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Measurement of *Vaccinium corymbosum* Firmness during Low Temperature Storage: Comparison of Different Methods

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Abstract

Flesh firmness is one of the most important blueberry characteristics for fresh market consuption, as it relates to consumer appeal and to post-harvest decay of fruit. Berry firmness is also an important attribute because it is considered to be a measurement of its freshness. This attribute is related to both the stage of maturity and the variety itself. Berries lose their firmness by loss of water and/or by changes in their structure.

In this study, firmness was measured with a rapid nondestructive instrument (Durofel®, CTIFL Copa Technologie, France) and with a laboratory instrument (Texture Analyzer TaxT2i® Stable Micro System, UK), using a penetrometer test.

Samples of berries were collected weekly at different picking dates, then weighed and stored for 40 days under two different conditions: traditional (3°C, 85% R.H.), or innovative (adding ozone to the normal atmosphere).

Statistical analysis of data showed a significant correlation between the two methods tested. The Durofel® offers an alternative and low cost measurement of blueberry firmness, but the result on the dial is not expressed as a unit of strengh, but as a index having only a relative value. On the countrary, tests with Texture Analyzer gave a force-deformation curve with international parameter of force max (N).

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INTRODUCTION

Firmness could be used as an acceptability criterion, an important quality attribute, or, including tomatoes and cherries, an indication of the fruit handling characteristics. Also parameters such picking and grading may be based on this measurement.

Fruit firmness is also an important component of final quality of small fruits. Fruit softening is the result of over maturity during post-harvest conservation, resulting in rapid decay and deterioration throughout the distribution process (Ballinger W.E. *et al.*, 1973; Ceponis M.J. *et al.*, 1985; Sanford K. *et al.*, 1991). This mechanical property affects not only the oral perception of the texture and hence its eating quality, but also post-harvest properties.

For many years the firmness of fruit has been used as a helpful guide for growers, quality inspectors and purchasers and various methods have been used to measure fruit firmness, most of which were slow and laborious (Barrit B.H., *et al.*, 1980, Robbins J., *et al.*, 1986).

Traditionally, firmness has been measured by a penetrometer, in which a cylindrical rod is pushed into the fruit and the force required is measured. Various types of penetrometers have been developed for large fruits like apples and pears, but they are less satisfactory for softer fruit such as strawberry and blueberry, because they are not sensitive enough for such small fruits.

For measure of blueberry firmness many instruments investigated, included: FirmTech II firmness tester (NeSmith D.S. *et al.*, 2002), « BerryBounce » system (Patel N. *et al.*, 1993), Ametek compression tester and Instron Universal Testing Machine (Rohrbach R.P. *et al.*, 1993).

Unfortunately, most of these methods are destructive. For this reason, several attempts have been made to develop non-destructive testing methods to assess firmness.

One of this is the Durofel® instrument, which allows large numbers of fruit to be quickly and non-destructively measured for firmness. It is a tool for controlling soft fruit on the farm and on commercial sites. The Durofel® is a portable, simple to use dynamometer and has been widely used for the evaluation of soft fruit firmness for strawberry and cherry (Balmer M., 2001; Khanizadeh S. *et al.*, 2000; Planton G., 1992).

The aim of this work was to compare the results of Durofel® test with these obtained using a Stable Micro System TA.XT2i Texture Analyzer® largely used for food texture analysis (Anon, 1996; Smewing J., 1997).

MATERIALS AND METHODS

The trial was carried out during the summer of 2004, in the AGRIFRUT Cooperative in Peveragno (Cuneo Province, Italy), using the highbush cultivar Bluecrop.

Berries were harvested by hand from commercial plantings and only fully colored fruit were used. At regular four days intervals, starting in the first week of July, samples were harvested at three different picking dates. 12 samples of 250 g of blueberries were harvested at each picking date and placed directly into plastic clamshell containers.

After collection, the samples were cold stored under two different storage conditions:

1. Traditional storage: normal atmosphere (3°C, in a temperature-controlled cold room, with an average relative humidity of 90-95%).
2. Innovative storage: innovative atmosphere (3°C, in a temperature-controlled cold room, with an average relative humidity of 90-95% + 0,30-0,50 ppm of ozone). Ozonation is created by AgroCare™ (Grupo Interozone, Cile); it is an environmental ozone generator.

Firmness was evaluated at each picking date and once a week during storage at both normal and innovative atmosphere. The two methods used were:

1. a penetrometer test by Durofel® (CTIFL Copa Technologie, France), a dynamometer with a bolt of 3 mm Ø (0.10 cm^2), on a scale of 1 (soft) to 60 (firm);
2. a penetrometer test by TA-XT2i Texture Analyzer ® (Stable Micro System, UK) equipped with a 5 Kg loadcell. The probe penetrated the skin and the mesocarp tissues 3 mm into the berry at a crosshead speed of 3 mm/s, with P3-3mm DIA CYLINDER STAINLESS probe in the equatorial part of the blueberry. Data, force max (N), were calculated with Texture Expert Version 1.17 (Fig. 1).

