**RUFORUM Working Document Series (ISSN 1607-9345) No. 14 (1): 903-909.**
***Available from http://repository.ruforum.org***

Research Application Summary

# Reducing susceptibility of fresh produce to physical damage during postharvest handling: The case of pomegranate fruit

Hussein, Z.[1, 2], Fawole, O.A.[2] & Opara, U.L.[2]
[1] Department of Food Science, Faculty of AgriSciences, Stellenbosch University, Private Bag X1, Stellenbosch, 7602, South Africa
[2]Postharvest Technology Research Laboratory, South African Research Chair in Postharvest Technology, Faculty of AgriSciences, Stellenbosch University, Private Bag X1, Stellenbosch, 7602, South Africa
**Corresponding author:** 18038166@sun.ac.za

## Abstract

A large percentage of fruit waste in the horticultural industry results from mechanical damage such as bruising. Fruit bruise damage is mostly caused by impact, compression or vibration during handling, packaging and transport. This study investigated the susceptibility of three pomegranate fruit cultivars ‘Acco’, ‘Herskawitz’ and ‘Wonderful’ to impact bruising at varying fruit temperature and drop heights. The first experiment investigated the bruise threshold for each cultivar by subjecting selected pomegranate fruit into three minimal drop heights (10 – 20; 5 cm increments) and evaluated the probability of bruise occurrence (PBO). Study of bruise susceptibility was then carried out by dropping pomegranates stored at 5 and 20 ºC from three drop heights (20, 40 and 60 cm) onto a flat ceramic floor. A linear relationship between drop height and bruise volume (BV), bruise area (BA) and bruise susceptibility (BS) across all cultivars was observed. At 10 cm drop height, ‘Wonderful’ fruit had the highest PBO (0.44) whereas neither ‘Acco’ nor ‘Herskawitz’ were bruised. Lowest bruise threshold (515.38 mJ) was found on ‘Acco’ followed by ‘Herskawitz’ fruit (838 mJ). Low temperature (5 ºC) influenced more bruising whereas higher fruit temperature (20 ºC) reduced the bruise damage of all fruit cultivars. Using Pareto charts, effects of drop height, temperature, cultivar and their interactions on bruising were significant ($p < 0.05$). Overall, this study showed that both drop and/ or impact energy and fruit temperature affect the bruise damage of pomegranate fruit of the investigated cultivars. This study represents the findings of a pilot research aimed at providing the science-based tools to support handling management of fruit in the South African pomegranate industry.

Key words: Bruise susceptibility, cultivar, drop height, impact energy

## Résumé

Un grand pourcentage de déchets fruitiers dans l’industrie horticole est le résultat des dommages mécaniques tels que les meurtrissures. Les meurtrissures des fruits sont principalement causées par l'impact, la compression, ou des vibrations lors de la manutention, l'emballage, et le transport. Cette étude a examiné la sensibilité de 'trois cultivars de fruit de grenade « l'Acco », «Herskawitz» et «Wonderful» aux meurtrissures dues à l'impact en variant la température des fruits et les hauteurs de chute. La première expérience a étudié le seuil de meurtrissure pour chaque cultivar sélectionné en soumettant des fruits de grenade aux trois hauteurs minimales de chute (10 - 20, 5 cm incréments) et en évaluant la probabilité d'occurrence de meurtrissure (POM). L'étude de la susceptibilité à la meurtrissure a ensuite été effectuée en laissant tomber des grenades stockées à 5 et 20 ºC à partir des trois hauteurs de chute (20, 40 et 60 cm) sur un plancher plat en céramique. Une relation linéaire entre la hauteur de chute et le volume de meurtrissure (VM), zone de meurtrissure (ZM) et la susceptibilité de meurtrissure (SM) dans tous les cultivars a été observée. A 10 cm de hauteur de chute, les fruits 'Wonderful' avaient la plus forte POM (0,44), alors que ni «Acco» ou «Herskawitz» étaient meurtris. Le seuil le plus bas de meurtrissure (515,38 mJ) a été trouvé sur les fruits 'Acco' suivi de 'Herskawitz' (838 mJ). La basse température (5°C) a influencé les meurtrissures alors la température élevée de fruits (20ºC) a réduit les dégâts de meurtrissure de tous les cultivars de fruits. En utilisant des diagrammes de Pareto, les effets de la hauteur de chute, la température, le cultivar, et leurs interactions sur les meurtrissures étaient significatives (p <0,05). Dans l'ensemble, cette étude a montré que les la hauteur de chute et / ou l'énergie d'impact et la température des fruits affectent les dommages par meurtrissure  des cultivars de grenade étudiés. Cette étude présente les résultats d'une recherche pilote visant à fournir les outils scientifiques pour appuyer la gestion de manutention de fruits dans l'industrie de grenade sud-africaine.

