CONTENT OF SUGARS, DIETARY FIBRE AND VITAMIN C IN HYBRIDS OF 'NANTE' CARROTS CULTIVATED IN LATVIA

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Abstract
Carrots *(Daucus carota* L.*)* are a globally important vegetable crop providing a source of important nutritional compounds through their carotenoid content whilst adding flavour and texture to many diets across the world. The current research focuses on the evaluation of sugars, vitamin C and dietary fibre content in 'Nante' hybrid carrots. The research was accomplished on fresh in Latvia cultivated carrots harvested in Zemgale region in the first part of October 2011 and immediately used for experiments. Late-bearing hybrids of 'Nante' carrots were used for analysis: Nante/Berlikum, Nante/Maestro, Nante/Forto, Nante/Bolero, and Nante/Champion. The major sugars (fructose, glucose and sucrose) were determined by applying the method of high performance liquid chromatography, vitamin C - by titration with 0.05 M iodine solution, and dietary fibre - using standard method No 985.29. In the present experiments it was found that there are significant differences in the sugar, vitamin C and dietary fibre content between different carrot hybrids. The highest content of total sugars was found in Nante/Maestro and Nante/Champion 7.99 g 100 g^{-1} and 7.57 g 100 g^{-1} hybrids in fresh weight, respectively. The lowest total sugars content was in Nante/Berlikum hybrid − 4.03 g 100 g^{-1}. Vitamin C content in carrot hybrid Nante/Maestro was the highest 17.61±0.17 mg 100 g^{-1}, but in hybrid Nante/Champion - the lowest 8.39±0.17 mg 100 g^{-1} of fresh weight. The dietary fibre content in analysed carrot samples ranged from 34.25±0.47 g 100 g^{-1} in Nante/Maestro to 25.78±1.54 g 100 g^{-1} in Nante/Champion hybrids.
Key words: carrots, sugars, dietary fibre, ascorbic acid.

Introduction

Carrots *(Daucus carota* L.*)* are a globally important vegetable crop providing a source of important nutritional compounds (including pro-vitamin A) through their carotenoid content whilst adding flavour and texture to many diets across the world (Baranski et al., 2011). Around 28 million tonnes of carrots are produced globally each year, giving the crop a financial and horticultural significance (Baranski et al., 2011). Vegetables are an important part of our diet. They provide not only the major dietary fibre component of our food, but also a range of micronutrients, including minerals, vitamins and antioxidant compounds (Singh et al., 2012). Vegetables, an important component of a balanced human diet, are low in fat, low in energy, with high carbohydrate and fibre contents, providing significant levels of some micronutrients. Fresh vegetables have a short durability and are exposed to conditions that destroy their superior quality in a short period of time, before cooking and consumption (Giannakourou and Taoukis, 2003). Carrot is a vegetable extensively consumed both raw and cooked because of its pleasant flavour and nutritive properties, derived from its high content of pro-vitamin A (especially β-carotene), vitamins, minerals and fibre (Soria et al., 2009). Carrot is mainly constituted by water (approximately 90 g 100 g^{-1} of fresh weight) and carbohydrates, which account for 5 g 100 g^{-1} of carrot edible portion (Soria et al., 2009). The major consumer requirements for carrot consumption are taste and nutritional quality. Therefore, carrot quality should be assessed in terms of sensory attributes such as sugar content, an important component of taste, and the contents of secondary plant compounds (Zude et al., 2007).

The quality of carrots is mainly dependent on the sweetness determined by the level of soluble sugars such as glucose, fructose and sucrose. Sweetness is the major determinant of quality and marketability of fruits and vegetables. Sweetness of fruits and vegetables depends mainly on type and composition of sugars present, which is primarily genotype dependent. In addition, sugar content varies with plant nutrition, climate, soil and storage conditions (Nookaraju et al., 2010). Carrots can vary in quality dependent on the amount of volatile flavour compounds and non-volatile bitter testate and sugars, as these compounds influence the sensory perception of the volatile compounds, and thus the total impression of the sensory quality (Kreutzmann et al., 2007). Sweet flavour, not surprisingly, is associated with higher sugar content which is polygenic, although a single major gene, Rs, determines whether reducing sugars glucose and fructose, or sucrose, are the primary storage carbohydrates (Nuez and Prohens, 2007). The organoleptical (taste) qualities of carrot are controlled by a balance between a range of compounds including both reducing and non-reducing sugars (Baranski et al., 2011).

