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Texture variation in apricot: Intra-fruit heterogeneity, impact of thinning and relation with the texture after cooking

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ABSTRACT

The rapid texture loss of apricot fruit during storage and transformation is a limiting factor for its commercialisation and use. Apricot flesh exhibits different tissue zones which differ in texture. To better understand texture in apricot fruit, we have studied (i) the intra-fruit heterogeneity of texture measured by puncture test (tissue firmness) (ii) the effect of thinning on whole fruit firmness (global firmness), measured by compression, and on tissue firmness and (iii) the evolution of texture upon steam cooking, on apricots of contrasted texture. Nine tissue zones were defined in fresh apricot fruits in order to study differences in texture from the peduncle to the pistil zones and from the external to the internal tissue. In the nine apricot varieties used, tissue firmness decreased gradually from the external to the internal tissue. However, from the peduncle to the pistil zone, the variation of texture seemed to be variety-dependent. Overall the textures measured for the nine tissue zones were highly correlated, indicative of the major differentiation between soft and firm fruits. However distinct heterogeneity patterns could be observed on axes 2 and 3 of a principal component analysis carried out on the textures of the nine zones. The effect of thinning on fruit firmness appeared variety-dependent. Tissue firmness of the raw apricots assessed by penetrometry explained about two-thirds of the variability of firmness of cooked apricots, versus only 40% for the compression test. High correlations between texture after cooking and prior to cooking were found for four (external equatorial, external pistil, median equatorial and median pistil) out of the nine tissue zones.

1. Introduction

Apricot is a fruit of high economic and nutritional relevance. With a world production of 2.8 million tonnes in 2005 (FAOSTAT, 2005), it is the third most widely grown stone fruit crop. Apricot fruit is consumed fresh or used to make various apricot-based products such as dried, frozen or canned apricot, jam, jelly, marmalade, pulp, juice, etc. However, the marketing of apricot remains quite difficult because of their rapid softening and the associated susceptibility to physical damage and disease. Firmness is one of the fundamental quality attributes in apricot fruit which determines the harvest date and fruit resistance to postharvest manipulation and suitability for processing into different products. Commonly, apricot fruits are harvested firm (thus early) to limit damage during handling and shipping, but at this stage, the other quality attributes such as appearance, taste, aroma and nutritional value are not sufficiently developed (Bruhn et al., 1991; Botondi, Crisà, Massantini, & Mencarelli, 2000). Harvest of riper fruits provides apricots with better quality attributes but their shelf-life is short and fruits are easily damaged (DeMartino, Massantini, Botondi, & Mencarelli, 2002, Kovacs, Meresz, Kristof, & Németh-Szerdahel, 2008). In addition, apricot appears to be particularly susceptible to heat-softening problems. In thermally processed products such as canned apricot, some severe cases result in the total disintegration of fruit halves (Chitarra, Labavitch, & Kader, 1989). It is therefore necessary to find high-quality apricot varieties acceptable for fresh consumption and more compatible with postharvest manipulation and processing. Apricot quality attributes, including firmness, have been reported to depend on pomological traits (Audergon, Souty, & Breuils, 1990; Crossa-Raynaud & Audergon, 1991) or genetic factors (Asma & Ozturk, 2005; Audergon, Reich, & Souty, 1991; Badenes, Martínez-Calco, & Llácer, 1998; Hagen, Khadari, Lambert, & Audergon, 2002; Hormaza, 2002; Ruiz & Egea, 2008). Thinning is commonly used to increase fruit size, but its effects on fruit firmness could depend on its precise timing. Thinning consists in eliminating part of the immature fruits at an early stage so as to allow a better nutrition of the remaining fruits. Early thinning, while the fruits are still in the cell division phase, could presumable lead to different effects than late thinning during the cell extension phase. The relationship between firmness of fresh fruit and

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firmness of thermally processed products has, to our knowledge, not been studied. Only little information is available on texture of canned apricot fruit (Chitarra et al., 1989; Mallidis & Katsaboxakis, 2002). A specific trait of apricot is the high heterogeneity of tissue structure which can be seen on radial slices. Three areas are clearly visible to the naked eye. The external tissue, close to the skin, is composed of smaller cells, the longest axis of which is parallel to the surface of the fruits, and which may be partially lignified. A median tissue appears quite homogeneous, with typical parenchymal cells. These cells are organized relative to the vascular bundles, as illustrated by Devaux, Bouchet, Legland, Guillon, and Lahaye (2008) for tomato, and have no preferential orientation relative to the fruit structure. The internal zone shows a radial structure with bundles of cells that tend to separate with maturity. Each of these bundles actually corresponds to a derivative of the main vascular network towards the stone. In this part, the longest axis of the cells is perpendicular to the fruit surface, and physical constraints during growth result in a fairly regular organisation of increasingly separated bundles. Depending on variety, the proportion of these tissues varies.

Our aim was to substantiate the variability in texture of apricots at the cultivar and at the fruit level. We investigated firstly the effect of thinning on fruit firmness for several apricot varieties and secondly change in texture through the different tissue zones of fresh apricot fruits and the relationships among these tissue zones. Thereafter, correlations were established between firmness of fresh tissues and firmness after thermal processing.