Mots clés : Susceptibilité à la meurtrissure, le cultivar, la hauteur de chute, l'énergie d'impact

## Background

Like any other fruit, pomegranate (*Punica granatum* L.) fruit is subject to mechanical damage by mechanical handling systems due to the action of static and dynamic forces in which they are predisposed (Shafie *et al.*, 2015). Bruising is the most common type of mechanical damage which results from excessive impact and compression forces due to improper handling, poorly designed equipment or improper packaging (Opara and Pathare, 2014). Bruise damage is a type of subcutaneous tissue failure without rupture of the skin where the discolouration of injured tissues indicates the damaged spot (Opara and Pathare, 2014; Stropek and Go³acki, 2015).

Bruise susceptibility of fruit and vegetables is a measure for the response to external loading (Mohsenin, 1986). Impact test, which involve dropping the fruit on rigid surface is the most common test that has been used to study bruise damage of various produce such as apples, citrus, peaches, strawberries, etc. (Montero *et al.*, 2009; Stropek and Go³acki, 2015). However, given the fact that pomegranate fruit rind and internal structure is different from other fruits, previous research on pome, citrus and stone fruits cannot be extrapolated. Thus, the objective of this study was to investigate the bruise susceptibility of pomegranate fruit cultivars at different impact levels and temperature conditions, and establish the minimum impact energy level required to cause bruising.

## Literature summary

Bruising results from the action of excessive external force on fruit surface during the impact or compression against a rigid body or fruit against fruit (Opara and Pathare, 2014). Impacts may also occur as the result of sudden fall of fruits onto other fruits, parts of the trees, containers, parts of any grading and treatment machinery and on any improperly cushioned surfaces (Idah *et al*., 2007; Opara and Pathare, 2014). Bruise damage generally causes produce quality deterioration and subsequent economic losses due to decay and microbial spoilage, loss in fresh weight, change in epicarp colour and visual quality (Stropek and Go³acki, 2015). The extent of bruise damage in fruit may significantly detract consumer perceptions and consequently affecting the level of acceptability prior to purchase (Montero *et al*., 2009). Bruising also affects the produce physiological processes such as respiration and transpiration, causing loss of nutritional value and overall quality change of produce. Bruising is also one of the most significant factor limiting the mechanisation and automation in harvesting, sorting and transport of many fruits and vegetables (Opara and Pathare, 2014).

## Study description

Three pomegranate fruit cultivars (Acco, Herskawitz and Wonderful )were hand-picked at commercial maturity from a commercial orchard in the Western Cape Province, South Africa. Fruit were carefully sorted to ensure use of fruit free of any physical defeats (such as cracking, sunburn and husk scald) for the experiment. Drop test technique was used to generate impact energy to cause bruising by dropping the fruit against a rigid flat ceramic floor along a graduated wooden ruler and caught by hand after rebounding to avoid a second impact. Impact energy (E, mJ) for each drop height was calculated from $Ei = mgh$, where m is the mass of each individual pomegranate fruit, g is the gravitational constant, and h is the drop height.

To investigate the bruise threshold (impact level where all fruits are bruised), 72 fruit from each cultivar were subjected to 3 minimal drop heights (10 – 20; 5 cm increments), and for each data set of 16 impacts (8 fruit per drop height), proportion of the fruit at each drop height that sustained a visible and measurable bruise was calculated as the probability of bruise occurrence (PBO), i.e., ratio of non-zero bruises to the number of replications of the same treatment (Jarimopas *et al*., 2007). In the second study of bruise susceptibility, 144 fruit from all cultivars were selected and pre-conditioned at 5 ± 2 ºC, 90 ± 5 and (22 ± 5 ºC, 60 ± 5 % ± 5 RH) for 24 h and dropped from three drop heights (20, 40 and 60 cm) onto a flat ceramic floor using similar procedures as previously described. Each fruit in six replicates was dropped twice from the same height, one impact at each of the two equidistant points on the cheek position of the fruit. For all sets of experiments, impact tests were followed by fruit incubation at ambient condition (19 - 22ºC, 60 ± 5% RH) for 48 h to allow bruise manifestation on damaged tissues (Fig. 1). Fruit were then sliced through the centre of the impact (marked) region. The bruise damage of the fruit sliced through the impact region was identified by the presence of visible damaged tissues or arils which were clearly distinguishable from other unbruised parts of the same fruit. Measurement of bruise

