EFFECTS OF SKIN CHARACTERISTICS ON IMPACT RESPONSE AND BRUISING OF APPLES AND PEARS

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ABSTRACT

Skin properties have an important influence on impact parameters and bruising. Skin deformation at puncture (a measure of the turgidity of the fruit skin) is negatively correlated with bruise volume in Golden apples after cold storage.

1. INTRODUCTION

Bruise damage is a major cause of quality loss for fresh market apples and pears. Numerous studies have been undertaken to relate bruise damage with physical characteristics of the fruits as firmness, weight, or fruit density (Klein, 1987; Siyami *et al.*, 1988).

Skin characteristics are not usually taken into account. The first model used to analyse the impact problem applies the Hertz contact theory considering the fruit as an elastic homogeneous body. The most usual procedure to measure firmness (Magness-Taylor force) is performed removing the skin.

However, skin strength probably has an influence on impact response and bruising. Rodríguez *et al.* (1991) suggested that impact response in postclimacteric pears may be explained by the role played by the skin rather than by the flesh.

The objective of our present work is part of a research aimed at studing changes happening in impact response and bruising when the characteristics of skin in apples and pears are modified.

2. MATERIALS AND METHODS

"Golden Delicious" apples and "Conference" pears were harvested from several orchards in Lérida, the main exporter area of Spain, before and during the commercial harvest period. Part of the fruits were tested the day after harvest (440 apples, 240 pears). The rest (277 apples, 40 pears) were held in conventional cold storage at 1°C and 80% RH for approximately five months. Then, fruits were removed from storage and tested along 10 days. Tests were the following:

- Penetration test. Performed using an Instron Universal Testing Machine with a standard Magness-Taylor 8-mm-diameter rod at 20 mm/min. Two tests were made at two opposed locations along the equator of each fruit; the skin was previously removed.

- Skin puncture. Performed using the same Instron Machine with a 0.5-mm-diameter puncture rod at 20 mm/min. Two tests were made at two opposed locations along the equator of each fruit.

- Impact test. Used impact tester has been described previously (Garcia *et al.*, 1988). The test was conducted using an instrumented free falling mass (50.6 g) with 15-mm-diameter spherical head. The head was previously smeared with ink to know the contact point on the fruit. Two impact tests were made, with drop heights of 8 cm (0.039 J), at opposed locations along the equator of each fruit. Impact variables were calculated and recorded on a computer disk file.

- Bruise size measurement. Bruises produced by the impact test were allowed to develop for over 2 h. Then, bruise maximum width and depth were measured with a stereoscopic microscope cutting through the center of the bruised region. Bruise volume (BV) was estimated by the following relation (Chen and Sun, 1981):

$$BV = \frac{1}{6} \pi \, h D^2$$

  in which h and D are the depth and width of bruise (mm), respectively.

Additional impact tests (8-cm-height, 0.039 J) were carried out on fruits held in cold storage. Each fruit suffered impacts with intact skin (control) and in one of the following conditions:

- 1) Without skin, removing an area of 1 cm^2. Conference pears, n = 25.
- 2) With a rigid layer over intact skin (adhesive tape). Granny Smith apples, n = 15.
- 3) With an elastic layer over intact skin (rubberized paint). Granny Smith apples, n = 15.

3. RESULTS

Skin characteristics changed in a different way in Golden apples and Conference pears (Table 1).

Skin resistance (measured by maximum force at skin puncture, SMF) decreased after storage in pears, but remained fairly constant in apples. However, maximum deformation at skin puncture (SMD) increased after storage in both apples and pears, although the increment was lower in pears, since skin resistance decreased (Figures 1-2). SMD seems to be a measure of skin tension; a turgid fruit shows low values of SMD while a wrinkly one shows high values.

