BRUISE SUSCEPTIBILITY IN POME FRUITS UNDER DIFFERENT LOADING AND STORAGE CONDITIONS

P. Barreiro
M. Ruiz Altisent
Dpto. Ingeniería Rural, ETSTI Agrónomos,
Avda. Complutense s/n, 28.040 Madrid, Spain.

ABSTRACT

Samples of "Golden" and "Granny Smith" apples and "Conference" and "Doyenne of Comice" pears have been tested. A great effect of storage conditions has been detected for pear but not for apple varieties. Both apple cultivars show to be equally resistant to quasi-static and to dinamic loading while pear varieties show great differences. All these effects can be quantified in order to describe mathematically species and varieties behaviour.

1. INTRODUCTION

The current Research has been carried out following the main objective of the European Project CAMAR nº 8001-CT-91 0206, and also of the Spanish Project AGF-92-1255CE. "Quality of fruits: Engineering research for improving the quality preservation during pre and post-harvest operation" is the title for these two Projects. In order to achieve this objective, it is necessary an exhaustive knowledge of the main traded varieties, as well as of the effect on fruit quality of the common conditions employed during handling, storaging and transporting.

At the current study, the behaviour of the main pome species and varieties through common storage treatments and loading levels has been described and modelised. Though the main stone species and varieties have also been studied the results were not avaiable at the moment of writing this paper.

2. MATERIALS AND METHODS

Selecting the varieties to be studied has been the first step at the current research. It was decided to choose the main stone and pome cultivars at foreign trade, including not only actual main varieties but lately arising cultivars. (Apple variety Starking is no longer cultivated in Spain).

Apple	Pear
"Golden"	"Conferencia"
"Granny Smith"	"Decana de Comicio"

After deciding the cultivars to be studied it was necessary to define the maturity stage at harvest. In order to reproduce current conditions of fruits it was decided to take all samples from commercial fields at the same time as commercial harvesting was taking place.

The fruit came from Lérida (Lleida), North-East of Spain. Once the fruits were harvested, they were transported using insulated vehicles at 5ºC temperature approximately. The fruits arrived at the Physical Properties Laboratory of the E.T.S.I.A., Polytechnic University of Madrid, the day after harvest and were selected in order to make similar samples (5-10% weigth variation coefficient); over 250 kg of fruit has been processed.

From each shipment three groups were made, one for each storage treatment:

- Treatment 1: without cold storage.
- Treatment 2: low temperature storage of fruits inside low density polyethylene bags (0,015 cm).
- Treatment 3: the same low temperature storage without bag but controlling moisture inside the cool chamber.

The storage period and conditions employed for each variety were:

- "Golden" and "G. Smith" apples: five weeks at storage, 80% RH and 1ºC.
- "Conferencia" and "Comicio" pears: four weeks at storage, 80% RH and 1ºC.

After storage, fruits were taken to room temperature (20ºC approximately) where they were left in order to study maturity evolution of each cultivar. Different evolution periods were selected depending on each species characteristics:

- apple: four weeks (1 testing date per week).
- pear: two weeks (2 testing dates per week).

Finally, fruits were tested three or four times (lots) along the maturity period in order to represent each variety evolution.

The varieties were tested along following dates:

August	August	October	November

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Pear cv. "Conferencia"
"" Apple cv. "Golden"
** Pear cv. "Comicio"
>> Apple cv. "G. Smith"

Two kinds of tests were carried out: mechanical and chemical tests.

2.1. Mechanical Tests

This group of tests was carried out in order not only to determine fruit maturity stage but also to find bruise susceptibility of each commercial variety.

The mechanical tests preformed were: skin puncture test, controlled impacts on fruits, fruits'quasi-static compression and, finally, the measure of impact and compression bruise.