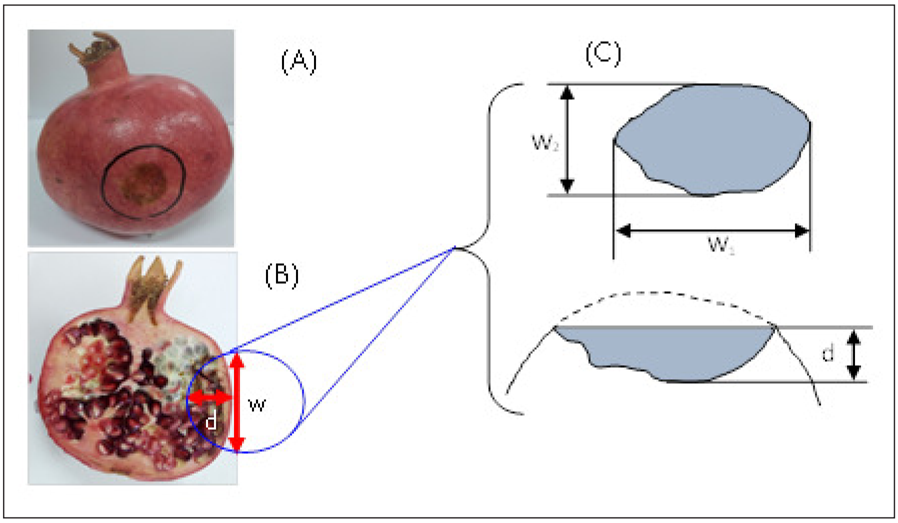


**Figure 1. Bruised pomegranate fruit (A), fruit sliced across the bruised region (B), and idealized bruise (C) showing symbols used in determination of bruise volume and bruise area**

dimensions; $w_1$ and $w_2$ as major and minor width, respectively (Fig. 1), and bruise depth (d) were all conducted using a digital calliper (Mitutoyo, ± 0.02 mm accuracy). Results of bruise damage were expressed as bruise volume (BV, $mm^3$), bruise area (BA, $m^2$) and the ratio of bruise volume to the energy absorbed during impact, (BS, $mm^{-3}/mJ$) using equations:

$BA = (\pi/4) * w_1 w_2$; $BV = (\pi/8) * w^2 d$; and $BS = BV/Ei$, respectively.

**Research application**

**Probability of bruise occurrence below and above the bruise threshold.** Probability of bruise occurrence (PBO) of pomegranate fruit due to drop impact varied linearly with drop height and/ or impact energy across all cultivars. At the lowest drop height (10 cm), neither 'Acco' nor 'Herskawitz' fruits were bruised while a small proportion of 'Wonderful' fruit (PBO = 0.44) was damaged. This could suggest that the 'Wonderful' could be more susceptible to bruising at drop height of 10 cm or lower. Moreover, increment of drop height by 5 cm to 15 cm resulted in BPO of 0.75 and 0.5, for 'Acco' and 'Herskawitz' cultivars, while PBO for 'Wonderful' increased to 1. The highest drop height (20 cm) was revealed as the threshold level, where all the investigated fruit cultivars were bruised.

**Pomegranate fruit bruising in relation to drop height and impact energy above threshold.** The results of bruise volume – impact energy (BV – Ei) relationship showed that the drop height significantly ($p < 0.05$) affected BV and the energy absorbed during impact. Furthermore, fruit of 'Wonderful' were characterized by the highest bruise volume, BV and bruise area (BA) whereas 'Acco' had the lowest. Given that mass of fruit for each cultivar is in the order of 'Wonderful'> 'Herskawitz' > 'Acco', the observed impact energy (E, mJ) could have resulted from higher mass for 'Wonderful' and 'Herskawitz' fruits as opposed to 'Acco' fruit which had comparatively lower mass. Accordingly, signiûcant differences (p <0.05) were obtained for impact energy amongst the cultivars at each drop height, again, with the order being 'Wonderful' > 'Herskawitz' > 'Acco' (Table 1). Bruise susceptibility (BS) followed a similar trend as it increased with increase in drop height for all cultivars (Table 1).

