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Nutritional value and chemical composition of Greek artichoke genotypes

Spyridon A. Petropoulos [a,*], Carla Pereira [b], Georgia Ntatsi [c], Nikolaos Danalatos [d], Lillian Barros [b,e], Isabel C.F.R. Ferreira [b,*]

[a] Laboratory of Vegetable Production, University of Thessaly, Fytokou Street, 38446 N. Ionia, Magnissia, Greece
[b] Mountain Research Centre (CIMO), ESA, Polytechnic Institute of Bragança, Campus de Santa Apolónia, 1172, 5300-253 Bragança, Portugal
[c] Laboratory of Vegetable Production, Agricultural University of Athens, Iera Odos 75, 11855, Athens, Greece
[d] Laboratory of Agronomy and Applied Crop Physiology, University of Thessaly, Fytokou Street, 38446 N. Ionia, Magnissia, Greece
[e] Laboratory of Separation and Reaction Engineering (LSRE) – Associate Laboratory LSRE/LCM, Faculty of Engineering, University of Porto, Porto, Portugal

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ABSTRACT

The nutritional value and chemical composition of various artichoke genotypes cultivated in Greece were evaluated. Significant differences were detected in water content, as well as in fat, ash, protein and carbohydrate content. Proteins and carbohydrates were detected in high amounts in all the genotypes. Antioxidant activity was also varied between the studied samples. Palmitic and linoleic acids were the most abundant fatty acids in artichoke heads, while stearic, oleic, alpha-linolenic, arachidic, behenic and lignoceric acids were detected in lesser amounts. 3,5-*O*-Dicaffeoylquinic acid and 5-*O*-caffeoylquinic acid were the main phenolic compounds. In conclusion, heads of artichoke genotypes cultivated in Greece showed a high nutritional value and antioxidant activity which signifies the importance of this vegetable for the Mediterranean diet, while the diversity in chemical composition between the studied samples should be further exploited for the selection of elite cultivars with specific end-uses of the final product.

1. Introduction

Artichoke or globe artichoke (*Cynara cardunculus* ssp. *scolymus* (L.), Hegi; Astreaceae family) is a native perennial plant of the Mediterranean basin, known for its nutritional value and therapeutic properties since the ancient years (de Falco, Incerti, Amato, & Lanzotti, 2015). Commercial cultivation is widespread throughout the world, with Europe and especially Italy being the main world producers with an annual production of about 725.422 and 457.799 tonnes, respectively (FAO (Food, Trade Statistics. FAO, & Italy, 2013). In Greece, globe artichoke is not considered as a major crop (an annual production of 29.000 tonnes in 2013; FAO, 2013), however it is a main ingredient in many traditional dishes of the Mediterranean diet and is highly appreciated for its nutritional value and beneficial health effects.

Although the plant is usually propagated through vegetative propagation, there is a great diversity in the species, with many landraces and wild genotypes spread throughout the Mediterranean basin and Italy in particular. Commercial cultivars and hybrids are also available and are distinguished by plant morphology (plant height, leaf shape etc.), the head shape, the color of bracts, the earliness of maturity and end-uses of the final product (processing or fresh products) (Ciancolini, Rey, Pagnotta, & Crinò, 2012).

The edible portion of the plant is the immature inflorescences (capitula or heads), including the inner bracts and the upper part of the receptacle, which can be eaten either as fresh, or as canned or frozen vegetable after minimal processing (Lattanzio, Kroon, Linsalata, & Cardinali, 2009). The high nutritional value of globe artichoke heads is attributed to the low content of lipids and the high levels of minerals, vitamins and bioactive compounds. According to Lutz, Henríquez, and Escobar (2011), the edible portion contains a high dry matter content (16%), carbohydrates (17.75% f.w.), proteins (3.73% f.w.), crude fat (0.27% f.w.) and ash (1.65% f.w.), while it is also a rich source of vitamin C (10 mg 100 g^{-1} f.w.; Gil-Izquierdo, Gil, Conesa, & Ferreres, 2001), macrominerals such as K, Ca (360 and 50 mg 100 g^{-1} f.w., respectively; Romani, Pinelli, Cantini, Cimato, & Heimler, 2006), and microminerals Fe and Zn (1.5 and 26.2 mg kg^{-1} d.w.; Gaetano Pandino, Lombardo, & Mauromicale, 2011). Seed oil is a rich source

