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Storage of fresh-cut swede and turnip: Effect of temperature, including sub-zero temperature, and packaging material on sensory attributes, sugars and glucosinolates

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ABSTRACT

Freezing point of fresh-cut swede (*Brassica napus* L. var. *napobrassica* Rchb.) and turnip (*Brassica rapa* L. ssp. *rapifera* Metzg.) dice was measured by the cooling curve method, and mean equilibrium freezing points were found to be −2.67 and −1.97 °C, respectively. This indicates that storage of fresh-cut swede and turnip at temperatures below 0 °C is possible. Fresh-cut swede and turnip were packed in pouches made of biaxially oriented polypropylene film, and a film based on polylactic acid, and stored for 10 d at −2, 0, 5 and 10 °C. One sample of each vegetable was stored at −2 °C for 5 d, followed by 5 d of storage at 5 °C. Differences in sensory quality between storage at −2 °C and 0 °C were found in appearance attributes only. Both swede and turnip had higher evenness of colour at −2 °C than at 0 °C. Storage at −2 °C vs. 0 °C gave lower whiteness for swede but higher for turnip, and lower intensity of hue for turnip only. Increased storage temperature from 0 °C to 5 or 10 °C did not change appearance in swede, but in turnip hue and colour intensity increased, and colour evenness and whiteness decreased. Differences in odour, taste and flavour during storage at 5 or 10 °C vs. 0 °C were prominent for turnip: decreased sour odour and flavour, green odour and flavour, sulphurous odour and sweet taste, and increased muddy odour and cloying odour and flavour for 5 °C or 10 °C. For swede, higher storage temperature gave only increased intensity of sulphurous odour and pungent odour. Texture changed for turnip only with decreased juiciness with increased temperature. The lowest temperature (−2 °C) gave the highest sucrose content in both swede and turnip, the highest total sugar content in turnip and the lowest glucose content in swede. Higher storage temperature resulted in higher content of total indolic glucosinolates in both fresh-cut swede and turnip, but a lower content of total aliphatic glucosinolates in turnip only. Increased contents with increased storage temperature were found for glucobrassicin and 4-methoxyglucobrassicin in both vegetables, and decreased contents for glucobrassicanapin and gluconapin in turnip and glucoalyssin in swede. Storage in polylactic acid film resulted in higher weight loss than the biaxially oriented polypropylene film in both vegetables.

1. Introduction

Fresh-cut vegetables are perishable food products with physiological changes during storage faster than in the whole raw materials. This might lead to undesirable quality changes such as discolouration, flavour, odour and texture alterations, and loss of nutritional value (Barrett et al., 2010). Glucosinolates in *Brassica* vegetables have gained interest due to their possible health-beneficial effects (Jahangir et al., 2009), and since they together with sugar could influence flavour (Beaulieu and Baldwin, 2002).

Temperature is an important factor known to influence quality of fresh-cut vegetables. It is well known that the temperature varies considerably in the distribution chain of different food companies. This will have an impact on product quality, shelf-life and food waste (Nunes et al., 2009).

Storage temperature just below 0 °C, close to the freezing point of perishable foods, has gained more research attention, especially for fish (Kaale et al., 2011). However, research on keeping fresh-cut

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vegetables at sub-zero temperatures is scarce. Freezing point can be defined as equilibrium freezing point (James et al., 2009), and is the temperature where the slowest cooling rate on a freezing curve occur (Rahman and Driscoll, 1994). Freezing point for garlic cloves have been investigated, and garlic may be stored at −2.7 °C without freezing (James et al., 2009). Recommended storage temperature for root vegetables, like swede and turnip, are just above 0 °C (Stoll and Weichman, 1987). However, information on the effect of storage at 0 °C or just below on the quality of these commodities after peeling and cutting has not been found.

The packages used for vegetables are often made of petroleum-based materials (Mangaraj et al., 2009). As an alternative, materials with polylactic acid (PLA) from renewable sources have gained interest. PLA-based biodegradable films are commercially available, and have been found suitable for packing peppers (Koide and Shi, 2007) and fresh-cut celery (González-Buesa et al., 2014). Although several properties of PLA based packaging material has been found similar to petroleum-based materials (Almenar et al., 2008), the hygroscopic nature of PLA-based packaging material has been found to influence the product quality (González-Buesa et al., 2014; Koide and Shi, 2007). The moisture absorbing property of PLA could also influence ice crystallisation in the plant tissue, since surface moisture might influence ice nucleation (Pearce, 2001).

The aim of this study was to determine the freezing point of fresh-cut swede and turnip, and to study the effect of different storage temperatures, including sub-zero (°C) temperature, and packaging material on sensory attributes, sugar and glucosinolate contents of fresh-cut swede and turnip.

