Tangerine quality losses in response to compression forces

Perdas de qualidade em tangerinas em consequência de danos mecânicos

Cândida R. Scherrer Montero [1]
candidaraquel@gmail.com
Renar J. Bender [2]
Universidade Federal do Rio Grande do Sul, Brasil
https://ror.org/041yk2d64
rjbe@ufrgs.br

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Abstract

Most of the external injures on produce are mainly caused at harvest and along the postharvest handling chain. Impacts, vibrations and compression forces result in damages that devalue the product for the fresh market. Some citrus species are remarkably susceptible to an epidermal blemish, oleocelosis, a characteristic disorder resulting from mechanical forces. In the present work two tangerine cultivars, Ponkan and Michal were submitted at lab facilities to compression forces of up to 60N to identify effects on internal quality and oleocelosis and decay incidence. Both cultivars had noteworthy losses on titratable acid and ascorbic acid after seven days at room temperature of the compression treatment. Cv. Ponkan is more susceptible to oleocelosis incidence probably because of a higher number and more superficial oil glands facilitating their rupture.
Keywords: **Mechanical injuries, oleocelosis, physiological disorder.**

Resumo

Os danos superficiais em produtos hortícolas têm origem principalmente na colheita e ao longo da cadeia pós-colheita. Impactos, danos de vibração e forças de compressão resultam em lesões que desvalorizam o produto para o mercado *in natura*. Algumas cultivares de citros são notadamente susceptíveis a uma lesão na epiderme, a oleocelose, um dano característico resultante de danos mecânicos. No presente trabalho duas cultivares de tangerinas, Ponkan e Michal, foram submetidas em laboratório a forças de compressão de até 60N no intuito de identificar efeitos na qualidade interna e na incidência de oleocelose e de podridões. Ambas as cultivares apresentaram perdas significativas em acidez titulável e teores de ácido ascórbico após 7 dias em temperatura ambiente após a aplicação dos tratamentos de compressão. A cv. Ponkan apresenta maior susceptibilidade à incidência de oleocelose muito possivelmente pelo maior número e mais superficiais glândulas de óleo o que facilita o seu rompimento.
Palavras-chave: **Danos mecânicos, oleocelose, distúrbio fisiológico.**

Notas de autor

1 Research and Development Analyst, Dr., Embrapa, BR-392, km 78 Monte Bonito, Pelotas - RS, Brazil. 96010-971 Embrapa. candidaraquel@gmail.com

2 Professor, Postharvest Laboratory Faculdade de Agronomia/ UFRGS, 91540-000 Porto Alegre, RS, Brazil.

* Corresponding author: rjbe@ufrgs.br

Introduction

Tangerines, in Brazil, are predominantly destined for fresh consumption. Market demands require after harvest handling procedures to preserve external an internal quality that are important to a continuous build up on the amount of consumers (Bender, 2009). From production to consumption, fruits are susceptible to static and dynamic forces along the various steps of processing the fruit before reaching customers (Couto et al., 2002). Consequently, mechanical damages may occur at any point from harvest to the end consumer. Mechanical injuries are plastic deformations or superficial cracks that end up in physiological, chemical or biochemical changes that may affect aroma, flavor, color and overall quality (Clark et al., 1997).

Impact forces are caused by drops of the fruit during harvest, at the moment the fruit are transferred to transport containers and during sorting and packing for shipment to retailers. Compression forces result from overfilling of the boxes. Both give rise to opportunities to the causative postharvest decay organisms (Bender, 2009).

Ponkan tangerine is the most worldwide-planted tangerine cultivar with prominence of yields of Brazil and the Asian continent (Schwarz and Brugnara, 2009). The cultivar presents a thicker peel in comparison to the other tangerine cultivars and contains, as well, more essential oils. The peel is not tightly adhered to the segments that ends in some drawbacks for the postharvest handling chain.

The cultivar Michal, originated in Israel, is believed a natural hybrid in between the tangerine cultivars Clementina and Dancy. Michal is a big-sized fruit cultivar, easy to peel with a reddish epidermis, high juice contents and with an excellent sugar-acids equilibrium (Saunt, 1992). According to Brugnara et al. (2009) cv. Michal was recently introduced in the state of Rio Grande do Sul and very early turned into a market alternative as its harvest period is in the midst of satsuma Okitsu (*C. unshiu*) and tangerine Cai (*C. reticulata*).

