

Nutritional And Functional Properties of Cynara Crops (Globe Artichoke and Cardoon) and Their Potential Applications: A Review

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Abstract

Cynara genus, originating from the Mediterranean area, includes globe artichoke (*Cynara cardunculus* var. *scolymus* L) and cardoon (*Cynara cardunculus* var. *altilis* DC). Traditionally these crops have long been used as food and medicine. Nowadays, they are considered as functional foods, owing to their nutritional properties. Artichoke has exhibited hepatoprotective and antioxidative activities, as well as the ability to inhibit cholesterol biosynthesis and low density lipoprotein oxidation, due to its high content of polyphenolic compounds. Moreover, the edible and agro-industrial by-products of artichoke are rich sources of inulin. In addition, cardoon, having similar bioactive compounds, offers a wide spectrum of different uses: for medicinal purposes, as rennet substitute for the preparation of high quality traditional cheese, as oil suitable for human consumption, as biofuel or for paper production. Also, these plants can be used in ruminant nutrition as green forage or preserved as silage, with high organic matter digestibility.

Key Words: globe artichoke; cardoon; functional foods; inulin; polyphenols; ruminant nutrition

1. Introduction

Cynara is a relatively small genus, originating from the Mediterranean area that includes two crops, globe artichoke (*Cynara cardunculus* var. *scolymus* L.) and cardoon (*Cynara cardunculus* var. *altilis* DC), as well as their ancestor, wild cardoon (*Cynara cardunculus* L. var. *sylvestris* (Lamk) Fiori) (Foti et al., 1999; Portis et al., 2005; Ierna and Mauromicale, 2010). The earliest description of the *Cynara* comes from the 4th century BC Greek writer Theophrastus. These plants were popular in Greeks and Romans as food and medicine (Sonnante et al., 2007; Lattanzio et al., 2009).

Globe artichoke is a perennial, rosette plant, widely cultivated for its large fleshy head or capitula (immature flowers) which represent 30-40% of the fresh weight (FW). The edible parts of the artichoke are the tender inner leaves (bracts) and the receptacle commonly known as “heart” that constitute nearly 35-55% of the FW of the head (Ceccarelli et al., 2010). In addition, there are some non-food industrial by-products such as leaves, external bracts and stems. They represent about 80% of the biomass and may be used for the extraction of food additives and nutraceuticals (Lattanzio et al., 2009; Ceccarelli et al., 2010). The artichoke crop may last six or more years, reaching the maximum productivity in the third year (Ceccarelli et al., 2010). Artichoke plays an important role in human nutrition, especially in the Mediterranean area (Lattanzio et al., 2009). In addition, artichoke contributes significantly to the Mediterranean agricultural economy, where more than 60% of the total world production is produced.

Italy is the leading producer (about 474.000 t annually) followed by Spain (215.000 t), France (55.000 t) and Greece (25.000 t) (Lattanzio et al., 2009; F.A.O., 2007). Nowadays, artichoke is cultivated in many parts of the world, such as the United States – mainly in California, in South America (Argentina, Chile, Peru), North Africa, Near East (Turkey and Iran) and China (Ierna and Mauromicale, 2010; Lattanzio et al., 2009; Pandino et al., 2011a,b). Artichoke's commercial production is mainly based on perennial cultivation of vegetatively propagated clones (Sonnante et al., 2007). This plant is genetically robust with a marked tolerance to pathogens. This is due to the contained sesquiterpenes e.g. cynaropicrin, which have antifeedant activity, the late being also responsible for the typical bitter taste of artichoke (Ceccarelli et al., 2010).

The cultivation of cardoon is much less widespread than that of globe artichoke. It remains of regional importance in Spain, Italy, south France and Greece, where it is used in traditional dishes. The edible parts of this plant are the succulent young leaves, which are collected from late autumn to early winter (Foti et al., 1999; Pinelli et al., 2007). Leafy cardoon is seed propagated and mostly grown as an annual plant (Sonnante et al., 2007). The capitula contain small oil seeds with an average of 126 seeds per capitulum (Gominho et al., 2011). The wild cardoon is a robust thistle originating in the western and central parts of the Mediterranean area, with a characteristic rosette of large spiny leaves and branched flowering stems. The growth period ranges from September to July (Foti et al., 1999; Ierna and Mauromicale, 2010). *Cynara* spp. exhibit the typical botanical characteristics of the Asteraceae family with the flower arrangement in capitula and the special type of fruit that the flower produces – the fruit is called seed although seed is only the kernel inside (Curt et al. 2002), while the maturing seeds are named achenes (Foti et al., 1999; Gominho et al., 2011).

