Journal of Food Composition and Analysis 72 (2018) 57–65

Contents lists available at ScienceDirect

Journal of Food Composition and Analysis

journal homepage: www.elsevier.com/locate/jfca

Original research article

Sugar profiles as a promising tool in tracing differences between potato cultivation systems, botanical origin and climate conditions

Aleksandra M. Dramićanin[a], Filip Lj. Andrić[b], Dobrivoj Ž. Poštić[c], Nebojša M. Momirović[d], Dušanka M. Milojković-Opsenica[b,*]

[a] Innovation Center, Faculty of Chemistry Ltd., Studentski trg 12-16, 11000 Belgrade, Serbia
[b] Department of Analytical Chemistry and Center of Excellence for Molecular Food Sciences, Faculty of Chemistry, University of Belgrade, Studentski trg 12-16, 11158 Belgrade, Serbia
[c] Institute for Plant Protection and Environment, Teodora Drajzera 9, 11040 Belgrade, Serbia
[d] Faculty of Agriculture, University of Belgrade, Nemanjina 6, 11080 Belgrade-Zemun, Serbia

ARTICLE INFO

Keywords:
Food analysis
Food composition
Potato
Organic production
Conventional production
Integral production
Sugar profile
Starch
MANOVA

ABSTRACT

This research proposes a new way of tracing differences between potato cultivation systems, botanical origin, and climate conditions by using sugar profiles. A set of 90 potato tubers of four varieties with different ripening times, cultivated in three types of agricultural systems: conventional (C), integral (I), and organic (O) were characterized based on sugar profiles of their bulk and peel. A total of nineteen sugars were quantified. In order to determine the source of variation among the types of production, the years of production and varieties, multivariate analysis of variance (MANOVA) was conducted. The results indicated that starch may be considered an important indicator of the type of production, botanical origin, and ripening time. Additionally, the analyses showed that sugar macro and microcomponents such as fructose, glucose, saccharose, sorbitol, trehalose, arabinose, turanose and maltose were the main factors for the differentiation of production types, production years and botanical origin of potato.

1. Introduction

Potato (*Solanum tuberosum* L.) belongs to the group of angiosperms and is the fifth most widely spread crop after rice, maize, cassava and wheat (Pinhero et al., 2016; Yuan et al., 2016). Thanks to its excellent adaptive capabilities, high productivity and good nutritional value of tubers (Oruna-Concha et al., 2001), potato is cultivated in more than 165 countries with annual production margin of around 477 million tons (FAOSTAT, 2014). It does not require excessive processing before use and consuming, and in case its growth is enhanced through tuberizing, the yield index of potato tubers can be greater than 80%, which is almost double of that of cereals (Wheeler, 2009).

Based on the productivity, nutritional and biological value of tubers, potato is among the most profitable agricultural plants. Additionally, more than 85% of total production of potato is used in human nutrition (Gvozden, 2016). The main source of energy in human nutrition are carbohydrates, with the intake ranging between 40% and 80% of total energy needs. Besides providing energy, carbohydrates affect human physiology in numerous ways, for example the construction, regeneration, reparation and maintenance of tissues (Ikanone and Oyekan, 2014; Pinhero et al., 2016). In addition, carbohydrates are helpful in reducing the risk of certain diseases such as cancer, heart diseases and diabetes (Ikanone and Oyekan, 2014).

The main classes of carbohydrates significant for human nutrition are sugars (glucose, saccharose, fructose, lactose, and maltose), sugar polyols (sorbitol and mannitol), oligosaccharides and polysaccharides (starch and non-starch polysaccharides) (Folgado et al., 2014; Yuan et al., 2016). Considering the importance of potato in human nutrition, separation, identification and quantification of different classes of carbohydrates in potato tubers is essential for further understanding of its impact on physiological processes, and nutritive value (Muir et al., 2009). However, no comprehensive evaluation of sugar profiles of