In the present work both cultivars, Ponkan and Michal, were used to evaluate the effects on quality attributes of compression forces applied at laboratory facilities.

Material and Methods

Cv. Ponkan and Michal tangerines freshly harvested from an experimental grove at the Estação Experimental Agronômica located 70 west of Porto Alegre, the capital city of the state of Rio Grande do Sul were submitted to various compression forces in the Postharvest Laboratory. The forces were applied on an equipment consisting of a hydraulic jack fixed onto a metal structure (Figure 1). The fruit were positioned, one at the time, in between the metallic plate and an instrumented sphere.

Figure 1
Assembly of an unit to apply compression forces consisting of an hydraulic jack and an instrumented sphere and the fruit positioned in between.

The instrumented sphere used in the trials was developed in the electro-electronic lab of the School of Engineering/Universidade Federal do Rio Grande do Sul. The sphere is composed of four parts. 1) Three aluminum rings fitted with extensometers (strain gauges), sensors capable to detect mechanical deformations, 2) A printed circuit board fastened to the strain gauges located inside the sphere together with 3) instrumentation amplifiers for the strain gauges and 4) an external box containing a data acquisition system, which converts the analogic signals from the sphere into digital signals for communication with the computer through a specific developed software The instrumented sphere is calibrated to measure static forces (Muller, 2008).

When the hydraulic jack is manually set in motion, simultaneously compressing the tangerines and the instrumented sphere, the compression forces are identified by the developed software acquiring the data perceived by the instrumented sphere. The tangerines were compressed with 10N, 20N, 40N or 60N.

After the treatments, the tangerines were left at room temperature for seven days and then weighed to determine fresh mass losses. The fruit, at that time, were also analyzed for titratable acidity, soluble solids and .epidermal color. Color was determined with a Konica/Minolta colormeter model CR 400 under illuminant C. Three measurements on every fruit and the tristimulus L, a and b data were used to calculate chroma and *hue* angle according to McGuire (1992).

Ascorbic acid contents of the fruit was determined according to the photocolorimetric method at 530 nm of the reaction of the 2.6-dichlorophenol indophenol dye as described in Kechinski et al. (2012). Decay incidence was determined visually by counting the fruit with evident sings of decay. Oleocellosis incidence was also visually determined.

For every cultivar, the trial was conducted in a completely randomized design with three replicates and six fruit as experimental unit. Data were submitted to analysis of variance and when *f* values indicated significance, the Duncan multiple range test at $p < 0.05$ was applied.

Results and Discussion

Seven days after treatment application of compression forces to the tangerines, dissimilar responses in between both cultivars were observed concerning decay incidence and fresh mass losses. Cv. Ponkan tangerines presented an increment in fresh mass losses in response to mechanical injuries and, as well, an increase in decay incidence (Table 1). That same outcome was not observed on cv, Michal tangerines. That higher incidence of decay on Ponkan tangerines may be associated to the fruit morphology of the cultivar. According to Koehler-Santos et al. (2003) thicker peel and low adherence to segments is a favoring aspect for that occurrence.

Mechanical injuries are connected to elevated after harvest decay incidence. Steffens et al. (2008) determined increments of decay on cv, Gala apples after impacts on fruit. According to the authors, such an increase may be associated to lower flesh firmness that reduces tissue resistance favoring infections. Mechanical injuries along grapefruit processing (C. paradise) were also followed by increments in decay (Skaria et al., 2003).

Table 1

Fresh mass losses of cultivars Ponkan and Michal tangerines seven days after compression forces treatments application at laboratory facilities.

Fresh mass losses (%)			
Compression treatments on cv. Ponkan (N)		Compression treatments on cv. Michal (N)	
0	2,58 bc *	0	5,07 a*
10	2,52 bc	10	3,81 b
20	2,42 c	20	4,40 ab
40	2,99 b	40	4,10 ab
60	3,90 a	60	4,50 ab
Coefficient of Variance	9,33	Coefficient of Variance	5,86
Decay incidence (%)			
0	0 c *	0	11,11 a*
10	0 c	20	11,11 a
20	0 c	20	5,56 a
40	22,22 b	40	5,56 a
60	66,66 a	60	11,11 a
Coefficient of Variance	64,04	Coefficient of Variance	150,90

* Averages followed by the same lowercase letters in columns are not significantly different after the Duncan multiple range test t $p<0{,}05$.

