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Effects of harvest time and variety on sensory quality and chemical composition of Jerusalem artichoke (*Helianthus tuberosus*) tubers

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ABSTRACT

Sensory evaluation and analysis of volatile compounds, sugars and inulin were used to assess the eating quality of three varieties of Jerusalem artichoke (*Helianthus tuberosus* L.) tubers harvested at three different times. Forty-one volatile compounds were isolated by dynamic headspace sampling and analysed by GC–MS. The total concentration of sampled volatiles was low with an average of 25.4 ng/g fresh weight and consisted mainly of terpenes. The sensory quality was determined by quantitative descriptive analysis of 19 sensory attributes. Significant differences were found between harvest times and varieties for sensory scores and concentrations of aroma volatiles. The sensory and aroma results separated the red-skinned variety Rema from the white-skinned Mari and Draga. Rema had a higher content of terpenes and was more associated with the unpleasant attributes iron flavour, fungus/earthy aroma and dried nut flavour compared to Mari and Draga.

1. Introduction

The Jerusalem artichoke (*Helianthus tuberosus* L.) tuber is a vegetable with a low caloric value and a high content of inulin, vitamins and minerals (Saxholt et al., 2008; Somda, McLaurin, & Kays, 1999). It has a sweet and nutty flavour and a crisp texture when eaten raw, which makes it an interesting culinary ingredient. However, the applicability of Jerusalem artichoke tubers as raw material in the human diet has only been rarely investigated.

Jerusalem artichokes store carbohydrates in the form of inulin instead of starch. Inulin is a fructooligosaccharide, which has a range of healthy characteristics. Inulin can be regarded as a dietary fibre, as it is not degraded by enzymes in the digestive system. Inulin and its degradation products are known prebiotics, which are compounds capable of stimulating and/or activating health-promoting bacterial growth in the colon (Gibson & Roberfroid, 1995). Inulin in Jerusalem artichoke has been shown to have a prebiotic effect in humans (Kleessen et al., 2007; Ramnani et al., 2010). Besides this, inulin also affects the blood sugar level to a lesser extent than other carbohydrates, and it is therefore suited as a constituent in a diabetic diet (Rumessen, Bodé, Hamberg, & Gudmand-Høyer, 1990). Fructooligosaccharides can be used as a functional food ingredient, and inulin can be added as a low-caloric sweetener, as a bulking agent and to increase smoothness and creaminess of low-fat products (Kaur & Gupta, 2002). Commercially, fructooligosaccharides are extracted from chicory (*Cichorium intybus* L.) or synthesised from sucrose.

The application of Jerusalem artichoke for biofuel production and as an inulin source has been examined, but little is known about its eating quality. Hence, an investigation of its sensory and chemical properties can give an understanding of which characteristics influence the eating quality of the Jerusalem artichoke tuber. Recently the sensory and functional quality of dried chips prepared from Jerusalem artichoke tubers were investigated (Takeuchi & Nagashima, 2011), but to our knowledge no sensory evaluation of raw Jerusalem artichoke tubers has been performed. The volatile compounds in Jerusalem artichoke tubers have been investigated previously (Macleod, Pieris, & de Troconis, 1982).

The aim of the present work was to determine the eating quality of Jerusalem artichoke tubers. Increased knowledge on Jerusalem artichoke as a raw material can be used to promote the consumption of this vegetable in the human diet, and provide consumers with a larger selection of vegetables for human consumption. The effects of harvest time and variety on the aroma profile, inulin and sugar content and sensory quality were investigated.

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2. Materials and methods

2.1. Plant material

Three varieties of Jerusalem artichoke were grown at the Department of Food Science, Aarhus University, Aarslev, Denmark (55°18′N, 10°27′E) in 2009/2010. The Jerusalem artichokes were transplanted in sandy loam soil in April 2009. The field experimental design was a complete block design in three replicates. Denmark is maintaining a gene collection of Jerusalem artichokes clones placed at the Aarslev site, and the investigated Jerusalem artichoke tubers were selected from this collection, in order to span a large variation in sensory quality. The white-skinned Mari and Draga and the red-skinned Rema were chosen. Mari and Rema are of Danish origin (G.K. Bjørn, personal communication) whereas the origin of Draga is unknown (Kays & Nottingham, 2008). Of the three varieties, the early variety Mari is the only one reaching flowering during the Danish growing season. Rema is designated as a middle-late variety and Draga as a late variety. The tubers were harvested at three different times: 30, 38 and 46 weeks after planting corresponding to temperature sums of 2716, 2898 and 2916 of average daily temperature above 0 °C, respectively. The tubers were graded into weight sizes of <10, 10–29, 30–45 and >45 g. Tubers of size 30–45 g and free of defects were used for chemical and sensory analysis. After harvest, the tubers were washed and kept at 4 °C and ⩾98% relative humidity until analysis (maximum one week). The field replicates were used as true repetitions during the analysis.

Before analysis, the Jerusalem artichoke tubers were manually peeled and shredded into 4 × 4 mm sticks using a food processor (Robot Coupe CL50, Vincennes, France) and thoroughly mixed. Samples were taken for immediate analysis of volatile compounds, sensory quality and dry matter content. A representative sample of each variety was pre-frozen using liquid nitrogen and freeze-dried (Gamma 1–20, Martin Christ, Osterode, Germany). The freeze-dried samples were subsequently milled and kept at −24 °C, until sugar and inulin analyses were performed in April 2010.

