MECHANICAL SEGREGATION OF APRICOT VARIETIES AND THEIR RIPENESS LEVELS AT HARVEST

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ABSTRACT

Some laboratory tests consisting on quasi-static compression and puncture forces carried out on twelve varieties of apricot during 1990 and 1991 were effective in sorting them. These mechanical properties show a high correlation with the ethylene production rate per fruit, so allowing to discriminate between ripeness levels at harvest.

In this study it is also demonstrated that puncture seems to be the less variable mechanical test. The values (N/mm) obtained with it show a highly significant correlation with compression resistance and with quasi-static compression damage of the fruits.

1. INTRODUCTION

The source of this study can be found at the CEBAS-CSIC (Research Center on Soil and Biological Sciences) where the third author has been working for a few years on different apricot varieties selection and classification.

During the 1989-1990 season, at the Physical Properties Laboratory from the Department of Rural Engineering in Madrid, it was found that apricot varieties may be segregated by mechanical tests (Ruiz Altisent *et al.*,1991) and that this species suffers also less damage by impact than by quasi-static compression (Fridley *et al.*, 1966).

When the current study was planned, the main objectives selected were: to obtain the segregation of different varieties of apricot by mechanical tests in relation to the resistance of fruits to handling damage; to determine the most reliable test selection, and to find the relationship between mechanical response and ethylene production rate of the fruits.

Finally, the objective was also considered to prove whether there is any relationship between puncture and quasi-static compression resistance (both as N/mm of fruit deformation). This correlation was found for industry-tomato by Rodriguez Sinobas *et al.*, 1986.

2. PROCEDURES

Varieties

Twelve varieties of apricot have been tested:"Currot" (1), "Priana" (2), "Valenciano-3" (3), "Valenciano-4" (4), "Bulida-1" (5), "Moxó" (6), "Arrogante" (7), "Chicano" (8), "Ojaico-2" (9), "Harcot" (10), "Canino" (11) and "Velazquez fino-1" (12). From each one a harvesting date was selected, picking three or four maturity stages per variety, as many as it was possible by color segregation. The number of fruits at each stage varied from eight to sixteen from one variety to another, but it was constant within them.

Murcia-Madrid transportation was carried out under isothermal conditions (12°C) using insulated boxes. The apricots arrived to the Physical Properties Laboratory one day after harvest and were tested on the same day.

Four were the mechanical tests carried out: skin puncture; fruit compression until 3mm deformation was achieved; fruit deformation to reach a 10 N resistance at compression force; and finally flesh Magness-Taylor penetration after manually removing the skin. It was important to maintain this testing sequence, as it was selected in order to produce the least damage charge as possible.

Mechanical and Physiological Tests

a) Tests for mechanical resistance determination of each variety.
   a.1.) Magness-Taylor flesh penetration without skin, using 8 mm diameter cylindrical rod mounted to an INSTRON device working at 20 mm/min speed. Penetration maximum force (N) was determined.
   a.2.) Skin puncture using a cylindrical device of 0.5mm diametre and flat base. This test needed also the use of an INSTRON testing machine. The work speed was 20 mm/min. Maximum force (N) and deformation (mm) at puncture were measured.

b) Application of controlled damage using quasi-static compression forces.
   b.1.) Compression with a 30 mm diametre sphere mounted on an INSTRON device working at 20 mm/min speed. The fruits were compressed until they reached a 3 mm de formation.
   b.2.) Fruit deformation by quasi-static compression until it reached 10 N of measured resistance. The sphere used and the working speed were the same as in b.1.

c) Internal damage observation by measuring bruise depth in apricot slices from the damaged area. A binocular microscope was used in order to achieve enough precision.
   It was useful to wait approximately two hours before measuring damage due to the necessary period for the polyphenol oxidations to be developed (Kader *et al.*, 1983; Rodriguez *et al.*, 1990; Vamos Vigyazo, 1981).

d) Ethylene production rate measured by gas chromatography in order to determine ripeness level of the fruits at harvest.

3. RESULTS

First of all, it is very interesting to analyze the varia- tion coefficient of each test, which should be between 15 and 30% when working with fruits. At the first sight it appears that this coefficient increases as maturity stage increases.

It is also demonstrated at the current study that the most reliable test is puncture, due to its lowest variation coefficient in comparison to Magness-Taylor test, which shows the highest values. Searching for the reason for the enormous variation percentage in this test, it seems that some of it was due to the fact that the testing device used was too large and that the way for removing the skin was not uniform enough.