Oleocelosis incidence on Ponkan tangerines is dependent of the forces applied. Compression forces beyond 40N did result in the disorder while forces of 10 or 20 N did not result in oleocelosis (Table 2). On Michal tangerines no oleocelosis was determined even at the highest compression force applied. Oleocelosis is a physiological disorder on the epidermis of citrus fruit as a result of the rupture of oil glands releasing essential oils that are phytotoxic to the albedo cells (Knight et al., (2001)).

Anatomical studies of citrus pericarp of Montero et al. (2012) showed higher numbers of oil cavities in cv. Ponkan tangerines in comparison to all the other examined citrus species, including cv. Michal. ‘Ponkan’ pericarp has bigger cavities and the largest volume and its proximity might probably favor the rupture of oil glands causing the outflow of higher amounts of oil into the surrounding tissues (Montero et al., 2012).

Table 2
Oleocelosis incidence on cv. Ponkan and Michal seven days after compression forces treatments application at laboratory facilities.

Compression treatments on cv. Ponkan (N)	Oleocelosis incidence (%)	Compression treatments on cv. Michal (N)	Oleocelosis incidence (%)
0	0 c *	0	0*
10	0 c	10	0
20	0 c	20	0
40	11,11 b	40	0
60	100 a	60	0
C.V.	19,36	C.V.	-

* Averages followed by the same lowercase letters in columns are not significantly different after the Duncan multiple range test t p<0,05.

The ratio of SS/TA is indicative of flavor (Table 4). The equilibrium in between the sweet constituents and the acids. Therefore, the ratio becomes an important qualitative parameter (Mattiuz, et al., 2003). The authors did indicate that fruit could turn into an overripe flavor either due to higher sugar contents as well as a reduction in acids, rendering the fruit less tasty.

Table 3
Soluble solids ant titratable acidity of cv. Ponkan and Michal tangerines seven days after compression forces treatments application at laboratory facilities.

Soluble solids			
Compression treatments on cv. Ponkan (N)	° Brix	Compression treatments on cv. Michal (N)	° Brix
Initial analysis	11,00	Initial analysis	11,63
0	10,67 b*	0	11,33 a*
10	11,04 ab	10	11,42 a
20	11,42 a	20	11,00 b
40	10,75 b	40	10,92 b
60	11,08 ab	60	10,92 b
Coefficient of Variation.	2,89	Coefficient of Variation	1,54
Titratable acidity			
Initial analysis	10,06	Initial analysis	13,45
0	9,90 a	0	12,83 a*
10	9,50 ab	10	12,28 a
20	9,49 ab	20	11,07 b
40	7,97 c	40	10,37 b
60	8,59 bc	60	10,64 b
Coefficient of Variation	6,32	Coefficient of Variation	4,70

* Averages followed by the same lowercase letters in columns are not significantly different after the Duncan multiple range test t p<0,05.

With regards to flavor, soluble solids and titratable acidity the main changes were observed on acidity contents. Soluble solids had only a slight reduction in response to the applied compression forces on cv.

Michal tangerines. That result was not repeated on cv. Ponkan cultivar. (Table 3). Titratable acidity reduces in both cultivars. The decreases in acidity did result in increments of the sugar-acid ratios.

Organic acids commonly reduce along the ripening processes, as acids are the first respiratory substrate to be consumed for tissue maintenance (Mattiuz et. al., 2003). The compression forces may have accelerated oxidative reactions to synthetize energy necessary for damages repair.

Table 4

Ratio of soluble solids/acids of tangerines cv. Ponkan and Michal seven days after compression forces treatments application at laboratory facilities.

Compression treatments on cv. Ponkan (N)	Ratio	Compression treatments on cv. Michal (N)	Ratio
Initial value	17,08	Initial value	13,50
0	16,89 c	0	13,82 c*
10	18,24 bc	10	14,53 bc
20	18,80 abc	20	15,57 b
40	21,21 a	40	16,45 a
60	20,17 ab	60	16,04 a
Coefficient of Variation	7,65	Coefficient of Variation.	3,88

* Averages followed by the same lowercase letters in columns are not significantly different after the Duncan multiple range test t p<0,05.

Very significant responses were determined on ascorbic acids contents. On cv, Ponkan compression forces of 40 N and beyond did end in a reduction of ascorbic acid in the order of 23% (Table 5), That same response was not observed on cv. Michal tangerines. Ascorbic acid is an important constituent of fruits and vegetables. More than 90% of the human diet of the vitamin is delivered by the ingestion of produce. Mechanical injuries such as cuts, abrasion or wounds accelerate losses in ascorbic acid. The incidence and severity of the damages may also be influenced by the harvesting methods and procedures.

