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Influence of maturity degree, modified atmosphere and anti-browning dipping on texture changes kinetics of fresh-cut apples

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ABSTRACT

Consumer acceptability of fresh-cut apples is affected by texture characteristics, mainly by crispness attribute. The use of combined instrumental acoustic-mechanical techniques and the measurement of the absorption coefficient at 670 nm (μ_a670) by time-resolved reflectance spectroscopy (TRS) have been shown useful to assess fruit crispness and the maturity degree. The aim of this work was to evaluate the influence of the maturity degree measured by TRS, modified atmosphere and anti-browning dipping on the texture of fresh-cut apples as measured by means of an instrumental mechanical-acoustic test and the rheological behavior of the cell wall material. Apples were measured at harvest by TRS at 670 nm, ranked on the basis of decreasing μ_a670 (increasing maturity) and classified as less mature (LeM), medium mature and more mature (MoM). Only LeM and MoM apples were peeled and cut, half of them were dipped in the antibrowning solution and the other were not dipped. All samples were packed using air or 80% Ar + 20% CO_2 modified atmosphere (MA). Ethylene concentration and instrumental mechanical-acoustic characteristic were evaluated after 1, 4, 8, 11 and 15 d of refrigerated storage (4 °C). The rheological behavior of cell wall material was evaluated after 1 and 15 d. LeM and MoM samples showed a different ethylene evolution for fresh-cut apples packed in air. The mechanical-acoustic results showed that the maturity degree influenced the texture significantly, with LeM apples firmer and more rigid and producing also a higher number of acoustic events with more elevated maximum signal amplitude than MoM fruit. However maturity degree did not affect the evolution of texture throughout storage. Both dipping treatment and MA did not affect texture clearly. The rheological behavior of the cell wall material suggested an increase of elastic behavior with storage time. In order to obtain a fresh-cut product with homogeneous texture characteristics, these results suggest that it would be beneficial to process fruits of a homogeneous maturity class, which could be achieved by sorting using TRS.

1. Introduction

Consumers use textural properties as key indicators of food quality. One of the most studied textural property is crispness, a main attribute affecting consumer acceptability apart from taste, which is a desirable quality characteristic suggesting food freshness, the main evaluated and required property by the consumer at the time of purchase of fresh-cut products. Crispness has not only a hedonistic function, but it seems to have an important role for appetite psychology and satiety perception.

In the sixties for the first time Drake (1963) introduced the concept that auditory sensations are connected with texture perception. Texture is a quality attribute closely related to the structural properties of cellular tissue and the structure features have a large impact on the sounds produced when a food is bitten. Products, such as apple, which contain a lot of fluid inside cells, are defined "wet crisp products", while products with a cellular structure containing only air are termed "dry crisp products". Wet cellular products are composed of turgid cells with elastic cell walls. The turgidity is created by the liquid inside the cell pressing on the cell wall, which opposes this force with strength and

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elasticity (Vickers and Bourne, 1976). When the cells are broken, the contents expand rapidly when released, and a sound pressure wave is produced. This resulting sound is responsible for the perception of crispness. So a decrease in turgidity implies a decrease in crispness (Vickers and Bourne, 1976).

However, crispness is not always connected to the turgidity pressure and force applied by wall cell and the loss of crispness during the aging of an apple does not depend only on a significant humidity decline or on an evident histological modification. In fact, the aging process is combined with an increase of soluble pectin suggesting the progressive decay of substances which link together the cells. When a crisp apple is bitten, a sound is created by the break of middle lamella linking the cells together. When a not crisp and mealy apple is bitten, a weak sound derives from the breaking of the cells, being separated each other. This phenomenon is mainly due to the pectin solubilization (Reeve, 1970) and to the resulting loss of force which connects the cells.

Drake (1963) firstly studied the food sound analyzing width and time of acoustic signals produced during the chewing for a wide range of frequency. Vickers and Bourne (1976) were the first to postulate a psychoacoustical theory of crispness. The acoustic emission was described as an alternative analytical tool for the detection of apple crispness (Duizer, 2004). Sound measurement techniques, which are mainly destructive, consist in recording the sounds produced by instrumental compression probes or by the application of biting or chewing forces in the mouth.

Mealy and crisp "Cox's Orange Pippin" apples could be distinguished by principal component analysis (PCA), applied to Fourier-transformed chewing sounds (De Belie et al., 2000). Other promising results were obtained by De Belie and Harker (2002) regarding the use of chewing sounds to assess small differences in crispness between 'Royal Gala' apples. Piazza and Giovenzana (2015) confirmed that a more reliable analytical way to assess fruit crispness is the use of the combined instrumental acoustic-mechanical techniques studying seven apples cultivars with different textural characteristics; they found that apples can be efficiently distinguished for crispness by means of coupled acoustic and mechanical texture analysis. Merging distinctive parameters taken from the mechanical signals and simultaneously recorded acoustic traces allowed apples to be clustered based on their crispness attributes using PCA (Piazza and Giovenzana, 2015). It was observed that acoustic emission may depend on the maturity degree of fruit (Zdunek, 2013).