The non-destructive nature of Durofel® measurement enables to repeat assessment of berry samples. Thus it was possible to calculate berry firmness on the same fruit using the two methods described. In order to avoid measurement variations due to the temperature, blueberries were removed from cold storage and allowed to warm up to 20°C for 2 hours prior to firmness measurements.

Linear regression analysis of data was performed with STATISTICA ver. 6.0 (Statsoft Inc., Tulsa, OK, USA).

RESULTS and DISCUSSION

Data in figures 2 and 3 reports the results of measurements (F max and Durofel® index) of fruit firmness associated with storage conditions and post-harvest weeks were reported.

Both sets of data (Force max and Durofel® Index) in figure 2 shows an apparent rise in force during the first two weeks of storage, but began to fall significantly later in the post-harvest weeks. The rate of fall decreased and almost levelled out in the last weeks of storage for the Durofel® firmness readings, while the TA-XT2i® readings continued to fall. This trend is probably due to the slight sensitivity of measurement of Durofel® instrument.

Similar results are shown in Figure 3 where the firmness values of samples stored in normal atmosphere are reported.

Wide variability of a same fruit sample, in particular for the firmness measured by TA-XT2i®, is present and it is caused by the higher sensibility of this instrument and the higher fruit variability.

Due to the high fruit variability there are not significant difference ($p<0.05$) for firmness of fruits between the two atmosphere/storage methods. Firmness values covered the range of 0.75 to 2 N for samples stored with ozone atmosphere, and 0.85 to 2.1 N for normal atmosphere.

These results are in disagreement with other experiments (Guzel-Seydim Z. B. *et al.*, 2004; Machado N. P, *et al.*, 2004; Palou L. *et al.*, 2001) but ozone concentration is different in our test.

Despite the high variability of fruit firmness measured by Durofel® instrument are correlated to the corresponding data recorded with TA-XT2i® test (Figure 4). Regression analysis confirmed that there is a positive correlation between the two methods of determining fruit firmness with $R^2 = 0.687$ ($p < 0.01$).

Then Durofel® technique allows the possibility to monitor the evolution of the flesh firmness in a non-destructive way during post-harvest conservation. By the equation of correlation we can attribute a value of Force (N) to the correspondent value of Durofel® index, force (N) = - 0.37999 + 0.0822 * Durofel® index.

CONCLUSION

The Durofel® values are similar to the correspondent data recorded by TA-XT2i Texture Analyzer®, for this reason, then Durofel® method appears to show a considerable promise for the non-destructive evaluation of blueberries firmness by extension workers. But when soft fruit firmness accurate measure is required, a Texture Analyzer® instrument is needed.

So, the choice of method for determining blueberry firmness will depend on the objectives of the measurement. The Durofel® technique does not require a big investment in money and is certainly easy to use especially in field conditions, but it can't use when blueberries are very soft.

Ancknowledgements

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Figures

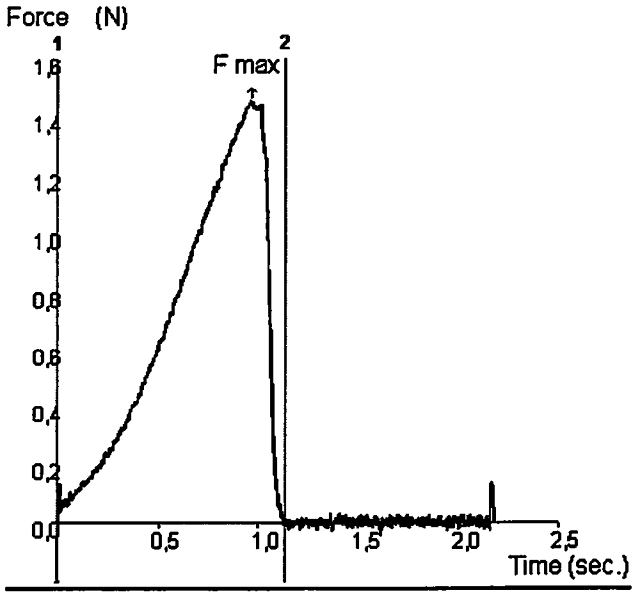

Fig.1 – Force-deformation curve under constant velocity compression.