Various references in the literature mention losses of ascorbic acid in produce in response to mechanical injuries. Mondy and Leja (1986) on potatoes, Moretti et al. (1998) on tomatoes and Durigan et al. (2005) Tahiti limes are some of the citations. For Tahiti limes, the authors did determine losses of vitamin C in response to impacts but not in response to compression forces of 49N for about 20 minutes. However, in the present study cv. Ponkan tangerines had significant losses of ascorbic acid after 40N compression for only one minute.

Table 5

Ascorbic acid contents on cv. Ponkan and Michal tangerines seven days after compression forces treatments application at laboratory facilities.

Compression treatments on cv. Ponkan (N)	Ascorbic acid (mL ascorbic acid /100gr juice)	Compression treatments on cv. Michal (N)	Ascorbic acid (mL ascorbic acid /100gr juice)
Initial analysis	17,08	Initial analysis	48,76
0	21,23 a *	0	40,04 a*
10	22,71 a	10	45,96 a
20	20,71 a	20	42,70 a
40	16,46 b	40	37,52 a
60	16,40 b	60	38,49 a
Coefficient of Variation	11,22	Coefficient of Variance.	12,07

* Averages followed by the same lowercase letters in columns are not significantly different after the Duncan multiple range test t p<0,05.

Ascorbic acid is degraded in tissues basically through three different routes: the enzymatic route by way of the action of oxidases. The thermal route and through aerobic or anaerobic reactions by way of which most of the vitamin C is degraded (Nagy, 1980). According to the author, during juicing processes succeeds an aeration that favors the reactions that reduce losses in ascorbic acid.

Tangerines damaged via compression forces probably resulted in breaks of tissues, which end up exposing juice and ascorbic acid to air accelerating vitamin C degradation. Silva et al. (2006) in a study of the effects of processing on ascorbic acid contents of oranges concluded that agitation at the homogenization process of juice reduced significantly ascorbic acid.

The dissimilarity of responses in ascorbic acid losses in between cv. Ponkan and cv. Michal may be related to morphological aspects of both cultivars. Cv. Ponkan with the segments only slightly adhered to the peel and also less packed segments turns the cultivar more likely to compression effects in comparison to cv. Michal.

Peel color of the tangerines Ponkan had no modifications even when oleocelosis was observed. Healthy tissues did not show peel color changes (Table 6). Cv. Michal did also not have color changes attributable to compression forces.

Table 6

Luminosity (L*), chroma and hue of cv. Ponkan and Michal tangerines seven days after compression forces treatments application at laboratory facilities.

Compression treatments on cv. Ponkan		Compression treatments on cv. Michal	
Luminosity (L*)			
Initial value	58,25	Initial value	57,24
0	63,08 a	0	55,96 a*
10	62,52 a	20	55,84 a
20	63,10 a	50	55,18 a
40	62,33 a	80	55,64 a
60	63,64 a	120	56,33 a
Coefficient of Variation.	2,78	Coefficient of Variation.	1,97
Chroma			
Initial value	84,30	Initial value	59,25
0	81,37 a	0	56,30 a*
10	81,68 a	20	56,91 a
20	80,59 a	50	56,26 a
40	83,46 a	80	56,73 a
60	80,78 a	120	57,22 a
Coefficient of Variation.	4,92	Coefficient of Variation.	2,13
Hue angle			
Initial value	84,30	Initial value	59,25
0	81,37 a	0	56,30 a*
10	81,68 a	20	56,91 a
20	80,59 a	50	56,26 a
40	83,46 a	80	56,73 a
60	80,78 a	120	57,22 a
Coefficient of Variation	2,63	Coefficient of Variation	1,99

* Averages followed by the same lowercase letters in columns are not significantly different in either color parameter after the Duncan multiple range test t p<0,05.

Conclusion

Compression forces change the internal quality of cv. Ponkan and Michal tangerines. The main changes are on losses of titratable acidity, the sugar-acids ratio and losses in ascorbic acid. Cv. Ponkan is also is more susceptible to oleocelosis incidence in comparison to cv. Michal a reason for extra care with that cultivar along after harvest procedures.

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rebasa@hmo.megared.net.mx

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