Ascorbic acid (vitamin C) is used extensively in the food industry, not only for its nutritional value but for its many functional contributions to product quality. Acting as an antioxidant, ascorbic acid can improve the colour and palatability of many kinds of food products. By removing oxygen from its surroundings, ascorbic acid in its reduced form becomes the oxidized form, dehydroascorbic acid (Figure 1). This oxidizing action reduces the available oxygen in its immediate environment, making ascorbic acid an effective antioxidant.

All varieties of carrots contain valuable amounts of antioxidant nutrients. Included here are traditional antioxidants like vitamin C. Carrot is not regarded as an important source of vitamin C due to its lower levels compared to other vegetable crops, such as peas and spinach (Singh et al., 2012).

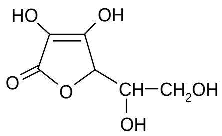

Figure 1. The structure of vitamin C (Bhat et al., 2007).

Nowadays, there is a considerable interest in studying the feasibility of using by-products from food processing plants as raw materials for production of DF (dietary fibre) powder since these wastes are inexpensive and highly abundant (Peerajit and Devahastin, 2012). Dietary fiber (DF) is a group of food components that are resistant to hydrolysis by human digestive enzymes. Dietary fiber consists of polysaccharides, oligosaccharides and lignin. The health benefits of dietary fiber have led to increased consumption of fiber-rich products. Fruits and vegetables are good sources of dietary fiber. By-products from the fruit and vegetable industry, in particular, are of interest since they are inexpensive and available in large quantity (Chantaro et al., 2008). Dietary fiber is part of a plant matrix which is largely intact. Non-digestible plant carbohydrates in foods are usually a mixture of polysaccharides that are integral components of the plant cell wall or intercellular structure (Slavin, 2008). Dietary fiber includes plant non-starch polysaccharides (e.g., cellulose, pectin, gums, hemicellulose, glucans, and fiber contained in oat and wheat bran), plant carbohydrates that are not recovered by alcohol precipitation (e.g., inulin, oligosaccharides, and fructans), lignin, and some resistant starch (Slavin, 2008). A diet naturally high in fibre helps prevent constipation and reduce the risk of colon cancer, improves gastrointestinal health and effect of satiety, as well as impacts weight loss by reducing food intake at meals (Eim et al., 2008; Brownlee, 2011; Chau et al., 2004; Leeds, 1982). Physiological effects of dietary fibre are greatly dependent on the physicochemical properties of the ingested material, e.g. the water-binding capacity, the molecular weight distribution, and the viscosity (Nyman and Svanberg, 2002).

It is important to enhance the nutritional status of carrot where possible. The aim of the current research was to investigate the content of sugars, dietary fibre and vitamin C in fresh carrots.

Materials and Methods

Experiments were carried out at the Department of Food Technology of the Latvia University of Agriculture. The research was accomplished on carrots *(Daucus carota* L.*)* grown in Latvia and harvested in Zemgale region from four farms in the first part of October 2011 and immediately used for experiments. Serotinous ‘Nante’ carrot hybrids Nante/Berlikum, Nante/Maestro, Nante/Forto, Nante/Bolero, and Nante/Champion were analysed.

The content of glucose, fructose and sucrose of carrots grown in Latvia was determined by applying the method of high performance liquid chromatography (HPLC). The method is based on the fact that the chromatographic separation of glucose, fructose and sucrose is based on their delayed time differences (Kūka, 2008). To 5 g of the sample, 20 mL of water were added into a 50 mL volumetric flask, heated for 20 min at 60 °C in a water bath and cooled to ambient temperature (20±2 °C). Then, 1 mL of Carrez I and 1 mL of Carrez II solutions were added and shaken. A volumetric flask was filled up with water till the mark and shaken well. First, the solution was filtered through the paper filter. The obtained extract was filtered through a membrane filter with pore size of 0.2 μm. Second, the extract was placed in a vial and tested by HPLC Prominence (Shimadzu, Japan) equipped with SypelcosilTM LC-NH_2 column (250 × 4.6 mm, particle size – 5 μm) and autosampler SIL-20A. Sugars were detected with a refractive index detector RID-10A (Shimadzu); acquired data were processed using Shimadzu LabSolutions software (LCsolution Version 1.21 SP1). Acetonitrile: water (80:20 v/v) was used as eluent while column temperature was held at 30 °C. The flow rate was 1.0 mL min^{-1}. Injection volume of samples was 10 μL. Calibration curve was acquired after two repeated HPLC runs of seven standard solutions of reference compounds. The chromatography data processing system fixed the composition of glucose, fructose, and sucrose in carrots by comparing the carrot chromatography with the chromatography of sugar standard-solution (Figure 2). Composition of carbohydrates in the analyzed samples was calculated in the form of g kg^{-1}. The following formula was used in calculations (1):

$$W = \frac{C \times V}{m} , \quad (1)$$

where
C – concentration, g L^{-1};
V – capacity of the extraction solution (total), L;
m – weighed mass, g.