2. Biological Compounds Of Globe Artichoke

Globe artichoke has a low content of fat and high levels of minerals (potassium, sodium, phosphorus), vitamin C, fibres, polyphenols, flavones, inulin and hydroxycinnamates - caffeoylquinic acid derivatives. (Ceccarelli et al., 2010; Pandino et al., 2011a, b) According to Foti et al. (1999) the chemical composition of artichoke seeds was the following: crude protein 21.6%, crude fiber 17.1%, crude oil 24.05% and ash 3.8%. The artichoke flower heads have a high content of vitamin C (10 mg / 100 g FW) and minerals (K 360 mg / 100 g FW; Ca 50 mg / 100 g FW) (Ceccarelli et al., 2010). Leaves and heads of artichoke have been found to be rich in polyphenolic compounds, inulin, fibre and minerals (Lattanzio et al., 2009). Artichoke leaf extract has shown antioxidative, antibacterial, anti-HIV, bile-expelling, hepatoprotective, urinate and choleric activity, as well as the ability to inhibit cholesterol biosynthesis and LDL oxidation (Llorach et al., 2002; Wang et al., 2003). Although artichoke extract has been used as medicine for many years, it has not been extensively examined as antimicrobial agent. Nevertheless, some researchers (Zhu et al., 2004; Mossi and Echeverrigaray, 1999) reported that these extracts have broad inhibitory activities against microorganisms and they could be of promising use in food industry. The exact polyphenol content varies greatly depending on the extraction method (Llorach et al., 2002).

The main phenolic compounds are the caffeic acid derivatives which include the caffeoylquinic acid derivatives. Using the International Union of Pure and Applied Chemistry (IUPAC) nomenclature, 5-O-caffeoylquinic acid (chlorogenic acid) is the most abundant single substance (39%), followed by 1,5-O-dicaffeoylquinic acid (21%) and 3,4-O-dicaffeoylquinic acid (11%), based on total caffeoylquinic acid content (Lattanzio et al., 2009; Merck, 2006). Furthermore, the 1,3-O-dicaffeoylquinic acid (cynarin) content in methanolic extracts of artichoke is very low (about 1.5%), the majority of which is located in the pulp of the leaves, although the dried leaves and stems of artichoke also contain this compound (Lattanzio et al., 2009). The above phenolics substances have an important scavenging activity against reactive oxygen species (ROS) and free radicals, and perform as a protective shield against oxidative damage to biological molecules, such as proteins, lipids and DNA (Ceccarelli et al., 2010; Dangles and Dufour, 2008)

In addition, other phenolics such as the flavones 5,7-dihydroxy-2-(4-hydroxyphenyl)-4H-1-benzopyran-4-one (apigenin) and 2-(3,4-Dihydroxyphenyl)- 5,7-dihydroxy-4-chromenone (luteolin), as well as the anthocyanidins such as 2-(3,4-dihydroxyphenyl) chromenylium-3,5,7-triol (cyanidin), 2-(4-Hydroxy-3 methoxyphenyl) chromenylium-3,5,7-triol (peonidin) and 2-(3,4,5-trihydroxyphenyl)chromenylium-3,5,7-triol (delphinidin) have been isolated in only in the heads of artichoke (Lattanzio et al., 2009; Merck, 2006). The above flavones apigenin and luteolin have been identified in leaves and heads of the plant in form of glucosides and rutinosides, whereas anthocyanin pigments are present only in heads in form of glucosides and sophorosides (Lattanzio et al., 2009).

These pigments are responsible for the color of artichoke capitula which ranges from green to violet (Lattanzio et al., 2009). Anthocyanins, besides the health promoting properties, have also an important role in the appearance of food plants and therefore in food acceptance by consumers (Brown and Rice-Evans, 1980). Since apigenin, as well as other flavones, are not found in many food plants, artichoke represents a significant source of this substance and its conjugates (Pandino et al., 2011).

Moreover, the external bracts, the fleshy and developed artichoke roots and the flower heads could be used for the extraction of inulin – a fructose polysaccharide belonging to the fructans (Lopez-Molina et al., 2005). Globe artichoke synthesizes inulin molecules with a chain length of up to 200 (Hellwege et al., 2000). Inulin in roots is varied from 30.6% to 36.7% on a dry matter basis (Costabile et al., 2010), or 50-70 g/kg of artichoke's fresh weight (Leroy et al., 2010). Inulin content in artichoke is strongly affected by storage temperature and preservation method (Leroy et al., 2010). It is a highly water-soluble carbohydrate, not digested or absorbed in the small intestine because humans lack the enzymes required for hydrolysis of fructans, but is fermented in the colon by beneficial bacteria e.g. bifidobacteria, so inulin functions as prebiotic (Lattanzio et al., 2009; Lopez-Molina et al., 2005; Frutos et al., 2008; Kelly, 2008; Frank and Bosscher, 2009), can be consumed as dietary supplements or in functional food (O' Sullivan et al., 2010). Inulin has beneficial effects on mineral absorption, blood lipid composition and prevention of colon cancer. In addition, inulin is a low-calorie carbohydrate which can be used in the production of fat-reduced foods (Frank and Bosscher, 2009; Lattanzio et al., 2009). Moreover, it can be recommended for patients suffering from diabetes mellitus (Pandino et al., 2011b) Long chain length inulins have the ability to form inulin microcrystals that have a smooth creamy texture and provide a fat-like mouth sensation. Also, long chain inulin can be used for the inhibition of the growth of ice crystals in frozen foodstuffs (Costabile et al., 2010). Accordingly, inulin has already been used successfully to replace fat in table spreads, baked products, dairy products, frozen dessert and dressing (Lopez-Molina et al., 2005). Therefore, artichoke as a source of inulin can offer new chances to the food industry for novel and healthy future products.

