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Relationship between texture and pectin composition of two apple cultivars during storage

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Abstract

The texture of two apple cultivars was characterised by sensory and instrumental methods for five different storage periods. The aim of this study was to explain the changes in apple texture during storage by different physical (penetrometry, compression) and chemical measurements (extraction and analysis of pectin composition). The emphasis was on determining the most relevant biochemical markers in relation to different sensory properties of apple texture.

Contrary to 'Fuji', 'Golden Delicious' fruit softened easily during storage, became mealy and had higher neutral sugar concentrations in their alcohol-insoluble residues (AIR) and more galacturonic acid in the water-soluble pectin extracts (WSP). The most relevant biochemical marker linked to texture change was the galacturonic acid content in the water-soluble pectin extracts. High and positive correlation coefficients were observed between sensory *mealiness* ($R = 0.84$) and galacturonic acid content in the WSP while, sensory *crunchiness* and instrumentally measured firmness were negatively correlated with this component. The total neutral sugar content in the alcohol-insoluble residues and in the water-soluble pectin fractions also changed with apple texture properties.

Keywords: Apple; *Malus domestica* Borkh; Texture; Cell wall; Mechanical properties; Sensory analysis

1. Introduction

Apple texture is one of the most important quality properties that influence consumer acceptability of these fruit (Stow, 1995). Thus, postharvest softening of apples during storage and market distribution is a serious commercial problem resulting in quality losses for growers and distributors. Therefore, our research aims to explain the development of apple softening during storage using different physical (penetrometry, compression) and chemical measurements (extraction and analysis of pectin composition).

Knowledge of the mechanism of fruit tissue softening, cell-wall structure and cell-wall breakdown is very important for understanding and improving the texture and quality of apple fruit. A better understanding of the relationship between fruit texture and biochemical composition could lead to improvements in quality control and process design in the food industry and the marketplace. Many studies have already addressed either the changes in apple texture during storage (Abbott et al., 1984; Grotte et al., 2001; Johnston et al., 2001; Mehinagic et al., 2004; Varela et al., 2007) or changes in pectin composition during softening (Yoshioka et al., 1994; Massiot et al., 1996; Nara et al., 2001), but few studies tried to connect these two phenomena. Moreover, for the majority of these, sensory perception of changes in fruit texture was never carried out. Ben and Gaweda (1985) showed high correlation coefficients between the content of protopectin (non-cellulosic neutral sugar residues) and the firmness of 'Jonathan' apples in one storage season only. A study performed on 'Golden Delicious' apples attempted to determine the possible contribution of changes in cell-wall composition to fruit softening under various storage conditions (Siddiqui et al., 1996). More recently, Pena and Carpita (2004) reported a study

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of the chronology of the biochemical events associated with loss of firm texture and cell separation, and Lo Scalzo et al. (2005) described the results of research on pectin composition just after reddening and after cold storage of reddened 'Annurca' apple fruit in different atmospheres.

Loss of firm texture and cell adhesion are processes associated with ripening that affect fruit quality and postharvest storage. The cell walls of fruit have received considerable attention, as changes occurring in their structure and composition are clearly determining in fruit firmness (Knee, 1973a,b; Bartley, 1976; De Vries et al., 1981; Renard et al., 1990b, 1991a,b,c,d; Renard and Thibault, 1993; Massiot et al., 1994). Indeed, it is well known that separation and degradation of water-soluble pectic substances, erosion of the middle lamella and disintegration of the primary cell wall lead to softening of fruit flesh. Pectic substances are the most abundant class of macromolecules within the cell-wall matrix and are the main components of the middle lamellae. They have a role in the adhesion between cells, and in regulation of intercellular adhesion. Consequently, pectic substances have been assigned an important role in changes in texture of fruit tissues (Yoshioka et al., 1992; Grant Reid, 1997) and notably, changes in pectin composition have been implicated in decreased adhesion between cells (Ilker and Szczesniak, 1990). During fruit softening, pectins typically undergo solubilisation and depolymerisation, which are thought to contribute to wall loosening and disintegration. In apple, there is usually an increase in water-soluble pectin (WSP), and a decrease in galactose and arabinose residues (Knee, 1973b), with little depolymerisation occurring in any pectin fraction during ripening (Yoshioka et al., 1992; Fischer and Amado, 1994; Fischer et al., 1994). However, the association of biochemical changes with changes in fruit texture is still unclear; for example, it is still not known if the processes of pectin solubilisation and loss of galactose are causal, coincidental, or a consequence of apple softening (Redgwell et al., 1997).