* Corresponding authors.
E-mail addresses: fangio57gr@gmail.com (S.A. Petropoulos), iferreira@ipb.pt (I.C.F.R. Ferreira).

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of polyunsaturated and monounsaturated fatty acids such linoleic (51.68%) and oleic acid (34.24%), which make it suitable for human consumption (Raccuia & Melilli, 2007). However, the oil fatty acid composition may be altered by growing conditions such as water stress which may result in an increase of saturated at the expense of unsaturated fatty acids (Nouraei, Rahimmalek, Saeidi, & Bahreininejad, 2016).

Polyphenol content is highly affected by genotype, plant part and growing and processing conditions, and a great variation has been reported so far for both content and composition. According to Lombardo, Pandino, Ierna, and Mauromicale (2012) who studied seventeen Italian globe artichoke cultivars, total phenolic content and phenolic compounds composition differed significantly among the tested cultivars and the plant parts. Similar results have been reported by Pandino, Lombardo, Mauro, and Mauromicale (2012), who also observed variation in phenolic profile in relation to head part (receptacle and outer and inner bracts) and genotype. Moreover, Pandino, Lombardo, Mauromicale, and Williamson (2011) have reported that phenolic compounds tend to increase from the outer to the inner parts of the heads (outer bracts < inner bracts < receptacle), whereas for hydroxycinnamic acids the opposite trend has been observed, since they are involved in the lignification process of the outer bracts which takes place during maturation process. The main phenolic compounds reported for artichoke heads include mainly caffeoylquinic acids and apigenin derivatives, such as chlorogenic acid and apigenin-7-O-glucuronide (Alarcón-Flores, Romero-González, Martínez Vidal, & Garrido Frenich, 2014; Pandino, Courts, Lombardo, Mauromicale, & Williamson, 2010; Pandino et al., 2012), luteolin derivatives (Romani et al., 2006), and cynarin (1,3-*O*-dicaffeoylquinic acid) (Lutz et al., 2011). Apart from the main phenolic compound classes, Abu-Reidah, Arraez-Roman, Segura-Carretero, and Fernandez-Gutierrez (2013) have identified other hydroxybenzoic acids and flavonols, flavanones, lignans and other polar compounds, in a total of 61 compounds, suggesting their importance in globe artichoke heads therapeutic properties. Therefore, globe artichoke is a rich source of antioxidants which contribute to its well-known beneficial health effects. Most studies refer to antioxidant activity of leaves (Pereira, Calhelha, Barros, & Ferreira, 2013) and head extracts (El Sohaimy, 2009; Fratianni, Pepe, & Nazzaro, 2014; Garbetta et al., 2014; Kollia, Markaki, Zoumpoulakis, & Proestos, 2016), since these are the main plant tissues that are incorporated in dietary supplements and herbal preparations. However, Durazzo et al. (2013) and Falleh et al. (2008) have reported that artichoke and cardoon seeds are also a good source of antioxidants.

The aim of the present study was the evaluation of the nutritional value, chemical composition and bioactive compounds content of Greek landraces and wild genotypes, including the main commercial globe artichoke cultivars that are usually cultivated in Greece, in order to identify potential germplasm for future selection of elite genotypes with high nutritional value and bioactive compounds content.