Recently, three proteinases (cynarases A, B, C), which are glycoproteins composed of one large and one small subunit have been purified in flowers of artichoke (Sidrach et al., 2005; Chazarra et al., 2007). These cynarases exhibit milk clotting activity, but their full properties are not well known. Still, they could have potential applications in food and pharmaceutical industries (Sidrach et al., 2005).

3. Applications Of Globe Artichoke

Globe artichoke can be eaten as a fresh, canned or frozen vegetable (Lattanzio et al., 2009; Costabile et al., 2010). Historically, this plant has been used in folk medicine since Roman times, for its health benefits which are mainly due to the high content of polyphenols and inulin (Lattanzio et al., 2009; Pandino et al., 2011a). These substances are very important for the human nutrition since they are involved in the prevention of cancer (Williamson and Manach, 2005; Clifford and Brown, 2006). Among the common edible plants, artichoke is the richest source of dietary antioxidants (Brown and Rice-Evans, 1998), therefore it could be used in phytopharmaceutical applications (Lattanzio et al., 2009; Ceccarelli et al., 2010). The pharmacologic properties of artichoke flower heads are well documented in several in vivo and in vitro studies for the treatment of hepato-biliary dysfunction, dyspeptic syndromes, gastric diseases, as well as for inhibition of cholesterol biosynthesis and low density lipoproteins (LDL) oxidation – agents responsible for arteriosclerosis and coronary heart disease (Lattanzio et al., 2009; Ceccarelli et al., 2010). Artichoke leaf extracts decreased serum lipids, as well as hepatic and cardiac oxidative stress in rats fed on high cholesterol diet (Kucukgergin et al., 2010). Also, wild artichoke extracts fed to aged rats seemed to exert cardioprotective effects (Visioli et al., 2006). According to the European Medicines Agency (2011) the pharmaceutical forms of artichoke are acceptable with respect to clinical safety.

Apart from the edible parts of artichoke, the agro-industrial by-products such as leaves, external bracts and stems which represent about the 80% of the plant biomass and could be a promising and cheap source of health-promoting polyphenolic compounds and inulin (Lattanzio et al., 2009; Pandino et al., 2011b).

According to some researchers, water extract of artichoke was reported to give protection against the suppressive effects of ochratoxin A on egg production of laying hens (Stoev, 2010) or on humoral immune response in broiler chicks (Stoev et al., 2000).

Furthermore extracts of artichoke flowers have been insufficiently investigated as a source of natural enzymes to be used in cheese manufacture as an alternative to calfrennet or in addition with it, although some researchers (Costabile et al., 2010; Sidrach et al., 2005) reported that they could be used as a vegetarian source of enzymes for cheese production, in the same way as extracts from cardoon flowers.

4. Biological Compounds Of Cardoon

The main polyphenolic compounds found in cardoon leaves are caffeoylquinic derivatives with chlorogenic acid being the highest in content (Pinelli et al., 2007). Cynarin can be found in cardoon leaves as well as in artichokes, while another phenolic substance, silymarin is isolated only in cardoon – its content in leaves varies between 0.9 – 2.7% on dry matter basis (Fernandez et al., 2006). In addition, succinylcaffeoylquinic acid compounds were detected in cardoon - their percentages were higher in the wild cardoon (26.1 – 35.2%) with large range values in the cultivated cardoon (3.9 – 17.6%), while in the artichoke leaves they were absolutely absent (Pinelli et al., 2007). According to researchers Rossoni et al. (2005), and Kukic et al. (2008), two flavones – luteolin and apigenin were also identified in cardoon. In biological assays, *C. cardunculus* extracts demonstrated antimicrobial activity comparable with some antibiotics (Mossi and Echeverrigaray, 1999; Kukic et al., 2008). Foti et al. (1999) reported that the seeds of cardoons showed the highest oil content (25.2%) among the *Cynara* spp. In another research (Curt et al., 2002) it is reported that the average cardoon oil profile was 10.7% palmitic, 3.7% stearic, 25.0% oleic and 59.7% linoleic acids.