2. Materials and methods

2.1. Fruit and sampling

Apricots of different cultivars were collected in June and July 2009 in Gotheron's INRA experimental orchard (St Marcel les Valence) for Bergeron, Bergarouge, Candide, Orangered, Ravicille, Ravilong, Vertige, in Amarine's INRA experimental orchard (Bellegarde) for Hargrand and in traditional private orchard for Hybrid 07.107, all selected orchards being located in the Rhone valley in the south of France. During growth of the fruits, trees were subjected to manual thinning i.e. elimination of part of the immature fruits either early, late or not. Early thinning has been performed during the first fruit growth period, so during the cellular multiplication phase (around 3 weeks after bloom). Late thinning has been performed during stone hardening period or a little bit after at the beginning of the cell enlargement phase (around 5 weeks after bloom). For each variety and for each thinning treatment, about 40–60 fruits were harvested at commercial maturity defined according to fruit degreening, when only the suture zone is still green. After picking, they were stored in the same cool room at 7 °C and under ambient atmospheric pressure and humidity during 2–8 days, depending on variety. On the day of fruits analysis, firmness of entire fruits was assessed by compression (see Section 2.2.1) in order to constitute samples relatively homogenous in fruits firmness. So, for each variety and for each thinning treatment, a sample of 24 fruits was constituted. Each sample was then divided into two equal lots of 12 fruits. The first lot was used for firmness analysis by penetrometry in the different tissue zones of fresh fruits while the second lot was used for texture analysis of cooked fruits.

2.2. Mechanical characterizations

2.2.1. Whole firmness determination

This fruit whole firmness was measured with a compression test which gives a combination of skin resistance and flesh firmness (Grotte, Duprat, Loonis, & Pietri, 2001). It was assessed with a multi-purpose texturometer (Texture analyser TAplus: Ametek, Lloyd Instruments Ltd., Fareham, UK). This apparatus registered force/deformation curves by measuring the reaction force in response to an increasing mechanical constraint applied to the fruit by a 5 cm flat disc and 250 N load cell. The probe speed was 20 mm min^{-1} and the deformation was 3%. The registered maximum force was converted in Young's modulus assuming a spherical shape and a Poisson's ratio of 0.45. The Young modulus is the so called whole firmness.

2.2.2. Puncture tests of the different fruit zones

For each of the twelve fruits selected for tissue zones firmness determination, a tissue slice of about 1.5 cm thick was cut longitudinally. Nine tissue zones were defined on the surface section to obtain three series of three tissue zones from peduncle to pistil and from external to internal tissue as presented in Fig. 1: external peduncle (ExPe), median peduncle (MePe), internal peduncle (InPe), external equatorial (ExEq), median equatorial (MeEq), internal equatorial (InEq), external pistil (ExPi), median pistil (MePi) and internal pistil (InPi). Firmness at each tissue zone was measured by penetrometry test using a multi-purpose texturometer (Texture analyser TAplus: Ametek, Lloyd Instruments Ltd., Fareham, UK) equipped with a 50 N load cell and a flat tip cylindrical probe of 2.0 mm diameter. The test was carried out using a penetration rate of 20 mm min^{-1} with a full penetration depth of 15 mm. Tissue firmness (N) corresponded to the maximum force. One measurement was made per tissue zone and per fruit; the average value and standard deviation of the 12 fruits were calculated.

2.2.3. Cooked fruits firmness determination by Kramer shear test

The second lot of 12 fruits was directly steam-cooked during 10 min using a domestic vapour cooker (Cuiseur Vapeur S07, Seb, Ecully, France). After cooking, fruits were stored overnight at 7 °C prior to firmness measurement. Firmness was determined by Kramer shear test using a multi-purpose texturometer (Texture analyser TAplus: Ametek, Lloyd Instruments Ltd., Fareham, UK) equipped with a 1000 N load cell. The twelve cooked apricots were divided into three lots of 4 fruits corresponding to three replicates. Fruits were then cut in half and the seed removed. About 140–160 g of cooked half fruits was placed in the Kramer cell. The fruits were sheared at a speed of 60 mm min^{-1} at ambient temperature. Firmness (N mm g^{-1}) corresponded to the surface of the peak of the load–extension curves.

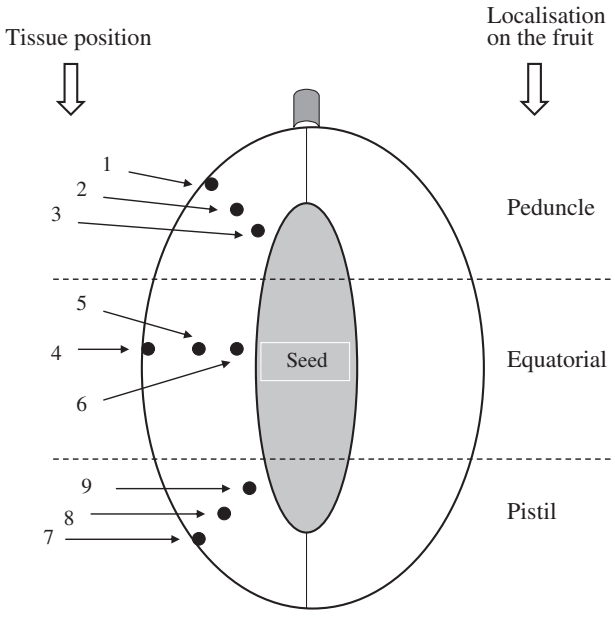

Fig. 1. Puncture points in different tissue zones defined for firmness measurements. 1. External peduncle (ExPe), 2. Median peduncle (MePe), 3. Internal peduncle (InPe), 4. External equatorial (ExEq), 5. Median equatorial (MeEq), 6. Internal equatorial (InEq), 7. External pistil (ExPi), 8. Median pistil (MePi), 9. Internal pistil (InPi).