- Skin puncture using a cylindrical stem mounted to an INSTRON device working at 20 mm/min speed. Maximum force (N) and deformation (mm) at puncture were measured.
- Controlled impacts on fruits. An impact device was used consisting of a 50.8 gr spherical mass. Two heights were selected (6 and 10 cm) in order to cause different controlled damages. The variables measured were the following:
  - . Maximum impact force (N)
  - . Maximum fruit deformation (mm)
  - . Permanent fruit deformation (mm)
  - . Impact duration (ms)
  - . Absorbed energy (mjul)
- Fruit quasi-static compression with a 15 mm diametre sphere connected to an 1122 INSTRON working at 20 mm/min speed. This test was carried out twice per fruit until two different loading levels were reached (5-50 N range). The compression lasted over 40 seconds and the parameters measured were:
  - . Maximum fruit deformation (mm)
  - . Absorbed energy until the maximum compression force was reached (mjul)
  - . Strain stress twenty seconds after the maximum force was reached (%)
- Internal damage observation by measuring bruise depth in fruit slices from the damaged area. A binocular microscope was used due to its high precision. It was necessary to wait more or less two hours before measuring damage; period for the polyphenol oxidations to be done.

2.2 Chemical tests

The chemical tests preformed were:

- Determination of sugar content (°BRIX) in fruit's juice by refractometry. The necessary temperature correction was used.
- Determination of tritatable acid (total acid). This measure gives the free inorganic and organic acids. They consist of a rule of tartaric acid, malic acid and citric acid. The titration of a 10 ml juice sample was carried out with 0,1 N-caustic soda and the end-point (8.1 pH) is found by the addition of phenolphthalein.

3. RESULTS

3.1. Non Destructive Measurements

As a first step, a Principal Component Analysis has been carried out using most mechanical and chemical parameters (Figures 1 to 2) and for a pooling of all the fruits tested. It shows that using three new created variables, which are the principal components or axes (also called factors), more than 70% of the variance of the population (for pooled pome fruits data) can be explained.

The first plane composed by the first couple of factors explains over 60% of the population variance. The main axe, explaining over 50% of this variance, is composed by nearly all the mechanical variables, being the "Force- deformation" and the "Force-bruise depth" ratios the most important.

All mechanical tests: high and low impacts and compressions, show a similar contribution to the first axe so any of them may be used to define the mechanical properties of fruits (correlations higher than 0.9) (Table 1). On the other hand, impact variables have the least coefficients of variation of the whole tests (Table 2), so it can be concluded that low energy impacts should be recommended in order to make non destructive measurements. These results agree with those published earlier in different studies (García *et al.*, 1.988, Ruiz Altisent *et al.*, 1990 and 1991, Rodriguez Sinobas *et al.*, 1991, Jarén Ceballos *et al.*, 1992).

The plane representing the first and third factors also explains over 60% of the population variance, as the second and third axes show the same contribution to the explained variance (10%). It is very interesting to verify that the third factor is mainly composed by the chemical and the bruise parameters though the correlation between them is nearly cero. This effect can be due to the difference between apple and pear species, and so the third factor represents the effect of the species characteristics.

The individuals (fruits) can be represented in those Principal Component planes. This kind of representation will be used to describe not only the ripeness evolution of varieties but also the effect of the storage treatments on each variety and species studied.

3.2. Common Mechanical Characteristics of Pome Fruit Varieties

Looking at the value of the skin resistance (N) it can be demonstrated that these apple varieties do not show any change in the mechanical resistance of skin along post-harvest ripening period. Pear varieties, however, show a great decrease of skin resistance as post-harvest ripeness level increases.

Using the representation of the individuals at one of the Principal Components plane (first and third axes) it is possible to describe flesh evolution of fruits after harvest. "G. Smith" apples do not show post-harvest evolution of flesh mechanical characteristics instead of "Golden" cultivar which shows a slight decrease in the "Maximum force/maximum deformation" ratio (N/mm) at any of the mechanical tests, as flesh becames softer along the post-harvest ripeness period. Finally, both varieties of pear suffer great changes at this "Maximum force/maximum deformation" ratio due not only to flesh changes but also to the

