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Predicting sensory attributes of different chicory hybrids using physico-chemical measurements and visible/near infrared spectroscopy

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ABSTRACT

Chicory (witloof) is a typically Belgian vegetable appreciated for its slightly bitter taste. Up until now no measurements exist to objectively quantify the sensory characteristics of chicory. Taste and texture of nine different chicory hybrids were analyzed by sensory and instrumental analysis (three-point bending test, high performance anion exchange with pulsed amperometric detection, high performance liquid chromatography and visible/near infrared spectroscopy). The main objective of the study was to correlate and predict the sensory attributes and consumer acceptance of chicory with destructive physico-chemical measurements and non-destructive Vis/NIR data, to avoid time- and money-consuming sensory profiling in the future. A univariate analysis showed that glucose and sucrose concentrations in chicory leaves were highly correlated with the attributes crunchiness and bitterness. The fructose concentrations however were correlated with the sweetness score of the panel. When performing partial least squares on all destructive instrumental parameters and Vis/NIR data for the major sensory attributes of chicory, satisfactory prediction models (ratio of standard deviation to root mean square error of cross-validation (RPD) > 2) could be established for all attributes but sweetness using all physico-chemical parameters. Using Vis/NIR data improved the prediction capacity of the sweetness model, and this technique proved to be useful in predicting the sensory quality of chicory.

1. Introduction

In Northwestern Europe several hybrids of chicory (*Cichorium intybus* L. var. foliosum) are cultivated for the production of chicons (witloof). The selection of hybrids is mainly based on disease resistance, crop yield and on the postharvest potential of the chicory heads. Up until now, taste has been of minor importance in hybrid selection (Peters et al., 1997). However, consumers are demanding fruit and vegetables that not only look nice but also taste well and have an appropriate texture (Nicolaï et al., 2005). These quality characteristics can be evaluated in fruit and vegetables by sensory analysis consisting of an acceptance test and a profile determination by a trained panel of experts. Yet instrumental measurements are preferred over sensory evaluations for many research and commercial applications because instruments reduce variations among individuals, are more precise, and can provide a common language among researchers, industry and consumers (Abbott, 1999). Since texture and flavour are the most important attributes for the consumer, numerous studies have been performed to find significant correlations between (i) the sensory properties of flavour and texture and (ii) objective instrumental measurements (Mehinagic et al., 2003). In chicory, properties scored by a sensory panel include crunchiness, sweetness and bitterness.

There are many methods in the literature to measure crunchiness, however none have been tested on chicory. Crunchiness is traditionally measured with a penetrometer (Nicolaï et al., 2005). The force required for penetration of the sample has often been correlated with sensory hardness, chewiness and crispness in apples (Abbott et al., 1984; Karlsen et al., 1999; Harker et al., 2002). Alvarez et al. (2000) used a three-point bending geometry to evaluate the crisp texture of carrots, celery and cucumber. The stiffness and fracture toughness of celery petioles were also measured using the technique of Raffo et al. (2006). A three-point bending test has already been used on chicory leaves (Verlinden et al., 2001) to calculate the elasticity modulus of the sample. However, to our knowledge, this technique has never been used to measure the crunchiness of chicory until now.

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To measure sugar content, the first choice for the analysis is high performance liquid chromatography (HPLC) (Hoberg and Ulrich, 2000). An improved chromatographic technique known as high performance anion exchange (HPAE) can also be used to separate carbohydrates in chicory. Coupled with pulsed amperometric detection (PAD), it allows the direct quantification of nonderivatized carbohydrates at the nanomolar level (Jahnel et al., 1998).

Chicory is appreciated as a vegetable for its fine, slightly bitter taste, caused by sesquiterpene lactones such as lactucin and lactucopicrin (Price et al., 1990; Peters et al., 1996). The level of various guaianine sesquiterpene lactones in chicory have been correlated with the bitterness perceived by a sensory panel (Peters and van Amerongen, 1998). Both HPLC and ELISA have been reported as appropriate techniques to quantify the concentration of sesquiterpene lactones, in chicory roots as well as chicory heads (Leclercq, 1984; Peters and van Amerongen, 1997; Hance et al., 2007). In the present work, lactucin, which is the most abundant sesquiterpene lactone in chicory, and lactucopicrin, which has the lowest taste threshold, were measured using HPLC.

As all of the methods described above are destructive, attempts are currently being made to develop new, reliable and non-destructive analytical techniques. One of the non-destructive techniques available for a range of fruit and vegetables is visible/near-infrared spectroscopy (Vis/NIRS). Vis/NIRS has gained wide acceptance in different fields of agriculture because of its advantages over other analytical techniques, the most salient of which is its ability to record spectra fast and without any sample preparation (Blanco and Villarroya, 2002). Vis/NIRS has been used in previous research to measure and predict the firmness, sugar content or acidity of apples and tomatoes (Lammertyn et al., 1998; Van Dijk et al., 2006). Mehinagic et al. (2003) tried to establish a relationship between sensory texture data and Vis/NIRS of apple cultivars. They found very good correlations between penetrometry and sensory texture, but somewhat poorer correlations between Vis/NIRS and sensory data. To our knowledge, no Vis/NIRS studies have been carried out before on chicory.