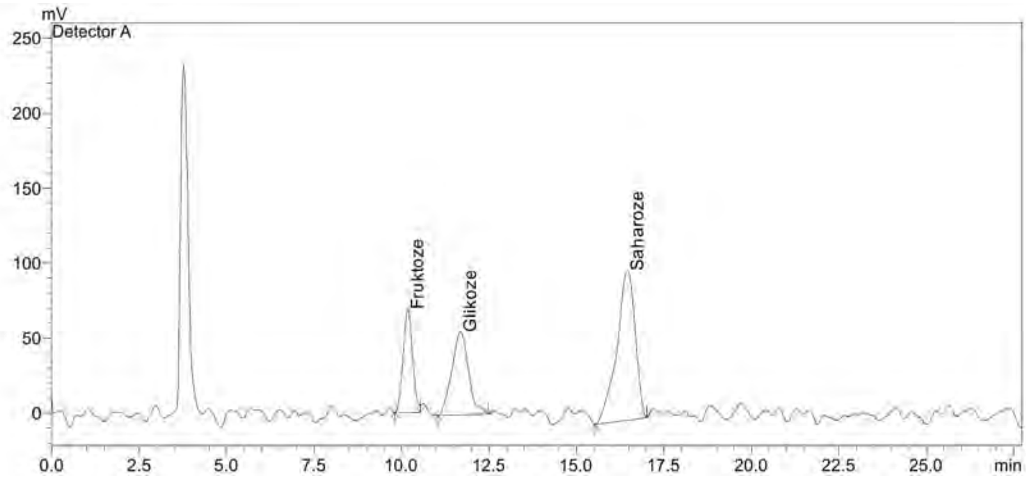

Figure 2. Sample-curve of carbohydrates for carrying out chromatography analysis.

The content of ascorbic acid was determined by titration with 0.05*M* iodine solution (Moor et al., 2005). Twenty five grams of carrots was mixed with 100 mL of 6 g 100 g^{-1} solution of oxalic acid and homogenized for 60 s, and then the sample was filtered. 10.0 mL of the filtrate and 2.0 mL of 1g 100 g^{-1} starch solution was titrated until the endpoint was reached (first sign of blue colour that persists after 30 s). The titration was repeated in triplicate for each sample. The ascorbic acid content was calculated using formula:

$$x = \frac{V_{sample} \times 5000}{V_{standard} \times g}, \qquad (2)$$

where
V_{sample} – iodine amount for sample titration, mL;
$V_{standard}$ – iodine amount for vitamin C standard solution titration, mL;
g – weight of sample, g.

The total dietary fiber in these samples was determined according to the AOAC approved method No 985.29 The experiments were carried out by using FOSS Analytical Fibertec E 1023 system providing enzymatic processing by incubation in a thermostatic shaking water bath, residue filtration was done by Filtration Module, and protein determination - by Kjeldahl (Method 46-12, 1995) nitrogen equipment. The analyses were performed in three repetitions. The samples were defatted and dried with a particle size less than 0.5 mm. Afterwards each sample was enzymatically digested with a–amylase incubation at 100 °C, as well as with protease and amyloglucosidase incubation at 60 °C. After digestion, the total fiber content was precipitated by adding 95 g 100 g^{-1} ethanol. Later the solution was filtered and fiber was collected, dried and weighed. The protein and ash content were determined to correct any of these substances which might remain in the fiber (Prosky, 1990).

Data were expressed as mean ± standard deviation; for the mathematical data processing the value of $p<0.05$ was assumed as statistically significant. One-way analysis of variance (ANOVA) was used to determine the significante of differences. In case of establishing statistically significant differences, homogeneous groups were determined by Tukey’s multiple comparison test at the level of confidence $\alpha=0.05$. The statistical analyses were performed using Microsoft Excel 2007.