Maccarone et al. (1999) claimed that cardoon oil, especially that belonging to wild cardoon genotypes, is of superior quality because it contains elevated amounts of oleic acid and linoleic acid, low amounts of saturated fatty acids and a significant amount of α -tocopherol, which offers stability against oxidation. Furthermore, cardoon's roots show high total sugar content (367 g / kg dry matter), inulin being the main compound (85% of total sugars) (Raccuia and Melilli, 2004). In the flowers of cardoon, a number of isoforms of aspartic proteinases called cyprosins or cardosins or cynarases (A, B, C) have been documented (White et al., 1999; Sidrach et al., 2005). According to Scintu and Piredda (2007), cardosin A and B can coagulate the milk by casein precipitation acting similarly to the enzymes chymosin and pepsin which are the main constituents of liquid or powdered rennet.

5. Traditional And Industrial Applications Of Cardoon

Traditionally cardoon has been cultivated as a vegetable for human food in some Mediterranean regions, but it is less well known that dried flowers of cardoon have been used since ancient times in southern Europe, especially Iberian peninsula as a vegetable rennet substitute (Vieira de Sa and Barbosa, 1972). In order to prepare high quality traditional goat and sheep milk cheese, suitable nowadays for vegetarian consumers (Fernandez et al., 2006; Pino et al., 2009). Moreover, cardoon leaves can be used in the preparation of alcoholic beverages as flavor (Foti et al., 1999).

Recently, interest in cardoon crop has been growing, because it offers a wide spectrum of different uses. It can be used in the production of lignocellulosic biomass for the energy – solid biofuel for heating applications (Raccuia and Melilli, 2004) or power generation (Fernandez et al., 2006). The average annual biomass yield varies from 15 to 20 t dry matter / ha, depending on soil and rain fall, with a moisture content of 10 – 15% at harvest (Gominho et al., 2009; Portis et al., 2010). It has been reported that cardoon consists of 40% stalks, 25% leaves and 35% capitula (Gominho et al., 2011). Also, the seeds of the cardoon can be used as a renewable energy source in the production of biofuels (Gominho et al., 2011). Furthermore, cynara oil is suitable for human consumption (Raccuia and Melilli, 2007).

Although cardoon is a nonwood plant, the stalks as well as the hairs and pappi in capitula (filamentous structures, representing 7% of the total plant biomass) could be used as a fibre source (17% lignin) for paper production. They can produce well delignified pulps with high yields, low rejects and very good strength properties (Gominho et al., 2001; 2009).

The roots of cardoon are a good source of inulin which has food and non food uses (Ritsema and Smeekens, 2003). Moreover, cardoon leaves find application for medicinal purposes due to the polyphenol content (Curt et al., 2002). Generally, these leaves have diuretic and hepatoprotective effects, improve gall bladder function, stimulate the secretion of digestible juices, especially bile and they can inhibit cholesterol synthesis (Fernandez et al., 2006; Grammelis et al., 2008).

6. The Use Of Cynara Crops On Ruminant Nutrition

Ensilage of artichoke by-products remaining after industrial processing is an economical and environmentally friendly way to decrease waste discharges and reduce the management cost. According to Meneses et al. (2007), these by-products are suitable for ensiling, with pleasant smell, good silage characteristics, crude protein content 88 g/kg dry matter and fibre content 509 g/kg dry matter. Such silage can be used in ruminant feeding, replacing conventional roughage sources such as hay (Gasa et al., 1989; Sallam et al., 2008). The use of artichoke bracts in lamb diets resulted in higher percentage of omega-3 fatty acids in fat deposits (Marsico et al., 1999). When artichoke silage was fed to dairy ewes, no difference was observed in milk composition, while the manufactured cheese had lower fat content and total free fatty acids than controls (Jaramillo et al., 2010).

According to Cajarville et al. (1999), green forage, dry leaves and stalks of cardoon had high nutritive value when they were fed to adult wethers. In particular, the forage had very high digestibility for organic matter (86%), while ensilage is the most appropriate way for preserving it for long periods. In another research, Cajarville et al. (2000) included in wethers' diets whole cardoon seeds and concluded that the most suitable level seemed to be around 10% in order to take advantage of the digestive effects. The above researchers reported that adding more than 10% seed to ruminant diets should be avoided in high productive animals, as the high fiber content of the seed could limit feed intake and the very low content of undergraded protein could decrease productivity.

7. Conclusion

In the near future a broader use of globe artichoke and cardoon is expected, since these two crops might be utilized in many novel applications, especially those that can satisfy the increasing consumer's demands for natural products and functional foods.

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