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A combined sensory-instrumental tool for apple quality evaluation

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ABSTRACT

A combined approach for perceptible quality profiling of apples based on sensory and instrumental techniques was developed. This work studied the correlation between sensory and instrumental data, and defined proper models for predicting sensory properties through instrumental measurements. Descriptive sensory analysis performed by a trained panel was carried out during two consecutive years, on a total of 27 apple cultivars assessed after two months postharvest storage. The 11 attributes included in the sensory vocabulary discriminated among the different apple cultivars by describing their sensory properties. Simultaneous instrumental profiling including colorimeter, texture analyser (measuring mechanical and acoustic parameters) and basic chemical measurements, provided a description of the cultivars consistent with the sensory profiles. Regression analyses showed effective predictive models for all sensory attributes ($Q^2 \geq 0.8$), except for green flesh colour and astringency, that were less effective ($Q^2 = 0.5$ for both). Interesting relationships were found between taste perception and flesh appearance, and the combination of chemical and colorimeter data led to the development of an effective prediction model for sweet taste. Thus, the innovative sensory-instrumental tool described here can be proposed for the reliable prediction of apple sensory properties.

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1. Introduction

Texture properties of fruit and vegetables are considered the most important drivers of consumer choice, followed by flavour characteristics (Daillant-Spinnler et al., 1996; Jaeger et al., 1998; Péneau et al., 2006, 2007; Harker et al., 2008). Food suppliers currently measure apple quality by considering basic pomological descriptors, such as fruit shape, size, colour, soluble solids content, titratable acidity, and by penetrometer-assessed fruit firmness, the most frequently used method for measuring fruit mechanical properties (Harker et al., 1997; Hoehn et al., 2003). Sensory analysis is not usually considered: it is expensive and limited to a small number of samples because it employs humans as sensory instruments. Moreover, it cannot be used for measuring quality properties in real time, an aspect particularly important for agricultural products, since their high variability require large sampling schemes. Moreover, the quality assessment of breeding material, normally represented by a single plant/individual, can be restricted by sample availability, which is often not sufficient for sensory panel evaluations. However, the best way to precisely describe the eating quality of food is still the sensory approach, which is able to define, measure, quantify, and explain what is really perceivable by human senses (Carbonell et al., 2008). Sensory analysis, in fact, provides a comprehensive description of a product (Murray et al., 2001). To overcome these limitations, and to allow quality characterisation on a large sample set, the prediction of sensory attributes by instrumental measures would represent a much needed innovation in quality control. The majority of recent studies address texture properties (De Belie et al., 2002; Harker et al., 2002a; Mehinagic et al., 2003; Chauvin et al., 2010). Harker et al. (2002a) through various instrumental measures to predict texture sensory attributes, show the possibility to predict sensory firmness, crispness, crunchiness, initial juiciness, and ease of breakdown through a puncture test. They also showed that a difference of 6–8 N in instrumental firmness is necessary before it can be perceived by a trained sensory panel (Harker et al., 2002a). Chauvin et al. (2010) found a strong correlation between texture sensory attributes and compression measurement by texture analyser. Mehinagic et al. (2003) compared the use of a penetrometer with non-destructive vis/NIR analyses, focusing on the correlations with sensory assessments, in

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order to propose a non-destructive measurement as a valid alternative. Brookfield et al. (2011) proposed the use of small panels (<4 subjects) as a cheaper alternative to measure apple texture, finding that a panel is efficient only if it concentrates on a very small number of attributes (such as crispness and juiciness). The same authors also highlighted that the instrumental-sensory relationship did not follow a unique trend, because each cultivar tends to respond differently to different tests (Brookfield et al., 2011). This observation suggests that a large set of apple cultivars, representing a wide range of variability for several sensory apple attributes, should be considered in such studies. Human assessment should always be considered as a reference to calibrate instrument readings, in order to develop tools falling within the range of textural parameters known to be accepted by consumers (Bourne, 2002; Harker et al., 2003).

While perceived texture can sometimes be predicted by instrumental data, flavour and taste attributes are, generally, more difficult. For instance, many studies, underline the difficulties in developing a reliable model to predict sweet taste, finding conflicting results between sweetness and texture properties (Harker et al., 2002b, 2006; Echeverría et al., 2008). Any sensory attribute could indeed have a potential influence on the perception of other properties not directly related to it. This is particularly true in the case of flavours, which derive from the integration of different senses (taste, smell and tactile stimuli; see Prescott, 2012; Small, 2012).

