<0,05$).

Mikal and Saltveit (1984) measuring bruise volumes in 'Delicious' apples observed that the greatest volumes of bruises were measured in impacted apples with highest pulp temperatures (20 or 30ºC). The authors indicate that bruise volume was smaller in apples maintained under low temperatures (0°C) before imposing impacts to the apples. That outcome was not observed in the present experiments with 'Fuji Suprema' and 'Gala Brookfield'.

When experiments with pulp temperature are conducted it is important to maintain a similar hydration degree for the tested fruit. Otherwise, indistinguishable effects of temperature and tissue hydration might evolve during the evaluation of bruising aspects, such as volume or size. On the present work care was taken to isolate the effects of temperature and hydration to evaluate each effect singularly.

It's important to understand the factors that influence the bruise formation in order to develop strategies to reduce the incidence of mechanical damage during post-harvest handling. If harvests have to keep on right after long rainfalls when the apples are exceedingly hydrated, this might lead to a greater susceptibility to bruise occurrence of bigger size.

Conclusions

Apples of greater size and mass endure more damages when submitted to impacts in comparison to apples of smaller size and mass.

The positive and significant correlations between fruit mass and size and bruise diameter and depth demonstrate the influence of fruit characteristics on bruise formation in apple tissues.

The hydration degree of the tissue influences the bruise formation; a more hydrated tissue increases the bruise diameter while the temperature of the pulp at the moment of impact does not determine significant differences on the size of the bruise resulting from impacts on 'Fuji Suprema' apples.

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