Results and Discussion

Until now there has been no detailed investigation of sugar content in carrot collections gathered in gene banks. Previously published studies focused only on advanced cultivars and populations used in research programmes. Only a few authors have evaluated non-orange carrots; these studies tended to be restricted to a few accessions only. Additionally, the lack of accession names or seed source makes comparison of the obtained results difficult. In the present experiment it was established that there are relevant differences between sugar content in analysed carrot samples. The total sugar content in carrots ranged from 4.03 g 100 g^{-1} to 7.99 g 100 g^{-1} (Figure 3). The results obtained in our research are very similar to those in the literature (from 5.10 g 100 g^{-1} to 13.60 g 100 g^{-1}) (Baranski et al., 2011). Substantial differences in total sugar content ($p<0.05$) between analysed carrot hybrid samples Nante/Berlikum and Nante/Forto were found. Main differences in sugars could be explained by plant nutrition, climate and soil (Nookaraju et al., 2010). Carrot sweetness depends on the presence of sucrose and the two reducing sugars - glucose and fructose (Baranski et al., 2011).

Highest total sugar content was detected in carrot hybrids Nante/Maestro and Nante/Champion – 7.99 and 7.57 g 100 g^{-1} respectively. It was approximately two times higher than in hybrids Nante/Berlikum and Nante/Forto (Figure 3). However, higher sucrose content was found in hybrids Nante/Champion and Nante/Maestro 4.82 g 100 g^{-1} and 4.71 g 100 g^{-1} respectively, what was approximately two times higher comparing to sucrose content in hybrids Nante/Forto and Nante/Berlikum. It is necessary to indicate that the lowest fructose, glucose and sucrose content was established in hybrid Nante/Forto. In other analysed carrots the content of fructose and glucose was very similar (Figure 3).

The levels of ascorbic acid found in the trialled carrot storage roots varied from 0.25 to 3.50 mg 100 g^{-1} fresh weight among the cultivars (Singh et al., 2012). In our experiment, substantial differences ($p<0.05$) were found in vitamin C content (Figure 4) between the analysed carrot hybrids. A significantly higher ($p<0,05$) vitamin C content was established in hybrids Nante/Maestro, Nante/Berlikum, and Nante/Bolero (17.61±0.17, 17.02±0.01, and 17.00±0.01 mg 100 g^{-1}, respectively) compared to hybrids Nante/Forto and Nante/Champion (8.51±0.01 and 8.39±0.17 mg 100 g^{-1} respectively). Such results could be explained by individual hybrids, such as chemical composition and growing conditions. In scientific material of (Singh et al., 2012) was mentioned that Vitamin C acts as an antioxidant in plants and its level is responsive to a variety of environmental or stress factors, for example light, temperature, salt and drought, atmospheric pollutants, metals or herbicides.

Dietary fiber (DF) is a group of food components which are resistant to hydrolysis by human digestive enzymes. Dietary fiber consists of polysaccharides, oligosaccharides and lignin. The health benefits of dietary fiber have led to increased consumption of fiber-rich products. Fruits and vegetables are good sources of dietary fiber (Chantaro et al., 2008).

The average fiber content in fresh carrots, as mentioned in the literature, is 45.45±0.41 g 100 g^{-1} DW (Chantaro et al., 2008), which is slightly higher than that obtained in our research (Figure 5). The content of total dietary fibre in 'Nante' hybrid carrots ranged from 25.78±1.54 to 34.25±5.79 g 100 g^{-1} DW. The highest total dietary fiber content was established in hybrids Nante/Bolero, Nante/Maestro, and Nante/Berlikum 34.25±5.79, 29.80±0.47, and 29.49±0.36 g 100 g^{-1} DW, respectively.