We aimed to study the relationship between texture and pectin composition of stored apples. Two cultivars with different textural characteristics were studied in order to investigate whether the differences in texture between different apple cultivars were due to differences in their pectin composition. 'Fuji' is a crunchy and juicy apple that stores well and 'Golden Delicious' apples become mealy during storage (Mehinagic et al., 2004). The apples were stored for up to 7 months at 2 °C. Their texture was assessed using two deformation tests (penetrometry and compression) and sensory analysis. At the same time, cell-wall content and pectin extractability of these fruit were characterised in order to try to relate texture modifications and sensory perceptions to different chemical changes occurring in apple cell walls.

2. Materials and methods

2.1. Fruit

Two different apple cultivars (*Malus domestica* Borkh), 'Fuji' (FU) and 'Golden Delicious' (GO), were studied. One hundred and forty fruit of each cultivar harvested in 2004 at commercial maturity were provided by a fruit-bearing test center ("La Morinière", Saint Epain, France). Their ripening stage was verified by starch regression measurements. These fruit were selected on the basis of uniformity and absence of damage or blemishes. They were all stored in the same cool room at 2 °C and under ambient atmospheric pressure and humidity for five different periods (1, 2, 3, 4 and 7 months). The choice of these storage periods was based on a previous study which showed that they resulted in a large range of apple mechanical properties (Mehinagic et al., 2004). For each storage period, 28 fruit per cultivar were brought up to room temperature 24 h before being analysed. Half of each fruit ($n = 28$) was analysed by sensory panel and the second half by penetrometry ($n = 14$) or compression ($n = 14$). Sensory and mechanical methods were carried out simultaneously and immediately after the apples were cut. For penetrometry and compression tests, apples were manually and carefully peeled by the same operator using the same vegetable knife. Fruit analysed by penetrometry were then sampled (taking care to remove the crushed part before sampling) and freeze-dried prior to chemical analysis.

2.2. Sensory evaluation

The sensory panel included 14 permanent trained panellists from the staff of the Ecole Supérieure d'Agriculture (ESA, Angers, France). These panellists, selected in 1999, are trained every week to evaluate apple texture according to the recommendations of AFNOR (1995) and of Fortin and Desplancke (1998). Their performances are evaluated once a year to ensure reliability. The sensory attributes studied on apple flesh were *crunchiness*, *juiciness*, *mealiness*, *chewiness* and *fondant*. These sensory attributes are defined and described in Table 1. During a sensory session, each panellist peeled and analysed two different half fruit from each cultivar. The washed unpeeled half apples, coded by a random three-digit code, were randomly presented to the panellists, at room temperature and under red light illumination to avoid apple cultivar identification. A 10 cm line scale was used for evaluation. The left end of the scale corresponded to the lowest intensity (value 0) and the right end to the highest (value 10). Each panellist used mineral water as a rinse between sample analyses. Five sessions, corresponding to five storage periods, were organised. In this way, each panellist analysed 2 cultivars × 2 half apples during each session. Thus,

Table 1
Texture sensory descriptors used for apples

Texture attribute	Definition (Mehinagic et al., 2003)
Crunchiness	Force required for the first bite and the noise resulting from this bite
Juiciness	Amount of liquid released on mastication just before swallowing
Mealiness	Dry and crumbly texture
Chewiness	Time and number of chewing movements needed to grind the sample prior to swallowing
Fondant	Force required to crush a piece of apple between the tongue and palate