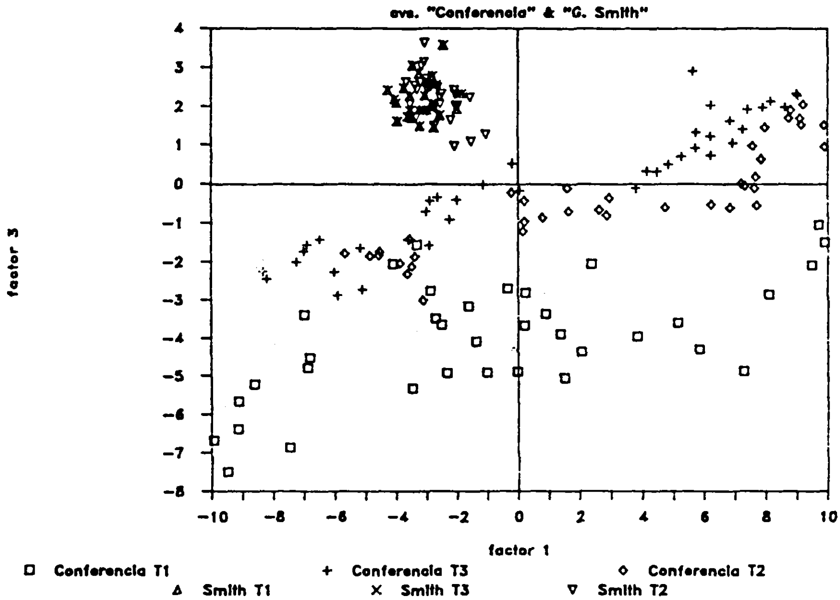

Fig. 1. Principal component analysis.

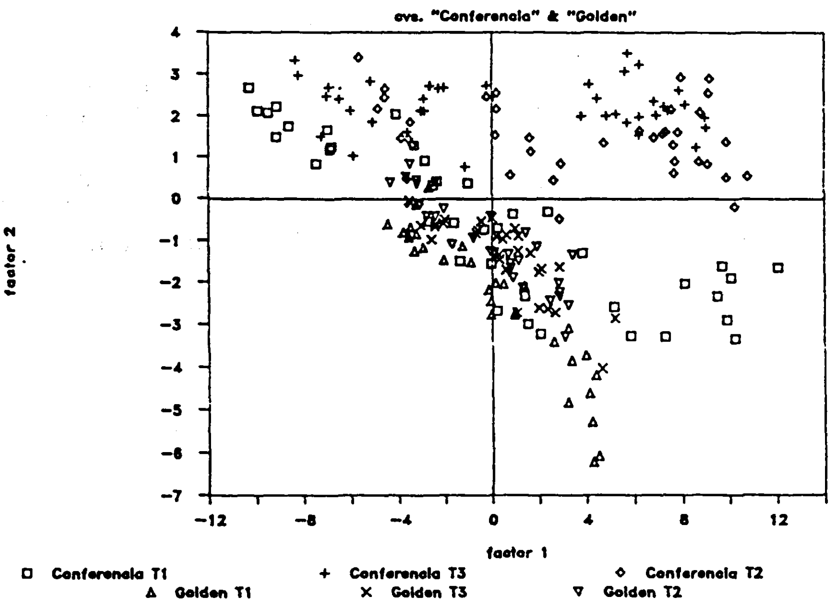

Fig. 2. Principal component analysis

skin resistance decrease mentioned (see "G. Smith" and "Conferencia" representation in Figure 1).

3.3. Response to Different Type of Loading

As the ratio maximum force-maximum deformation (N/mm) has demonstrated to be rather homogeneous in all mechanical tests: skin puncture resistance, high and low energy impacts to fruits and high and low energy compression of fruits, it has been decided to use it to compare fruit reaction to quasi- static and dynamic loading. Through these ratios it is clear that apple cultivars show similar response to quasi-static and compression loading, while pear varieties show great differences depending on the type of loading.

As for bruise susceptibility, measured as bruise depth (mm) and bruise depth-maximum force ratios, the apple varieties tested show similar values in the bruising variables while both varieties of pear seem to be more resistant to compression than to impact forces at initial post-harvest ripeness levels. As pear fruits ripen, compression resistance decreases, attaining lower resistance than at dynamic loading.

3.4. Differences between Storage Treatments

Storage treatments have been compared using the plane composed by the first and third Principal Components or factors. At the first sight it is clear that both varieties of apple: "Golden" and "G. Smith", do not show differences between treatments, so storage does not show initially great effect on fruit firmness. This result can be explained due to apple skin characteristics, resisant and very constant along post-harvest ripeness period.