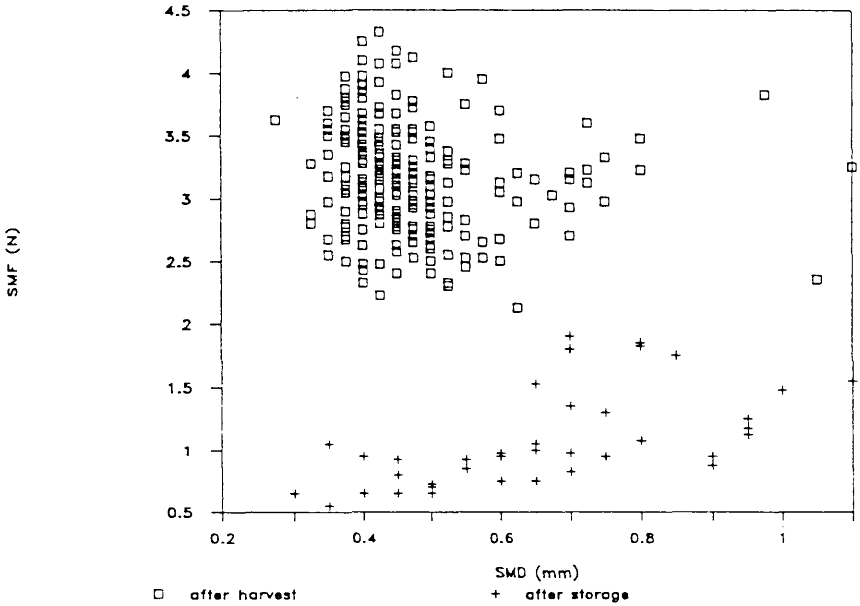

Fig. 1. Skin properties. Maximum force at skin puncture (SMF) vs. maximum deformation (SMD) for Conference pears, before and after cold storage. Maximum force (SMF) decreases after storage.

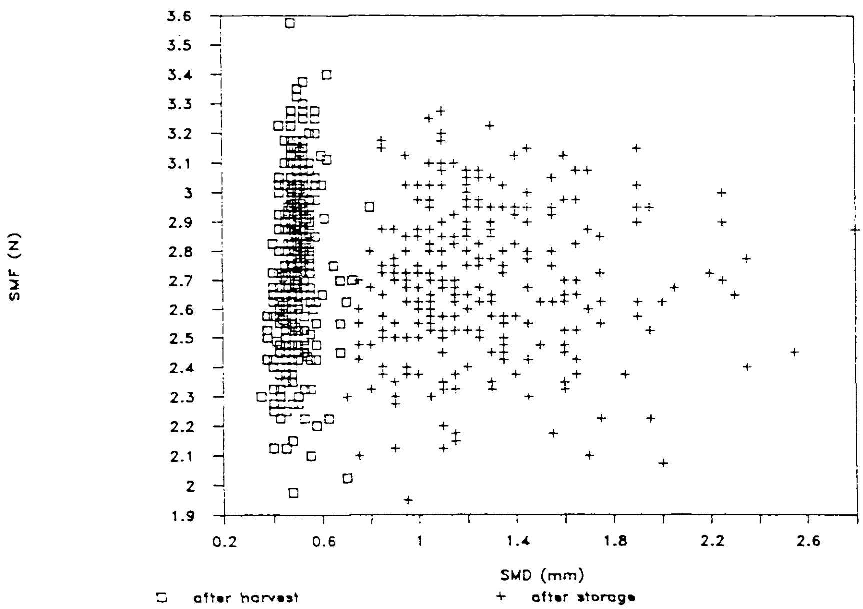

Fig. 2. Skin properties. Maximum force at skin puncture (SMF) vs. maximum deformation (SMD) for Golden apples, before and after cold storage. Maximum deformation (SMD) increases after storage.