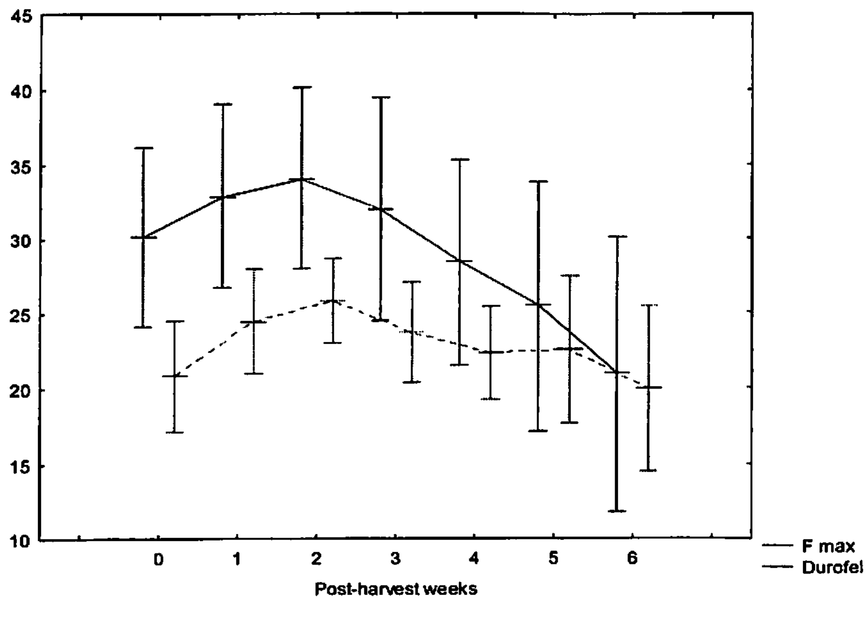

Fig. 2 – Fruit firmness as a function of post-harvest storage. The figure shows the mean values and the standard deviation (45 fruits per point) of F max (N*20) by Texture Analyzer and Durofel index. Samples stored in atmosphere with ozone.

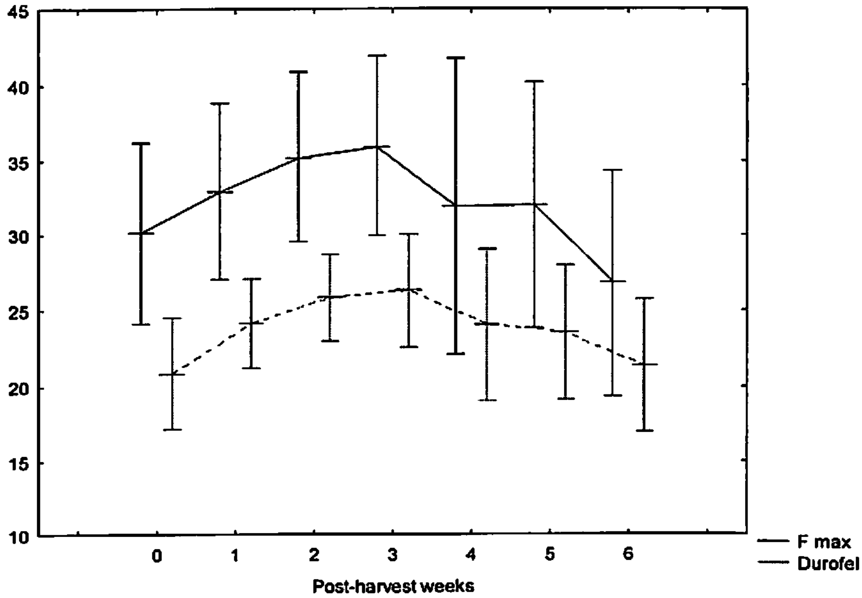

Fig. 3 – Fruit firmness as a function of post-harvest storage. The figure shows the mean values and the standard deviation (45 fruits per point) of F max (N*20) by Texture Analyzer and Durofel index. Samples stored in Normal Atmosphere.

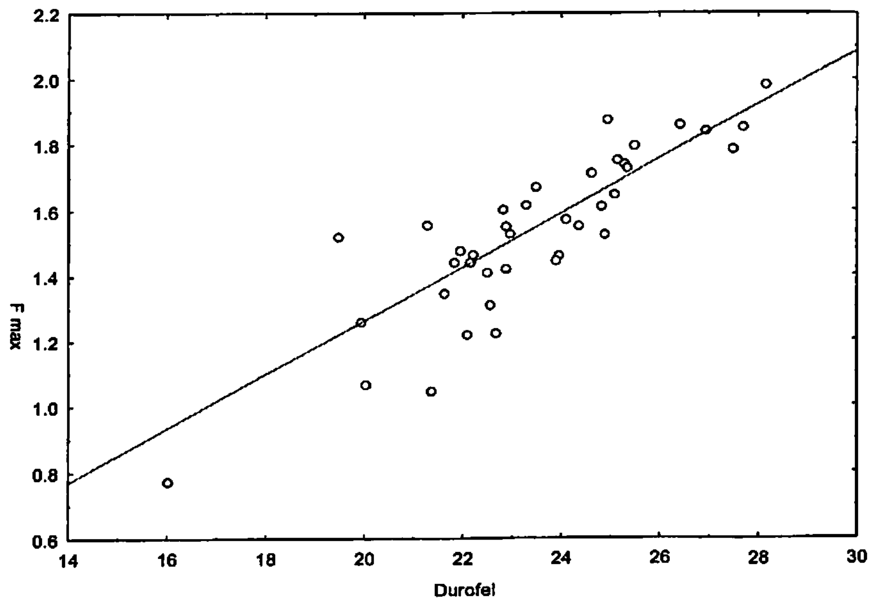

Fig. 4 – Scatter plots of Force max mean value obtained with TA-XT2i test correlated to Durofel Index and regression line. The figure shows the mean values (15 fruits per point) of the tree picking date and the six post-harvest weeks of the two storage conditions considered.