Among the different methods able to nondestructively assess the maturity degree of fruit, time-resolved reflectance spectroscopy (TRS) is recently gaining interest (Nicolai et al., 2014). Time-resolved reflectance spectroscopy (TRS) is a non-destructive method for optical characterization of fruit. In TRS a short pulse of monochromatic light is injected within a diffusive medium. Among its advantages compared with more traditional spectroscopic techniques, there is the feasibility to derive simultaneously two independent optical parameters, both being dependent on wavelength: the absorption of the light inside the irradiated body (μ_a, absorption coefficient), and the scattering of the photons across the tissue (μ'_s, transport scattering coefficient) (Torricelli et al., 2008). Light penetration achieved by TRS in most fruit and vegetables can be as great as 1–2 cm, depending on the optical properties (Cubeddu et al., 2001). Hence, TRS provides information on the internal properties of the medium and is not significantly affected by surface features (Saeys et al., 2008).

It has been proved that the absorption coefficient measured at wavelengths near the chlorophyll peak (between 630 and 690 nm) is an effective maturity index for different fruit species, and it was used to group fruit in a batch into TRS maturity classes, ranging from less mature class (LeM) with higher μ_a values, to more mature class (MoM) having lower μ_a values. In 'Jonagored' apples harvested at two dates and classified at harvest by μ_a at 630 nm (μ_a630), the absorption coefficient μ_a630 was significantly higher in first harvest apples, indicating less mature fruit. Apples with higher μ_a630 had lower fruit mass and lower per cent blush. Fruits classified as more mature by TRS had less titratable acidity at harvest and more soluble solids after storage; at sensory analyses these fruits were significantly sweeter, more aromatic and pleasant (Vanoli et al., 2005). Furthermore, high μ_a630 fruit (less mature) had at harvest a less advanced breakdown of insoluble protopectins to soluble pectins, compared to the low μ_a630 ones (more mature) (Vanoli et al., 2009). In a study on 'Braeburn' and 'Cripps Pink' apples classified according to μ_a670 measured after six months of storage, a different evolution of the pulp mechanical properties with shelf life as a function of harvest date and TRS maturity class was reported (Vanoli et al., 2013). Less mature 'Braeburn' apples showed the highest values of firmness, stiffness and energy-to-rupture and softened during the shelf life for all the harvests, whereas more mature 'Braeburn' apples, characterized by lower values of pulp mechanical properties, softened during shelf life only in fruit of early harvest. In contrast, the classification of 'Cripps Pink' apples was not so effective and firmness decreased with shelf life only in less mature apples from early harvest (Vanoli et al., 2013). Moreover Zanella et al. (2013) reported that the relationship between μ_a and firmness is cultivar-specific, as they found a good correlation for 'Braeburn' apple, even if not sufficient for a reliable nondestructive firmness estimation, and no correlation for 'Cripps Pink' cultivar.

Rizzolo et al. (2011) firstly applied TRS to apples that are to be processed. This methodology might be used as a management tool in selecting apple fruit in order to produce rings with constant sensory characteristics. The classification of apples at harvest based on μ_a670 was able to segregate fruit generating air-dried rings of different quality. The differences found in raw material, influenced by TRS maturity class, affected the changes occurring in apple rings with air-drying, mainly influencing weight loss, area shrinkage and how much ring color changed due to browning phenomena. For 'Golden Delicious' and 'Pink Lady®' cultivars, by processing the more mature fruits, i.e. either after long cold storage or by using apples having lower μ_a670 at harvest, air-dried rings with low shrinkage and low color changes (i.e. showing less browning) with lower ring hardness and crispness index were obtained (Rizzolo et al., 2012).

Recently Rizzolo et al. (2014) carried out an interesting approach combining the TRS technique with the coupled acoustic and mechanical texture analysis. The results indicated that using less mature apples based on μ_a670 measured at harvest by TRS, air-dried ring with higher porosity and higher average sound pressure level of peaks lower than 60 dB ($SPL_{av<60}$) could be produced, as well as osmo-air dried ring having a more connected solid structure, with lower tissue and pore degree of anisotropy, and defined less crispy by acoustic parameters (lower $SPL_{av>60}$ and lower average SPL of total sound peaks) than osmo-air-dried rings produced from more mature fruit.

The stress caused by technological steps involved in fresh-cut products processing, such as peeling and cutting, produces a physiological response with increased ethylene production and respiratory activity, with effects being observed very rapidly (Toivonen and Brummel, 2008). In climacteric fruit, wound-induced as well as exogenous ethylene may cause a hastening of ripening and softening (Toivonen and Brummel, 2008). The general effects of ethylene are usually detrimental to fruit quality (Saltveit, 1999); therefore, its concentration or activity should be minimized to lengthen product shelf life. As apple is a climacteric-type fruit, it results very sensitive to ethylene. It has been reported that low O_2 atmospheres and elevated CO_2 levels synergically act to reduce ethylene production and respiration rates (Soliva-Fortuny and