TABLE 1
Physical properties of tested fruits before and after cold storage

	W	MT	SMF	SMD	8MF	8MD	BV
Golden after	211.0	32.9	2.76	0.5	42.46	1.80	141.5
harvest CV%	11.8	15.1	9.5	10.9	6.3	5.0	15.0
Golden after	202.0	17.1	2.70	1.3	32.35	2.32	99.1
storage CV%	11.5	18.7	9.4	28.1	8.1	9.7	23.8
Conference after	/	58.3	3.16	0.5	54.88	1.43	/
harvest CV%	/	11.2	13.9	23.9	5.5	6.7	/
Conference after	/	18.2	1.06	0.6	35.37	2.09	/
storage CV%	/	65.1	35.9	31.5	16.8	13.4	/

W : Weight (g)
MT : Maximum force at Magness-Taylor (N)
SMF: Maximum force at skin puncture (N)
SMD: Maximum deformation at skin puncture (mm)
8MF: Maximum force at 8-cm-height impact (N)
8MD: Maximum deformation at 8-cm-height impact (ms)
BV : Bruise volume (mm^3)

Both flesh and skin characteristics influenced impact parameters (Tables 2-3). In pears, flesh and skin softened at the same time; impact parameters were highly correlated with Magness-Taylor firmness (Figure 3). In apples, flesh softened while skin resistance remained constant. Impact response was less related with Magness-Taylor firmness (Figure 4) and seemed to depend mainly on skin deformation (Figure 5). Bruised volume was only measured in apples. It was related to skin deformation, in a similar way as impact force (Figure 6).

As for the additional tests, impacts without skin produced lower impact forces and higher deformations than impacts with intact skin, which were more elastic (Table 4). Additional layers (adhesive tape, rubberized paint) increased impact forces and decreased deformations.

TABLE 2

Correlation coefficients of Golden apples before and after cold storage

A) Golden apples after harvest (n = 440).

	MT	SMF	SMD	BV	8MF	8MD	W
MT	1.00						
SMF	0.14	1.00					
SMD	-0.13	0.25	1.00				
BV	-0.18	0.03	0.04	1.00			
8MF	0.33	-0.04	-0.10	-0.21	1.00		
8MD	-0.48	-0.05	0.05	0.22	-0.60	1.00	
W	-0.33	-0.09	-0.09	0.10	0.07	0.13	1.00

B) Golden apples after storage (n = 277).

	MT	SMF	SMD	BV	8MF	8MD	W
MT	1.00						
SMF	0.05	1.00					
SMD	0.14	0.05	1.00				
BV	-0.27	-0.06	-0.63	1.00			
8MF	-0.14	0.18	-0.85	0.55	1.00		
8MD	0.08	-0.12	0.80	-0.52	-0.89	1.00	
W	-0.26	0.05	-0.27	0.26	0.26	-0.23	1.00

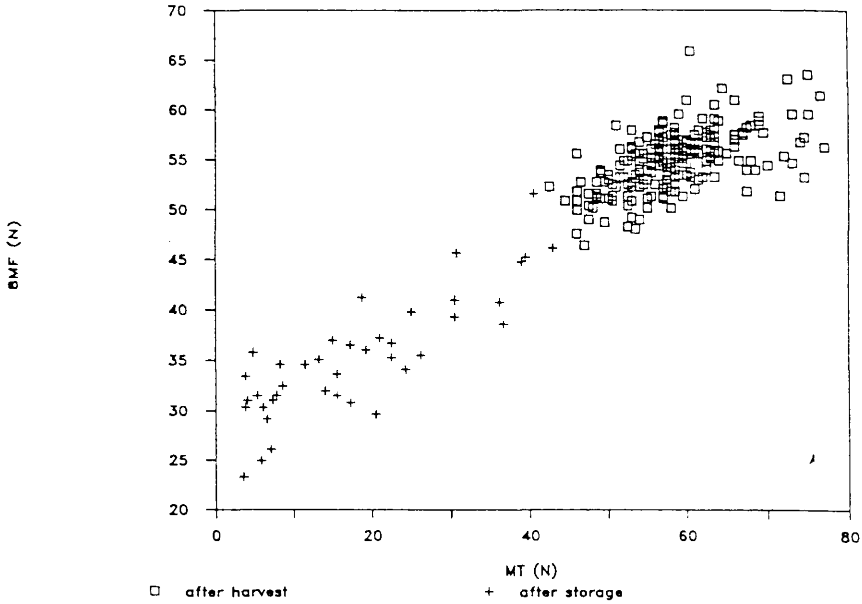

Fig. 3. Maximum impact force (8MF) vs Magness-Taylor firmness (MT) for Conference pears, before and after cold storage (correlation coefficient: 0.93).