Fruit cultivar significantly ($P$<0.05) influenced the BV, BA and BS of pomegranate fruit. Overall, 'Wonderful' fruit was the most bruise susceptible cultivar (as indicated by higher values of BV, BA and BS), followed by 'Herskawitz'. These results corroborate with a study reported by Ozturk *et al*. (2010), which showed that the bruise susceptibility differs among cultivars of apple fruit. These authors have previously indicated that different cultivars of the same fruit may respond differently to impact loading due to their differences in mechanical properties, which could also be the case of pomegranate.

Fruit temperature had a significant effect (p <0.05) on BV and BS across all cultivars (Fig. 2). Fruits stored at low temperature (5 ºC) had more bruising whereas those stored at high temperature (20 ºC) had less bruise damage at the same drop height. In addition, lowering the fruit temperature to 5 ºC increased the BV of 'Wonderful' by 32 and 49% at medium

**Table 1. Effects of drop height (Dh), fruit cultivars and temperature on impact energy (Ei), bruise volume (BV), bruise area (BA) and bruise susceptibility (BS) at 5 ºC. Similar trend of results were obtained at 20 ºC fruit temperature (results not presented)**

| Parameters | Dh (cm) | Pomegranate cultivars | | |
|---|---|---|---|---|
| | | Acco | Herskawitz | Wonderful |
| | 20 | $473.16 \pm 18.50^{bC}$ | $684.65 \pm 13.35^{aC}$ | $734.89 \pm 54.73^{aC}$ |
| Ei (mJ) | 40 | $982.02 \pm 43.66^{cB}$ | $1410.60 \pm 24.22^{bB}$ | $1777.43 \pm 50.98^{aB}$ |
| | 60 | $1472.32 \pm 89.82^{bA}$ | $1410.60 \pm 63.78^{aA}$ | $2474.26 \pm 53.63^{cA}$ |
| | 20 | $364.71 \pm 8.75^{bC}$ | $357.10 \pm 38.26^{bC}$ | $452.00 \pm 10.87^{aC}$ |
| BA ($mm^2$) | 40 | $621.46 \pm 9.06^{bB}$ | $735.32 \pm 24.03^{aB}$ | $783.35 \pm 20.15^{aB}$ |
| | 60 | $804.87 \pm 31.68^{bA}$ | $974.68 \pm 45.86^{bA}$ | $1081.21 \pm 28.52^{aA}$ |
| | 20 | $38.14 \pm 4.72^{aC}$ | $39.13 \pm 90.06^{aC}$ | $37.24 \pm 96.52^{aC}$ |
| BV ($mm^3$) x $10^2$ | 40 | $77.38 \pm 104.42^{cB}$ | $103.45 \pm 226.68^{bB}$ | $110.57 \pm 127.11^{aB}$ |
| | 60 | $105.58 \pm 239.99^{bA}$ | $222.30 \pm 331.09^{aA}$ | $187.81 \pm 176.98^{cA}$ |
| | 20 | $8.11 \pm 0.34^{aA}$ | $5.72 \pm 0.18^{bC}$ | $5.11 \pm 0.27^{bC}$ |
| BS ($mm^3$/mJ) | 40 | $7.91 \pm 0.36^{aA}$ | $7.33 \pm 0.09^{aB}$ | $6.23 \pm 0.12^{bB}$ |
| | 60 | $7.24 \pm 0.59^{bA}$ | $10.98 \pm 0.21^{bA}$ | $7.60 \pm 0.12^{aA}$ |

Mean values are presented as mean ± SE in the same column followed by different lower case superscript letter are significantly different ($p$ <0.05). Mean values in the same row followed by different upper case superscript letter are significantly different ($p$ <0.05), according to Duncan's multiple range test.