Figure nº 1 displays the results of a test of differences between means (5% significance level) between varieties at each mechanical test, showing at each cultivar the mean value of all maturity stages. It demonstrates how mechanical tests are able to segregate groups of apricot varieties. Furthermore, this classification is fairly similar in all four tests, being "Ojaico-2" and "Arrogante" the most resistant cultivars at mechanical tests, while "Moxo" and "Valenciano-4" varieties are shown to be the most susceptible. The variety named "Velazquez fino-1" appears always in a middle position.

The ethylene production rate, obtained at the CEBAS-CSIC in Murcia on the same harvesting day (last column in the table) verifies the mechanical results, in spite of color segregation. Even though ethylene measure and color segregation were made the same day, there is however much more coincidence between mechanical and physiological results than between mechanical groups and subjective color rating (see Figure nº 2).

Skin resistance vs fruit resistance correlation model.

The current study demonstrates a high correlation between skin puncture resistance (N/mm fruit deformation) and fruit quasi-static compression resistance (N/mm), r = + 0,905. Therefore, the skin puncture test is able to determine not only the skin mechanical properties but also flesh damage susceptibility. It is a fast and simple test to perform.

In order to see if there is any varietal difference in the relationship between skin resistance and fruit resistance a false variable (V_j) has been created which takes 1-12 values, one for each variety (see procedures for knowing the number of order of the varieties). This new variable allows to create models including all the different statistical adjustments for the apricot varieties tested. There is a comparison between a general and and a simplified model in order to select the most simple one explaining the puncture-compression resistance of the apricot varieties studied.

The lack of difference between two varieties models can be demontrated due to the lack of significant differences between a general model (one regression line per variety) and a simplified model, in which some varieties follow the same regression line or at least a common slope. The lowest significant difference between the models can be determined using Fishers distribution as follows:

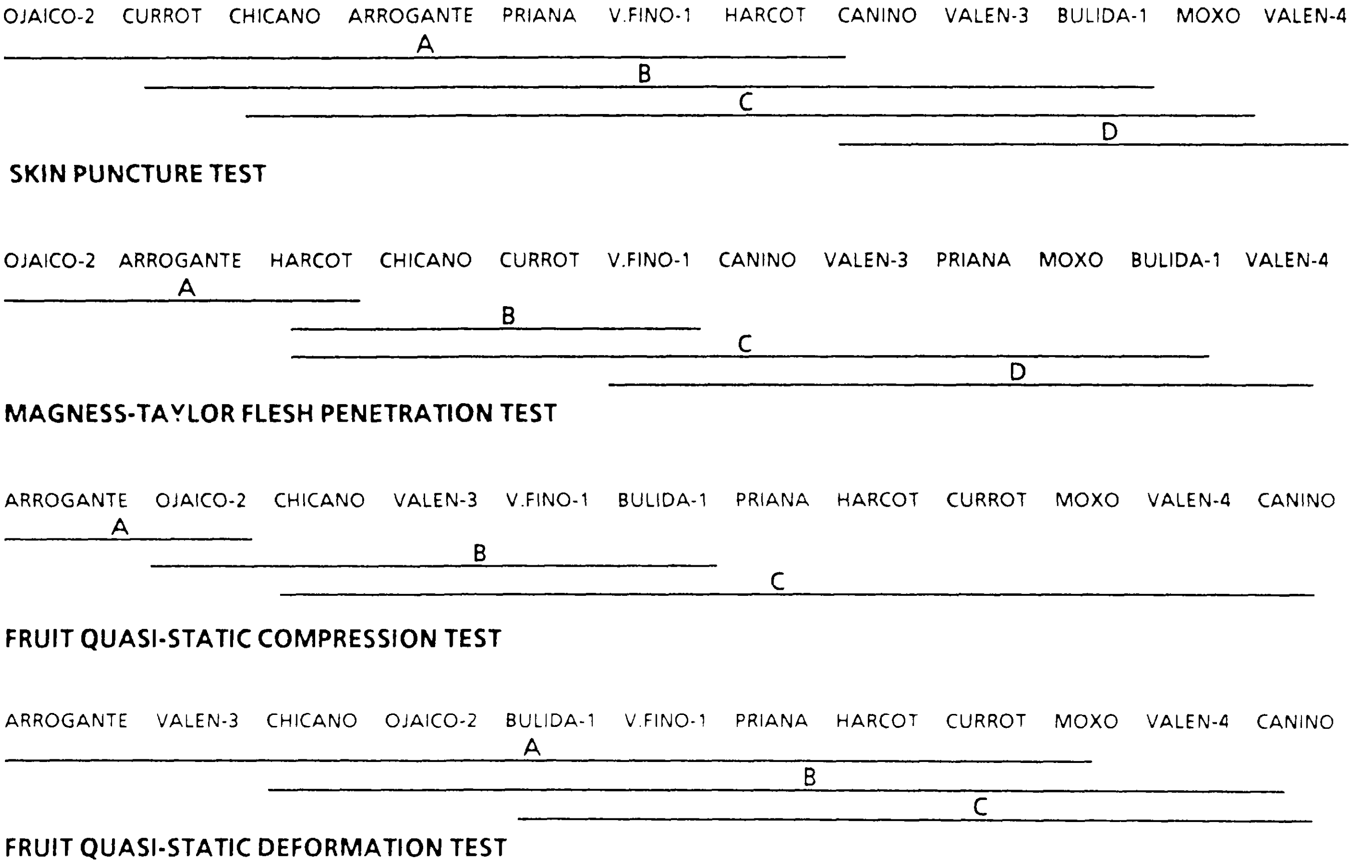

Fig. 1. Apricot varieties segregation. A means difference test is included for a sgnificant difference of 5%.

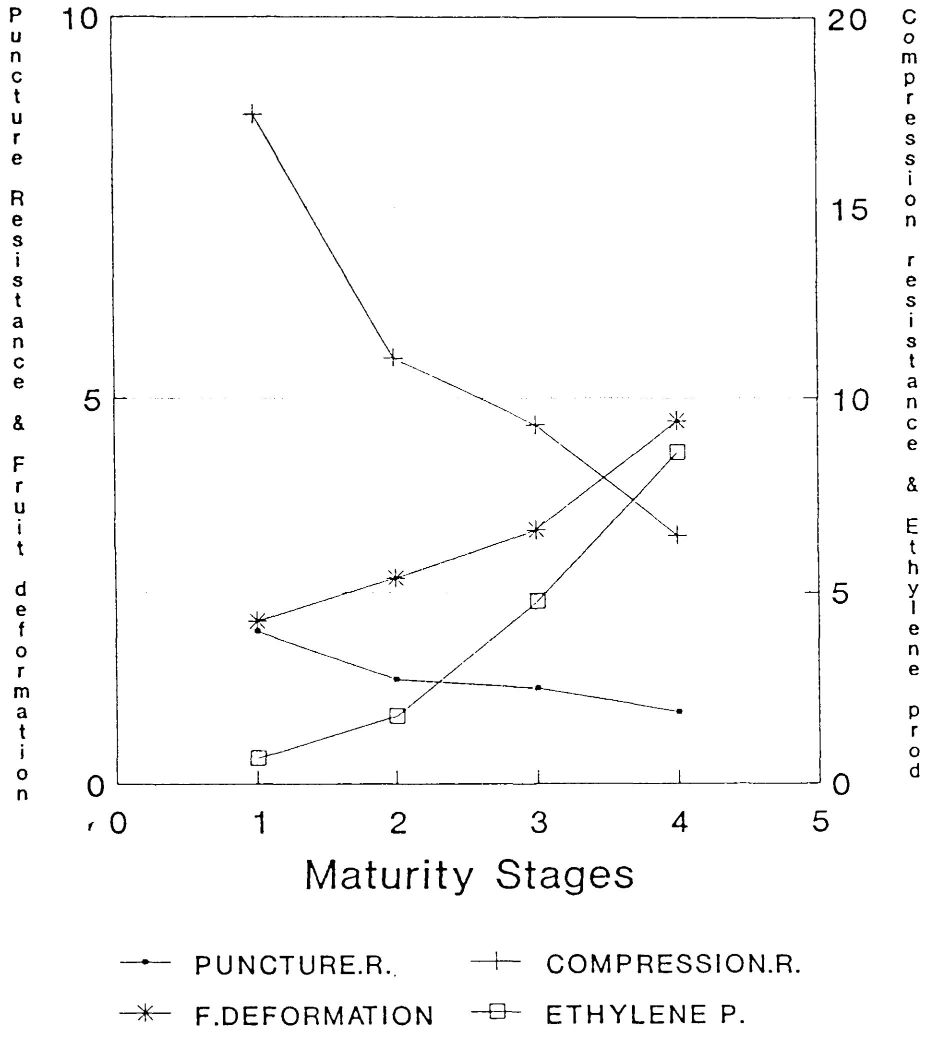

Fig. 2. Test's results in "Priana" variety.