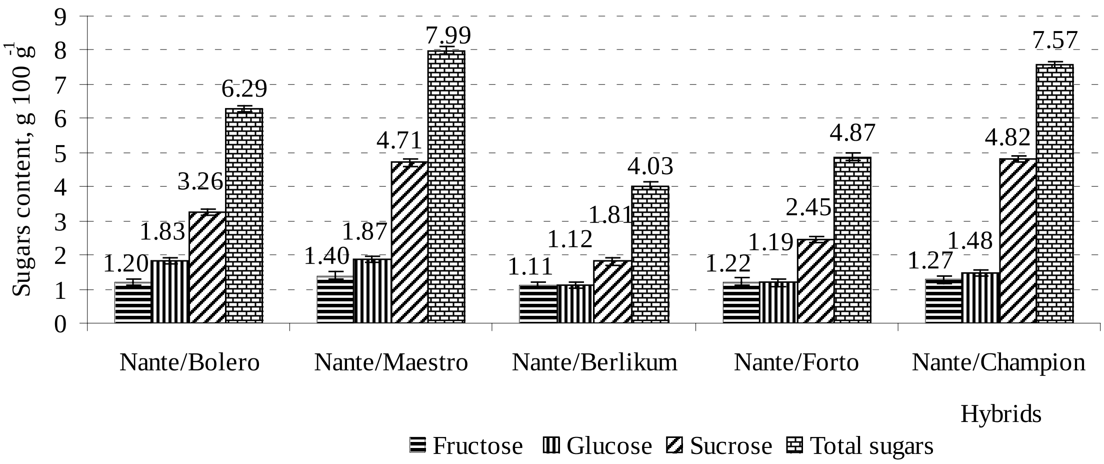

Figure 3. Composition of sugars in carrots.

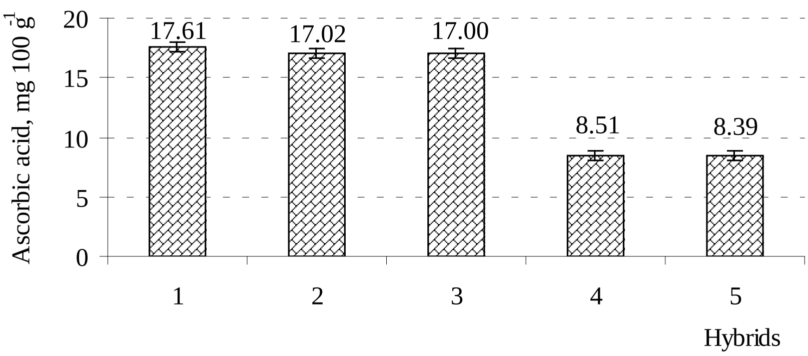

Figure 4. Vitamin C content in hybrids of carrot cultivar 'Nante': 1 - Nante/Maestro; 2 - Nante/Berlikum; 3 - Nante/Bolero; 4 - Nante/Forto; 5 - Nante/Champion.

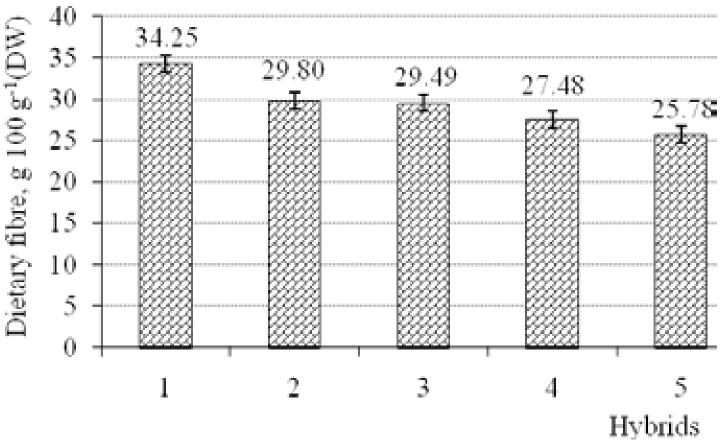

Figure 5. Dietary fibre content in hybrids of carrot cultivar 'Nante': 1 - Nante/Bolero; 2 - Nante/Maestro; 3 - Nante/Berlikum; 4 - Nante/Forto; 5 - Nante/Champion.

Based on current data, dietary fiber intake from whole foods or supplements may lower blood pressure, improve serum lipid levels, and reduce indicators of inflammation. Benefits may occur with intakes of 12.0 to 33.0 g of fiber per day from whole foods or up to 42.5 g of fiber per day from supplements (Slavin, 2008).

Conclusions

1. Significant differences were found in the content of sugar, vitamin C and dietary fibre between different carrot hybrids.
2. The highest content of total sugars was in Nante/Maestro and Nante/Champion hybrids – 7.99 and 7.57 g 100 g^{-1}, respectively; the lowest total sugars content was in Nante/Berlikum hybrid - 4.03 g 100 g^{-1}.
3. Vitamin C content in carrot hybrid Nante/Maestro was the highest (17.61±0.17 mg 100 g^{-1} of fresh weight) and in hybrid Nante/Champion - the lowest (8.39±0.17 mg 100 g^{-1} of fresh weight).
4. The dietary fibre content in analysed carrot samples ranged from 34.25±5.79 g 100 g^{-1} DW in Nante/Bolero hybrid to 25.78±1.54 g 100 g^{-1} DW in 'Nante/Champion' hybrid.

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