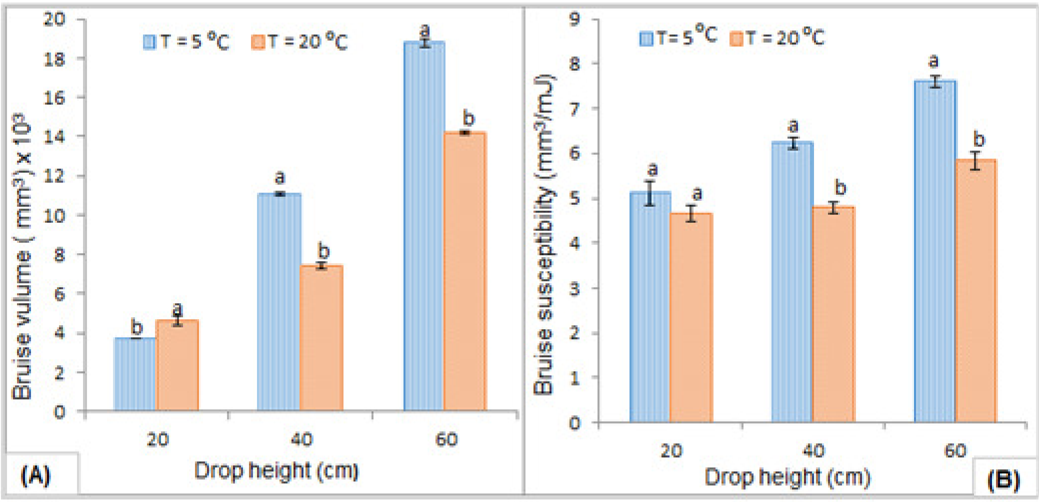


**Figure 2.** Effect of temperature on bruise volume (A), and bruise susceptibility (BS) of pomegranate fruit Cv. Wonderful. Similar trend of results were observed for 'Acco' and 'Herskawitz' cultivars (results not presented). Each pair of bars at the same drop height with different letter are significantly different (p <0.05), according to Duncan's multiple range test

and higher impact energy, respectively. Similar trend was observed in 'Herskawitz' fruit, even though exceptional case was found at the lower drop height where more than 100% increase in both BV and BS was as a result of temperature drop. Pareto chart was used to analyse the significance of main effects and interactions between main parameters (BV, BA and BS) and the dependent factors were obtained (results not shown). Effects of drop height, temperature, cultivar and their interactions on bruising were all significant ($p < 0.05$).

## Acknowledgement

This work was based upon PhD research supported by the Innovative Agricultural Research Initiative (iAGRI) and the Regional Universities Forum for Capacity Building in Agriculture (RUFORUM). This paper is a contribution to the 2016 Fifth African Higher Education Week and RUFORUM Biennial Conference.

## References

Idah, P.A., Ajisegiri, E. S.A. and Yisa, M.G. 2007. An assessment of impact damage to fresh tomato fruits. *Assumption University Journal of Technology* 10 (4):271 -275.

Jarimopas, B., Singh, I. S. P., Sayasoonthorn, S. and Singh, J. 2007. Comparison of package cushioning materials to protect post-harvest impact damage to apples. *Packaging and Technology Sciences* 20:315-324.

Mohsenin, N.N. 1986. Physical properties of plant and animal materials. Gordon & Breach Science Publishers, New York.

Montero, C.R.S., Schwarz, L.L., Dos Santos, L.C., Andreazza, C.S., Kechinski, C.P. and Bender, R.J. 2009. Postharvest mechanical damage affects fruit quality of 'Montenegrina' and 'Rainha' tangerines. *Pesquisa Agropecuária* Brasileira, *Brasília* 44 (12):1636 - 1640.

Opara, U.L. and Pathare, P.B. 2014. Bruise damage measurement and analysis of fresh horticultural produce: A review. *Postharvest Biology and Technology* 91:9 - 24.

Ozturk, I., Bastaban, Ercisli, I. S. and Kalkan, F. 2010. Physical and chemical properties of three late ripening apple cultivars. *International Agrophysics* 24:357- 361.

Shafie, M. M., Rajabipour, A., Castro-García, S., Jiménez-Jiménez, F. and Mobli, H. 2015. Effect of fruit properties on pomegranate bruising. *International Journal of Food Properties* 18:1837-1846.

Stropek, Z. and Go³acki, K. 2015. A new method for measuring impact related bruises in fruits. *Postharvest Biology and Technology* 110:131-139.