Recently, Costa et al. (2011) proposed the use of a texture analyser to dissect apple fruit texture into several components by simultaneously profiling mechanical and acoustic components. The method was tested on 86 different apple cultivars, and the data were compared with the sensory texture profiles provided by a restricted panel of experts, evaluating 21 apple cultivars for firmness, crispness, and juiciness attributes. Regression analyses highlighted that the instrumental force parameters from texture analyser measurements were necessary to predict both firmness and crispness sensory attributes, and that a high correlation between acoustic parameters and the sensory attribute of crispness does effectively exist (Costa et al., 2011).

In this study we propose a complete methodology for sensory profiling of apples. This was applied in parallel to instrumental measurements of specific physical and chemical properties, including texture analyser measurements (as proposed by Costa et al., 2011), dry matter concentration, extractable juice content, colorimeter measurements, and basic chemical composition.

This investigation was carried out for two consecutive years on a wide selection of apple cultivars, in order to study the sensory profiles of apples having the highest possible variability in their sensory properties. Our final objective was to propose an effective tool for the prediction of sensory properties through rapid instrumental characterisation.

2. Materials and methods

2.1. Plant materials

A set of 27 commercial apple cultivars (*Malus* × *domestica* Borkh.), commonly grown and commercialised in Italy, was analysed over two years (2010 and 2011), with 18 common cultivars shared between the two experimental years. Six cultivars in 2010 and two in 2011 were evaluated twice, since they were harvested from different orchards (Table 1). In 2011, two additional clones were analysed for two cultivars: Roho 3615 for the 'Pinova' cultivar and Red Spur Jeromine for 'Red Delicious'. All orchards were managed according to standard agronomical practices for thinning, pruning, disease and pest control. Fruit were picked at commercial harvest, determined by the standard descriptors used to monitor fruit maturity and ripening, such as flesh firmness, skin colour and starch degradation index. The instrumental parameters were monitored on fruit samplings starting from 10 days before the supposed optimum date (Asrey et al., 2008). References for each cultivar were provided by Consorzio delle Cooperative Ortofrutticole dell'Alto Adige (Werth, 1995). For each sample, a minimum of 20 apples of homogeneous size and without any visible external damage were selected and stored for two months in normal atmosphere at 2 °C and 95% relative humidity. Prior to the analyses, fruit were kept at room temperature for 24 h.

2.1.1. Sample preparation

Samples were prepared according to the protocol reported in Corollaro et al. (2013). Briefly, flesh cylinders (1.8 cm diameter; 1.2 cm height) were isolated from three apple slices cut around the equatorial plane perpendicular to the core. Each cylinder was immediately treated with an antioxidant solution (0.2% citric acid, 0.2% ascorbic acid, 0.5% calcium chloride). Cylinders coming from the same fruit were used for both sensory (8 cylinders put into clear plastic cups encoded with a random three-digit code) and instrumental analyses. Sensory evaluations were performed within 1 h of sample preparation, while instrumental analyses were carried out within 3 h, keeping the samples in sealed containers in refrigerated conditions until measurement. Apart from fruit weight, measured the day before the sensory analysis, all other sensory and instrumental measurements were performed after the antioxidant treatment in order to compare instrumental and sensory data.

2.1.2. Preliminary validation of sample preparation procedure

In order to study any possible influence of the antioxidant solution on sample sensory properties, a discriminant analysis was performed by a trained panel (15 males, 15 females; all FEM employees) according to the standard triangle test procedure (ISO, 2004). Three different apple cultivars known to be very different in terms of sweetness/acidity were chosen: 'Fuji' (high sweetness – low acidity), 'Cripps Pink' (medium sweetness – medium acidity), 'Granny Smith' (high acidity – low sweetness).

For each of the 3 cultivars, the triangle test compared samples treated with the antioxidant solution and samples treated with water to prevent the judges from perceiving visual differences related to surface moisture. The three paired samples were presented to the judges following a balanced design. In addition, the test was performed under red light to mask any possible browning defects in the samples not treated with the antioxidant solution. Test implementation, recording judges' responses and data analysis were performed with FIZZ software 2.46A (Biosystemes, France).

Titratable acidity and soluble solids content were measured in triplicate on the juice expressed by mechanical compression from flesh cylinders from treated and untreated apples (6 fruits per sample) following the procedures described in Section 2.3.4.

2.2. Sensory analysis

The trained sensory panel included 13 judges in 2010 (6 males; 7 females) and 14 in 2011 (4 males; 10 females), all FEM employees, with 7 judges in common for both years. Sensory profiling was performed based on the quantitative descriptive method reported by Stone and Sidel (2004). The sensory lexicon was instead developed using the consensus method described by Murray et al. (2001). In 2010, the sensory vocabulary was composed of attributes related to flesh colour, odour, texture, and flavour. Details about panel training, and about definition,evaluation procedure, and

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