Storage treatments have greater effects on pear varieties. These effects may be additionally expressed due to skin properties which, indeed, show great changes during post- treatment evolution (see "Golden" and "Conferencia" representation in Figure 2).

3.5. Bruise Susceptibility Regression Models

The main objective at the current research has been not only to describe storage and loading effects on pome varieties but to quantify these effects and also to develop mathematical models explaining and predicting bruise susceptibility in the main exported species and varieties. In order to verify that firmness can be measured by any mechanical testing the following criteria have been taken into account:

- using firmness (N/mm) measured not destructively by low energy impacts.
- using loading level and loading type as different response has been found in the pear varieties studied.
- including any of the common variables related with the absorbed energy as it has been shown highly correlated with bruising susceptibility (Holt *et al.*, 1984, Klein *et al.*, 1987).

Only prediction models for pear cv "Conferencia" have been developed up to now. Both quasi-static and dinamic models for cold storage inside polyethylene bags are discussed at the current paper, though other models have been developed for treatments 1 and 2 with similar results.

TABLE 1
Compression model

$$BD = e^{(2,0096 - 0,0371FI + 0,2420DC)}$$

r = 0,9144
$r^2 = 0,8362$
n = 80

Where: BD Bruise Depth (mm)
FI Firmness at non destructive impacts (N/mm)
DC Deformation at compression tests (mm)

Nº of days room temp.	Load level	FI	DC	(BD) obs. med.		(BD) calc.		
						min.	med.	max.
0	50N	36.35	2.11	3.5	C	3.1	3.2	3.4
4	50N	26.78	3.55	6.2	B*	6.1	6.5	7.0
7	25N	15.43	3.52	10.2	A*	9.2	9.9	10.6
11	10N	13.77	3.07	10.7	A*	8.6	9.4	10.3
0	25N	36.35	1.25	2.4	c	2.5	2.6	2.7
4	25N	26.78	1.95	4.4	b	4.2	4.4	4.7
7	10N	15.43	2.13	7.2	a*	6.7	7.1	7.5
11	7N	13.77	2.07	7.8	a*	6.8	7.4	8.0

* This value means fruit would not be considered as first class (< 1cm² bruised area)

TABLE 2
Impact model

$$BD = - 0.0555FI + 1.5280PD + 0.1063IH$$

r = 0,8981
$r^2 = 0,8065$
n = 80

Where: BD Bruise Depth (mm)
FI Firmness at non destructive impacts (N/mm)
PD Permanent Deformation (mm)
IH Impact height (cm)

Nº of days room temp.	IH	FI	DC	(BD) obs. med.		(BD) calc.		
						min.	med.	max.
0	10cm	36.35	1.06	4.7	C	4.4	4.6	4.8
4	10cm	26.78	1.21	5.2	C	5.2	5.4	5.5
7	10cm	15.43	1.62	6.6	B*	6.5	6.6	6.7
11	10cm	13.77	2.06	7.5	A*	7.2	7.4	7.6
0	6cm	36.35	1.25	2.4	c	3.4	3.5	3.6
4	6cm	26.78	1.95	4.4	b	4.3	4.5	4.5
7	6cm	15.43	2.13	7.2	a*	5.6	5.7	5.8
11	6cm	13.77	2.07	7.8	a*	6.0	6.2	6.3

4. CONCLUSIONS

Pears cv "Conferencia" and "Decana de Comicio" show great changes in their mechanical properties and their bruising susceptibility after cold storage during a one month period.

Apples cv "Golden" and "G. Smith" do not show any change either in their mechanical properties nor in their bruising susceptibility after five weeks of cold storage. This lack of effect can be due to the skin characteristics, so unchanging and resistant in spite of pear skin.

The response to quasi-static and dinamic loading is different in the pear than in the apple varieties tested. Pear cultivars seem to be more resistant to compression than to impact loading at the first ripening stages, becoming more bruise susceptible under compression loading at the latest stages; the apple cultivars, however, show rather similar bruising susceptibility either to dynamic or to quasi-static loading.

Bruising susceptibility can be mathematically described and predicted using firmness measured by non destructive impacts, loading type and level.

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