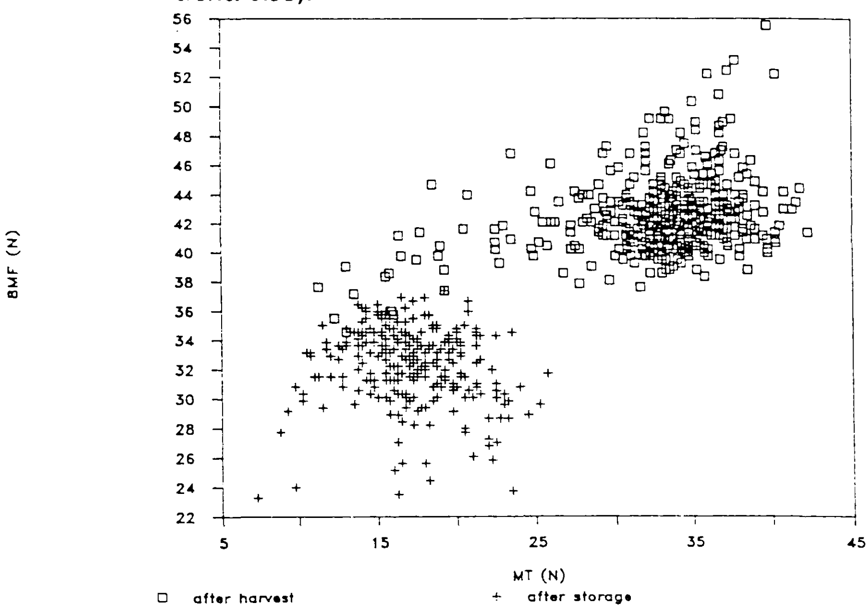

Fig 4. Maximum impact force (8MF) vs Magness-Taylor firmness (MT) for Golden apples, before and after cold storage (correlation coefficient: 0.81). Impact forces are higher before storage even for the same firmness values.

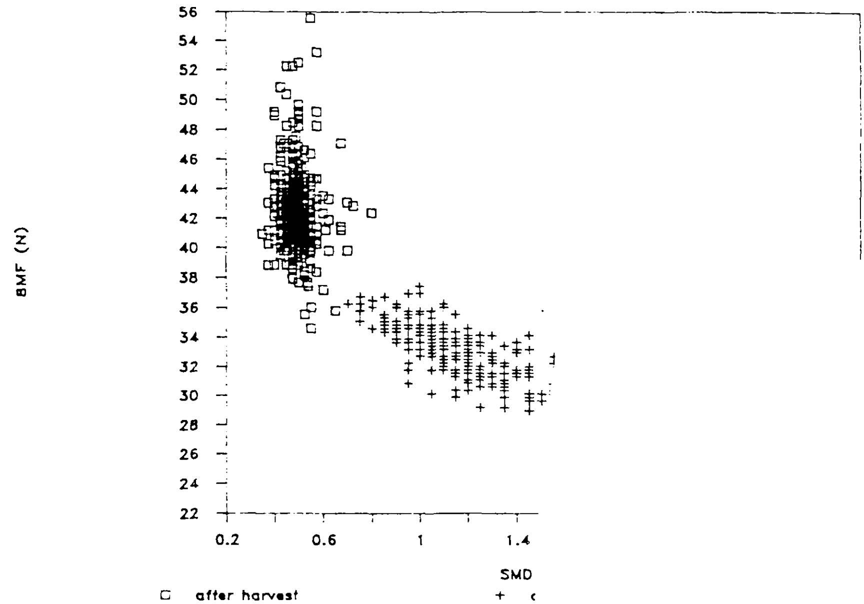

Fig. 5. Maximum impact force (8MF) vs maximum deformation at puncture (SMD) for Golden apples, before and after cold storage. After storage, impact forces seem to be highly related to maximum deformation at puncture.