Abbreviations: MANOVA, multivariate analysis of variance; Glc, glucose; Fru, fructose; Sac, saccharose (sucrose); Tre, trehalose; Mal, maltose; Ara, arabinose; Tur, turanose; Rib, ribose; Gent, gentiobiose; Ism, isomaltose; Pan, panose; Ismt, isomaltotriose; Malt, maltotriose; Mel, melibiose; Gal, galactose; Xyl, xylose; Sor, sorbitol; Glt, galactitol; C, conventional cropping system; I, integral cropping system; O, organic cropping system; F, Red Fantasy (middle early red variety); L, Laura (middle early red variety); M, Marabel (early yellow variety); J, Jelly (late yellow variety)

* Corresponding author.
E-mail addresses: akosovic@chem.bg.ac.rs (A.M. Dramićanin), andric@chem.bg.ac.rs (F.L. Andrić), pdobrivoj@izbis.rs (D.Ž. Poštić), emomirov@agrf.bg.ac.rs (N.M. Momirović), dusankam@chem.bg.ac.rs (D.M. Milojković-Opsenica).

https://doi.org/10.1016/j.jfca.2018.06.005
Received 28 December 2017; Received in revised form 3 May 2018; Accepted 12 June 2018

potato tubers has been performed so far. The data is rather scarce. Glucose and fructose are prevalent reducing monosaccharides with concentrations between 0.15% and 1.5%. The most abundant disaccharide is saccharose, the content of which ranges from 0.4 to 6.6%, while other sugars are present in traces (Burton, 1989; Woolfe and Poats, 1987; Zommick et al., 2014).

The content of carbohydrates in potato tubers varies depending on the sort, agroecological conditions, production, fertilizing, temperature and the duration of storage (Affleck et al., 2008; Arvanitoyannis et al., 2008; Bethke et al., 2009; Chen et al., 2010; Navrátil et al., 2007; Pedreschi, 2007; Thompson et al., 2008). Heat stress and the lack of water during the vegetation period induce the change in the activity of enzymes involved in the metabolism of carbohydrates (Thompson et al., 2008). Therefore, tracing the levels of sugars is a key step for determining which tubers need to be processed (Rady and Guyer, 2015).

Among all polysaccharides, starch is particularly interesting due to its many useful functional characteristics, such as thickening, coating, gelling, and adhesive properties, which makes it particularly suitable for use in a wide range of industrial products, and food industry (McCarthy et al., 2009; Ikanone and Oyekan, 2014; Yoon, 2013; Bradshaw and Ramsay, 2009). Physical, chemical and functional characteristics of starch systems and their uniqueness in various nutritional products vary depending on the biological origin (McCarthy et al., 2009).

Along with the sugar content, starch defines the inner and/or outer quality of the product (Stark and Love, 2003; Storey, 2007). Additionally, the ratio between starch content (polysaccharides) and reducing sugars (monosaccharides) determines the quality and the suitability of potato for industrial processing (chips and French-fries) (Arvanitoyannis et al., 2008). The content of starch is one of the parameters influencing the nutritional value of potato and is susceptible to high variations (Gvozden, 2016). It varies from 11% to 30% in cultivated potato, to 4–40% in wild sorts. In general, a fresh potato consists of around 20% of dry solid, out of which 60–80% is starch. The total content of starch in tubers is significantly influenced by their genotype, as well as environmental and cultivation conditions (Raatz et al., 2016).

Bearing in mind the significance of potato and the worldwide area under this crop, this study aims to better understand the influence of cultivation systems (conventional, integral and organic) on chemical composition (sugar profiles), productive characteristics, quality and biological value of potato tubers in order to identify possibilities for increasing the yield and the quality of potato, establishing a cost-effective and viable potato production, as well as obtaining a high quality raw material of good biological value that can be used for various purposes. Having that in mind, the goal of this research was to characterize tubers of four varieties of potato: two middle early red varieties (Red Fantasy and Laura), one yellow early variety (Marabel), and one yellow middle late variety (Jelly), cultivated in three different vegetation/production periods (from 2013 to 2015), based on the sugar profiles of potato bulk and peel. Considering the contemporary problems of organic crop production the aim of the present study was to investigate whether comprehensive sugar profiles could be used as indicators of potato cultivation systems