The aim of the present study was to correlate the major sensory attributes of chicory (crunchiness, bitterness and sweetness) and consumer acceptance with destructive measurements and non-destructive Vis/NIR measurements. The experiment was performed on chicory heads of nine hybrids, three of which were grown traditionally in soil while the remaining six were cultivated using hydroponics.

2. Materials and methods

2.1. Sample collection

Chicory belongs to the largest dicotyledonous family in the plant kingdom, the Asteraceae (Compositae), and is categorized in the subfamily Cichorioideae, the tribe Lactuceae and the genus *Cichorium*. The chicory heads used were harvested half November 2006. The roots of six hybrids, Focus (Nunhems), Goldwin (Vilmorin), Hermès (Hoquet), Novus (Nunhems), Yellowstar (Vilmorin) and Zilia (Vilmorin) were forced for 21 d in darkness using hydroponics in the Provinciaal Onderzoeks- en Voorlichtingscentrum voor Land- en Tuinbouw, in Rumbeke-Beitem, Belgium. Three cultivars grown traditionally in soil were purchased at a Belgian vegetable auction. The latter cultivars do not have a commercial name, and will be referred to as cultivars 1, 2 and 3. All chicory heads (5 kg per hybrid) were stored for one week in blue plastic bags in darkness at a mean temperature of 4 °C before being acclimatized to room temperature 1 h before analysis.

2.2. Sensory evaluation

The sensory evaluation of the nine chicory hybrids was done at the Provinciaal Proefcentrum voor Groenteteelt Oost-Vlaanderen, in Kruishoutem, Belgium (21–23 November 2006), which is equipped with a sensory test room constructed according to the ISO 8589 norm (ISO, 1988). Samples were cut into small pieces (0.5 cm × 0.5 cm) after removal of the two outer leaves, 2 cm at the top and some of the core and tasted raw.

Ten trained panelists scored the attributes 'sweetness', 'bitterness' and 'crunchiness' using unstructured line scales with the anchor points 'not perceptible' (=0) and 'strongly perceptible' (=10) under green lighting to mask differences in colour or other appearance characteristics. Per hybrid, six chicory heads were tasted by the trained panel—half of each head was stored for instrumental analysis.

For the consumer acceptance test, 60 consumers were asked to assess the chicory samples for liking using unstructured scales from 'like not at all' (=0) to 'like very much' (=10). Each panelist used mineral water and a piece of non-salted, white bread to cleanse the palate between samples. The samples were presented in under green light. Half of the ten heads per hybrid used for the acceptance test were kept for instrumental analyses.

2.3. Destructive measurements

2.3.1. Crunchiness

To assess crunchiness a three-point bending geometry was set up on a TA-XT.plus Texture Analyzer, fitted with a 50 N load cell (Stable Micro-Systems, Surrey, UK). Per hybrid, six half chicory heads were analyzed. Since preliminary results showed that measurements differ from the outer to the inner leaves in one chicory head, one head was represented by the average value of three leaves (namely leaves number 1, 5 and 9, 1 being the outer leaf). A piece of 2.2 cm × 2.2 cm was cut out of the basal part of the leaf and placed onto the supports (distance between supports was 18 mm) and loaded at the center until the fracture occurred. A square plunger was employed with a displacement rate of 0.5 mm s^{-1}. A diagram of the settings can be seen in Fig. 1. The force at the fracture

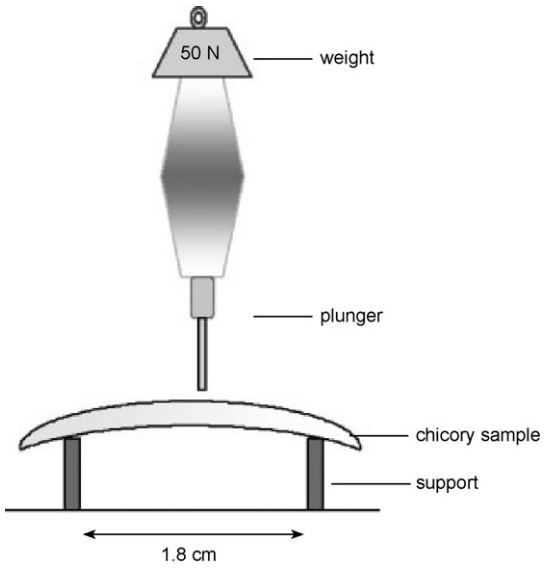

Fig. 1. Diagram of the TA.XT Plus Texture Analyzer, fitted with a 50 N load cell. A square plunger was employed to break the chicory sample with a displacement rate of 0.5 mm s^{-1}.