2. Materials and methods

2.1. Plant material and sampling

Samples of six globe artichoke [*Cynara cardunculus* L. ssp. *scolymus* (L.) Fiori] and two wild artichoke [*Cynara cardunculus* L. subsp. *sylvestris* (L.) Fiori] genotypes were assessed for their nutritional value and chemical composition. Field experiments were carried out at the experimental farm of the University of Thessaly, while local landraces were collected *in situ* from their places of origin. From plants grown at the experimental field, sample of heads were collected when they reached marketable size and prior to maturation. All samples were taken from plants grown from seeds, three years after crop establishment, which is the stage when artichoke plants are considered fully productive. For local landraces, sample of heads were collected *in situ* from well-established crops. All samples were chopped, put in air sealed bags and frozen at deep freezing conditions (−80 °C), and lyophilized prior to further analysis.

The studied genotypes were the following: a) local landrace with dark purple round heads (sample A1), collected *in situ* from the region of Volos (latitude 39°37′99″, longitude 22°95′16″), b) Greek cultivar "Purple of Attika" with purple round heads (sample A2), grown at the experimental field, c) wild artichoke with green small flat round heads and bracts with small spines (sample A3), grown at the experimental field, d) commercial cultivar with green round heads (Sample A4; Geniki Fytotechniki S.A.), grown at the experimental field, e) commercial cultivar with dark purple oblong heads and bracts with small spines (sample A5; Geniki Fytotechniki S.A.), grown at the experimental field, f) wild artichoke with green small round heads and bracts with big spines (sample A6), grown at the experimental field, g) Greek landrace "Mikromani", with green oblong heads and bracts with big spines (sample A7), collected *in situ* from the region of Mikromani, Messinia Prefecture (latitude 37°08′21″, longitude 22°03′56″), and h) Greek cultivar "Argitiki" (sample A8), collected *in situ* from the region of Argos, Argolis Prefecture (latitude 37°58′64″, longitude 22°72′21″).

2.2. Nutritional value and chemical composition analysis

For the macronutrient analysis, proteins, fat, carbohydrates and ash were determined using standard analytical methods described by AOAC procedures (AOAC, 2005) and following a procedure previously used by Guimarães et al. (2013). Energy was calculated following the equation: Energy (kcal) = 4 × (g protein) + 4 × (g carbohydrate) + 9 × (g fat).

For the mineral composition, samples of plant tissues were dried in a forced-air oven at 72 °C to constant weight, ground to powder, subjected to dry ashing and extracted with 1 N HCl to determine the mineral. Ca, Mg, Fe, Mn, Zn, and Cu content were determined by atomic absorption spectrophotometry (Perkin Elmer 1100B, Waltham, MA) and Na and K content by flame photometry (Sherwood Model 410, Cambridge, UK).

Free sugars were performed by high performance liquid chromatography with a refraction index detector (HPLC-RI; Knauer, Smartline system 1000, Berlin, Germany), as previously described by the authors (Guimarães et al., 2013). The sugars were identified by comparing their retention times with standard compounds and quantification was conducted by using the internal standard (IS, melezitose) methodology.

Fatty acids were analyzed with a DANI 1000 gas chromatographer (GC) coupled to a flame ionization detector (FID), after a transesterification procedure described by Guimarães et al. (2013) and results were recorded and processed using Clarity 4.0.1.7 Software (DataApex, Podohradska, Czech Republic).

2.3. Phenolic compounds and antioxidant activity analysis

Extracts were prepared by stirring the dry sample (1 g) and 30 mL of methanol/water (80:20 v/v, at 25 °C at 150 rpm) for 1 h and afterwards filtered using Whatman paper No. 4. The residue was then extracted with an additional portion of methanol/water and the combined extracts were evaporated under reduced pressure (rotary evaporator Büchi R-210, Flawil, Switzerland), until complete removal of methanol. The aqueous phase was frozen and lyophilized (FeeeZone 4.5, Labconco, Kansas City, MO, USA).

The hydroalcoholic extracts were re-dissolved in methanol/water (80:20 v/v) to a final concentration of 2 mg/mL for phenolic

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