2. Materials and methods

2.1. Plant material

Swede (*Brassica napus* L. var. *napobrassica* (L.) Rchb. cv. Vigod) and turnip (*Brassica rapa* L. ssp. *rapifera* Metzg. cv. Solanepe) were provided in 2013 from local growers in the Oslofjord-area and south-western part of Norway, respectively. Rutabaga was brought directly to the storage room after harvest. Turnip was transported to Ås in a refrigerated truck holding 4 °C. Both vegetables (approximately 100 kg) were harvested in October and stored in perforated plastic bags at 0–1 °C and used for the experiments after 1–2 months.

After washing in cold tap water including brushing, swedes and turnips were peeled by hand using a sharp stainless steel knife, or a potato peeler (Victorinox, Ibach-Schwyz, Switzerland), respectively. For each vegetable, 10 kg of peeled commodity were prepared. The roots were rinsed, and cut in 10 mm cubes using a cutting machine (KUJ V, Kronen GmbH, Kehl am Rhein, Germany). The cubes were shortly rinsed in cold tap water, followed by immersion in tap water mixed with crushed ice for 1 min, to cool the vegetables before packaging. The vegetables were spin-dried for 30 s using a vegetable centrifuge at 16.7 s^{-1} (Eillert, Machinefabriek Eillert B. V., Ulft, The Netherlands).

2.2. Determining freezing point

Freezing point measurements of diced swedes and turnips were based on the method described by James et al. (2009), with some modifications. A double semi-flexible 1.5 mm diameter probe with a PT 1000 sensor (Ellab AS, Hillerød, Denmark) was used to measure temperature in the centre of vegetable dice. Temperatures were recorded every 10th second using a wireless Track Sense Pro Logger system (Ellab AS). Four sensors connected to two loggers were used, allowing for the temperature to be followed in four vegetable dice in each session. For each vegetable a total of three sessions were carried out. Vegetable dice with sensor and logger were placed in an expanded polystyrene box (230 × 250 × 250 mm) with 20 mm thick walls and lid. The polystyrene box was then placed inside a freezer room (−20 °C). The time and temperature data from the loggers was used to determine equilibrium freezing point and ice crystallisation temperature, as described by Rahman and Driscoll (1994).

2.3. Packaging material, packaging and storage

Pouches (150 × 135 mm) were made from a 40 μm biaxially oriented polypropylene film (BOPP) (Scan Fresh®, Scanstore, Middelfart, Denmark), and a 40 μm film based on polylactic acid (PLA)(Bio-Flex® F 11,390, Fkur Kunststoff GmbH, Willich, Germany), as described by Pettersen et al. (2011), using a manually operated impulse sealer (Magneta 421, Audion Elektro BV, JL Weesp, Holland). Packages were perforated with 20 holes, using a 0.22 mm acupuncture needle to avoid modification of the atmosphere within the pouches. Vegetable dice (200 g) were weighed into the packages, followed by sealing. The packages were stored for 10 d at −2, 0, 5 and 10 °C. In addition, one set of samples was kept at −2 °C for 5 d, followed by 5 d storage at 5 °C in order to simulate a possible distribution temperature of −2 °C and a retail temperature of 5 °C. For every material and temperature combination, 4 packages were prepared.

2.4. Samples for sensory and chemical analysis

On the day of sensory analysis, 70 g material (dice) was sampled from each package for chemical analysis, and the remaining was used for sensory analysis. A control sample was prepared in the same way as the stored samples, taken from the same raw material batch. Material for chemical analysis was frozen in liquid nitrogen and stored at −80 °C, and then ground frozen using a Krups 708A food processor. For sugar and glucosinolate analyses, the ground frozen material was freeze-dried, further ground with a Retsch ZM100 mill (Retsch GmbH & Co., Haan, Germany), and stored in tight containers at −40 °C. For dry matter determination, frozen material was freeze-dried.

2.5. Sensory analysis

Quantitative descriptive sensory analysis was performed according to ISO 13,299:2003(E) by a trained sensory panel of 10 persons at Nofima (Ås, Norway). The assessors were selected and trained according to ISO 8586-1:2012(E), and the analysis were performed according to ISO 8589:2007(E). The sensory panel was calibrated, using the control sample and the sample stored at 10 °C in PLA material. The assessors agreed on sensory attributes to describe raw swede and turnip during a training session (Table 1). Room temperate vegetables (25 g) from each treatment and control sample were served in plastic trays, coded with a three-digit code, with lids. Each sample was served twice.

The panellists recorded their results at individual speed on a 15 cm non-structured continuous scale. The data registration system, EyeQuestion, v. 3.8.6 (Logic 8, The Netherlands) transformed the responses from 0 to 15 cm on the screen to numbers from 1.0 (low intensity) to 9.0 (high intensity). Due to the number of samples, the sensory evaluation had to be performed during two subsequent days. Which samples to be analysed on which day were randomly chosen before the experiment was started.

2.6. Sugar analysis

Sugars were analysed using a method described by Elmore et al. (2007) with modifications. Freeze-dried samples (50 mg) were weighed into 15 mL tubes. An internal standard (500 μL, 10 mg