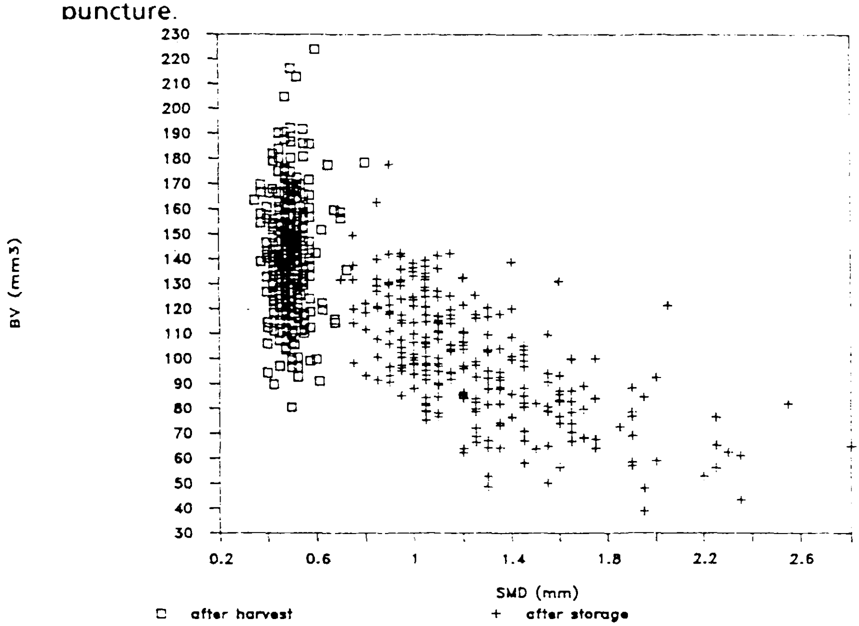

Fig 6. Bruise volume (BV) vs maximum deformation at puncture (SMD) for Golden apples, before and after cold storage. SMD increase seems to have an influence in the BV decrease after storage.

TABLE 3
Correlation coefficients of Conference pears before and after cold storage.

C) Conference pears after harvest (n = 240).

	MT	SMF	SMD	8MF	8MD
MT	1.00				
SMF	0.56	1.00			
SMD	-0.12	-0.12	1.00		
8MF	0.56	0.45	-0.26	1.00	
8MD	-0.46	-0.34	0.06	-0.59	1.00

D) Conference pears after storage (n = 40).

	MT	SMF	SMD	8MF	8MD
MT	1.00				
SMF	0.79	1.00			
SMD	0.52	0.62	1.00		
8MF	0.84	0.67	0.32	1.00	
8MD	-0.73	-0.59	-0.27	-0.93	1.00

TABLE 4
Impact parameters in additional tests, with different modifications of the skin.

	8MF	8MD	8AE	8T
Without skin	30.43	2.33	37.3	5.8
Control	35.19	2.11	34.9	5.1
	**	**	**	**
Adhesive tape	41.70	1.80	30.1	4.8
Control	38.98	1.90	30.9	5.3
	**	**	**	**
Rubberized paint	38.99	1.90	31.5	5.2
Control	38.20	1.95	29.9	5.4
	**	**	**	ns

8MF: Maximum force at 8-cm-height impact (N)
8MD: Maximum deformation at 8-cm-height impact (ms)
8AE: Absorbed energy at 8-cm-height impact (mJ)
8T : Impact time at 8-cm-height impact (mJ)
** : Significant at 0.01 ns: Not significant

4. DISCUSSION

Several researchers have shown that bruise susceptibility can decrease with moisture loss (Klein, 1987) even without a decrease in firmness (Johnson, 1990). It may be explained by the higher susceptibility of vegetative tissues as cell turgidity increases.

However, skin characteristics may have an additional influence in this process. When a fruit loses water, its volume decreases and the skin gets "loose", even forming small folds. Loose skin allows higher deformations in the flesh-skin ensemble, and as a result, impact forces are lower. Besides, a part of the deformation energy may be absorbed without damage in the small folds of the skin. Therefore bruises should be smaller. The results in this paper suggest this kind of relationship between skin and bruising.

Further experiments are needed varying skin properties without changing firmness. Moisture losses should be tested controlling skin characteristics.

5. REFERENCES

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