2.2. Collection and analysis of volatile compounds

The sampling of volatile compounds was done using a modified method of Kjeldsen, Christensen, and Edelenbos (2001). Headspace volatiles were collected from 100 g of shredded Jerusalem artichoke tubers. The plant material was placed in a 250-mL conical flask, equipped with a glass cap insert, which allowed gas to be purged through the sample. The sample was placed on a bed of glass globes (diameter 1.5 cm) to increase gas circulation during headspace sampling. The flasks were connected to an inlet of dry nitrogen gas with a flow rate of 100 mL/min, and the volatile compounds were collected on stainless steel sorbent tubes packed with Tenax TA, (0.200 g of resin, mesh size 60/80, C-TBP1T, Markes international Limited, Llantrisant, United Kingdom) for 120 min at 25 °C in a thermostatic incubator (Termaks 6000 Incubator, Lytzen Lab., Herlev, Denmark).

Sampled volatiles were desorbed using a thermal desorption system (Ultra-UNITY™, Markes International Limited) and analysed using a gas chromatograph (Finnigan TraceGC Ultra, Thermo, Waltham, MA) equipped with a split/splitless injector and coupled to a single quadropole mass spectrometric detector (Finnigan Trace DSQ, Thermo). Sorbent tubes were desorbed for 15 min at 250 °C, and the stripped volatiles were transferred via a 140 °C-transfer line to a cold trap (U-TIIGCP, Markes International Limited) with a trapping temperature of −10 °C. The cold trap desorption temperature was 300 °C with a subsequent on-column injection of the volatiles. The separation was performed using a 50 m × 250 μm CP-WAX52 CB, 0.25 μm film thickness, capillary column (Agilent, Santa Clara, CA) with the following oven temperature programme: starting temperature of 32 °C was maintained for 1 min, hereafter the temperature was increased to 45 °C at a ramp of 1 °C/min, and further increased to 125 °C at a ramp of 2 °C/min followed by a final increase to 220 °C at 18 °C/min with an isothermal stage of 20 min. A split of 1:4 was used and helium applied as a carrier gas at a flow rate of 1 mL/min. The mass spectrometer was operated with an ionisation energy of 70 eV in positive-ion mode, and a mass scan range of 30–650 amu was applied. Volatile compounds suggested by the NIST mass spectral data base (NIST, 2002) were verified by comparison of the unknown compounds with retention times and mass spectra of commercial standard compounds analysed under identical experimental conditions. The reference compound sabinene was supplied by Carl Roth & Co. (Karlsruhe, Germany), benzoic acid was supplied from Merck Chemicals (Darmstadt, Germany) and β-bisabolene was synthesised using the method of Crawford, Erman, and Broaddus (1972). All other authentic reference compounds were supplied by Sigma–Aldrich (St. Louis, MO, USA). Linear retention indices of the isolated compounds were calculated from a series of *n*-alkanes (C10–C23) run under the same conditions as described above. The isolated volatile compounds were divided into groups according to their chemical structure, and the compounds in a specific group were quantified using one of the following external standard curves: sabinene, 1-hexanol, dodocane and α-cedrene. The standards were injected onto Tenax TA traps, and desorbed and analysed using the method above.

2.3. Sensory evaluation

Quantitative descriptive analysis was performed by a panel consisting of eight (first harvest), six (second harvest) and eight (third harvest) assessors. The assessors had previously been tested for their sensory ability (basic taste, odour detection and colour vision) as well as their ability to communicate sensory descriptions of products as recommended in ISO 8586-1 (1993). The profiling was performed in a sensory evaluation laboratory according to international standards (ASTM STP 913, 1986). Prior to evaluation, the panel discussed the sensory properties of eight coded varieties of Jerusalem artichoke tubers and agreed on 19 sensory attributes and their definitions: Jerusalem artichoke aroma, raw potato aroma, raw apple aroma, green nut aroma, fungus/earthy aroma, sweet aroma, faded aroma, Jerusalem artichoke flavour, green nut flavour, roasted nut flavour, pea pod/green flavour, pea flavour, raw carrot flavour, raw potato flavour, raw apple flavour, fungus/earthy flavour, iron flavour, sweetness and sourness. The assessors were trained in the profile in order to obtain unified use of the attributes. The samples were coded with three-digit numbers and served in random order to each assessor in portions of 25 g at room temperature. During evaluation, the sensory lab was lit with red light in order to mask any colour differences between samples. References were made available for some of the attributes: raw potato, thawed frozen pea, raw carrot, raw mushroom, dry nut and raw apple. The samples were evaluated at individual speed on an unstructured 15-cm line scale ranging from low (value 0) to high intensity (value 15). All data were registered on a direct computerised registration system (FIZZ, Ver. 2.30C, Biosystèmes, Couternon, France).

2.4. Sugar and inulin analysis

Free sugars were extracted from 0.5 g freeze-dried Jerusalem artichoke tuber with 25 mL of acetate buffer (0.1 M, pH 5.0) in a water bath at 65 °C for 60 min. The samples were mixed on a vortex mixer before and several times during extraction. The samples