2. Materials and methods

2.1. Chemicals and materials

Ethanol was purchased from Zorka Pharma (Šabac, Serbia). Glucose (Glc), fructose (Fru), saccharose (Sac), trehalose (Tre), maltose (Mal), arabinose (Ara) were purchased from Tokyo Chemical Industry, TCI (Europe, Belgium); turanose (Tur), ribose (Rib), gentiobiose (Gent), isomaltose (Ism), panose (Pan), isomaltotriose (Ismt), maltotriose (Malt), melibiose (Mel), galactose (Gal) and xylose (Xyl) were obtained from Tokyo Chemical Industry, TCI (Tokyo, Japan); sorbitol (Sor) and galactitol (Glt) were purchased from Sigma–Aldrich (Steinheim, Germany). All chemicals used whose purity were of analytical purity grade. Ultra-pure water (MicroPure water purification system, 0.055 μS/cm, TKA, Thermo Fisher Scientific, Niederelbert, Germany) was used to prepare standard solutions and blanks. Syringe filters (13 mm, PTFE membrane 0.45 μm) were purchased from Supelco (Bellefonte, PA). Filter paper (Whatman No. 1) was supplied by Merck (Darmstadt, Germany).

2.2. Cultivation experiments

Two middle early red varieties–Red Fantasy (F), and Laura (L), one early yellow variety–Marabel (M), and one late yellow variety–Jelly (J), imported from Germany as seed material, were cultivated in three types of agricultural systems: conventional (C), integral (I), and organic (O) in the field trials and microtrials. Field trials were conducted on the alluvium soil type. Micro experiments were set up as two factorials in split-plot designs with four replications. The total size of the trail field was 720 square meters, and it was divided into three equal-sized sub-fields of 240 square meters, one sub-field for each examined production type. Sub-fields were further divided into 16 elementary parcels of 14.70 square meters each, on which four examined varieties were spread, each with four replications. The cultivation experiments were conducted in the Lijevče Polje region (northern Bosnia and Herzegovina), near the village Laminci (45° 06′ N, 17° 20′ E), KO Gradiška, at 90 m above the sea level. During the three-year long production period (2013–2015), potatoes were grown under standardized conditions. The differences in days and methods of harvesting, drying and processing after storage, sample collection and preparation were reduced to a minimum. Only fertilization and the presence of pests differed depending on the type of production.

2.3. Sampling and sample preparation

A representative set of 90 potato tubers, from a three year-long study, has been compiled using 36 samples of the middle early red varieties (18 samples from each, Red Fantasy and Laura), 27 samples of the early yellow variety (Marabel) and 27 samples of the late yellow variety (Jelly).

Potato tubers were thoroughly rinsed with slightly warm water and then peeled. The peel and the bulk were separated. The thickness of the peeled crust was in the range of 1 to 2 mm. The bulk was separated from the rest of the tuber by cutting a peeled tuber into half. Then 1.5 to 2 cm thick pieces were separated from the upper and lower sides of the tuber (along the larger diameter), and 1–1.5 cm thick pieces were separated from the right and the left side of the tuber (along the smaller diameter). The bulk was further chopped into 1–2 mm thick slices for easier drying. The samples were dried for 48 h at 50 °C, and then ground and pulverized for an efficient extraction of sugars. The obtained powder was kept in plastic bottles at 4 °C until the analysis was performed.

2.4. Extraction of carbohydrates

Around 0.1 g of a dry sample of peel or bulk was weighed into an Erlenmeyer flask and 25 mL of ultrapure water were added. The content was mixed in an ultrasonic bath for 25 min at room temperature before being centrifuged at 4000 rpm for 10 min. The extract was separated from the residue, and the extraction procedure was repeated on the remains. The extracts were combined and filtered through NY: 0.45 μm filters before the analysis.

2.5. High-performance anion-exchange chromatography with pulsed amperometric detection (HPAEC/PAD)

Chromatographic experiments were performed using DIONEX ICS 3000 DP liquid chromatography system (Dionex, Sunnyvale, CA, USA)