$$F = \frac{\dfrac{S^2_{Rg} - S^2_{Rs}}{(D.F.)_s - (D.F.)_g}}{\dfrac{S^2_{Rg}}{(D.F.)_g}} < F_{0,05}((D.F.)_s - (D.F.)_g, (D.F.)_g)$$

Where:

S^2_{Rg} = residual sum of squares for the general model
$(D.F.)_g$ = degrees of freedom for the general model
S^2_{Rs} = residual sum of squares for the simplified model
$(D.F.)_s$ = degrees of freedom for the simplified model
Y = bruise depth (mm)
x = mm of fruit deformation
V_j = 1 when variety j
V_j = 0 when variety = j; j = {1,2,...,12}
r = linear regression coeficient

General model

$Y = -0.93 + 1.21 V_1 + 0.96 V_2 + 2.13 V_3 + 1.11 V_4 + 1.35 V_5 + 0.46 V_6 + 0.58 V_7 + 1.92 V_8 + 0.80 V_9 + 1.28 V_{10} + 0.66 V_{11} + 3.46x - 0.90 (x . V_1) - 0.28 (x . V_2) - 1.10 (x . V_3) - 0.20 (x . V_4) + 0.51 (x . V_5) + 0.66 (x . V_6) + 1.79 (x . V_7) - 0.79 (x . V_8) - 0.17 (x . V_9) - 0.85 (x. V_{10}) - 0.90 (x . V_{11})$

r = 0.906
S^2_{Rg} = 383.49
$(D.F.)_g$ = 435

Simplified model

$Y = +0.57 - 0.34 (V_1 + V_{10}) - 0.54 V_2 + 0.35 (V_3 + V_8) - 0.25 (V_4 + V_9) + 0.63 V_5 - 0.65 V_6 - 0.92 V_7 - 0.85 V_{11} + 2.82x - 0.17 (x . (V_1 + V_3 + V_8 + V_{10})) + 0.36 (x . V_2) + 0.23 (x . (V_4 + V_9)) + 0.85 (x . (V_5 + V_6) + 2.43 (x . V_7) - 0.26 (x . V_{11})$

r = 0.905
S^2_{Rs} = 385.74
$(D.F.)_s$ = 443

$$F = \frac{\dfrac{(385,74 - 383,49)}{(443 - 435)}}{\dfrac{383,49}{435}} < 0,32 \quad F_{0,05}(8,435) = 1,96$$

The coefficients for each variety or varieties regression line can be obtained when "V_j" variables in the models are substituted by their correct values.

It is very interesting to verify that several varieties have equal skin/flesh resistance ratio: "Currot"-"Harcot";"Valenciano-3"-"Chicano" and "Valenciano-4"-"Ojaico-2" and others not. Besides, the slope is always larger than 1 since compression resistance means skin plus flesh resistance instead of puncture resistance which measures only skin response to load.

4. CONCLUSIONS

Twelve apricot varieties have been segregated through their mechanical response to different type of loading.

The classification obtained was similar for all four mechanical tests: skin puncture, Magness-Taylor flesh penetration and quasi-static compression and deformation of fruits. The "Ojaico 2", "Arrogante" and "Chicano" varieties showed to be the hardest cultivars, while "Moxó" and "Valenciano-4" were the most vulne rable.

Mechanical tests were are also very useful to discriminate ripeness differences at harvest. These test results verify higher correlations between mechanical and physiological properties than when using color segregation.

Significant correlation have been found between puncture and compression in individual fruits, when both measured as "Newton per mm of deformation" . This relationship allows to determine different mechanical properties with only performing one of these tests.

Finally, in the current study it is demonstrated that skin puncture is the most reliable test due to its lowest variation coefficient; this test is considered to be the most advisable, allowing to determine not only skin resistance but also bruise susceptibility of apricot flesh.

5. AKNOWLEDGMENTS

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