Chicory (*Cichorium intybus* L.) as a food ingredient – nutritional composition, bioactivity, safety, and health claims: A Review

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Abstract

Chicory (*Cichorium intybus* L.) is a perennial herb from the *Cichorium* genus, *Asteraceae* family, and is worldwide cultivated. So far, chicory has been used mainly in animal feed, but also in several cases in the food industry: as salad, for teas and tea blends, for coffee supplementation, and as a source for the inulin production. Nowadays there is an increasing interest in chicory utilization for food production and supplementation. Some compounds present in chicory, such as polyphenols, inulin, oligofructose and sesquiterpene lactones may be considered as potential carriers of food functionality. This review describes nutritional, mineral and bioactive composition of the chicory plant and summarized the main biological activities associated with the presence of bioactive compounds in the different plant parts. Finally, the review explores possibilities of uses of chicory and its implementation in food products, with intention to design new functional foods.

Keywords: chicory, nutritional composition, bioactive compounds, biological activity, food

1. Introduction

Since ancient times, plants have been studied for the purpose of their application in traditional medicine as well as in the food sector in order to improve the health benefit and sustainability of different food products. Particular attention was drawn to bioactive components present in such plants, mainly to secondary metabolites as prominent constituents which are mostly the cause of biological activity and functionality of these plants. Numerous studies have proven that many of these plants possess various biological activities (Akhtar, Ismail, Fraternale, & Sestili, 2015; Al-Snafi, 2016). Plants, seaweeds, microalgae and food by-products are the most important sources of functional compounds such as: dietary fiber, phenolic compounds, flavonoids, oils, plant sterols, proteins, prebiotics, probiotics, anthocyanins, carotenoids and many others (Da Silva, Barreira, & Oliveira, 2016; Herrero, Sánchez-Camargo, Cifuentes, & Ibáñez, 2015).

Previous scientific interest has resulted in the implementation of various plant species (such as fruits and algae) or their ingredients in different types of food products and beverages in order to find novel bioactive molecules which can bring them functionality (Mocan et al., 2017; Admassu, Zhao, Yang, Gasmalla, & Alsir, 2015). As a result, numerous scientific reviews summarized nutritional, mineral and bioactive composition of food and health potentially beneficial plants such as: lettuce (*Lactuca sativa* L.), true morels (*Morchella*) and carob pods (*Ceratonia silique* L.) (Kim, Moon, Tou, Mou, & Waterland, 2016; Tietel & Masaphy, 2018; López-Sánchez, Moreno, & García-Viguera, 2018).

According to our knowledge, only a few scientific publications investigated chicory in the context of food ingredient, and among these chicory was considered as a source of inulin, oligofructose and sesquiterpene lactones as potential carriers of functionality (Ferioli, Manco, & D'Antuono, 2015; Shoaib et al., 2016; Jeong et al., 2017).

Chicory (*Cichorium intybus* L.) is a perennial herb from the *Cichorium* genus, *Asteraceae* family, and is worldwide cultivated. The origin of this species is Europe (Mediterranean region), but it also may be cultivated in all other temperate regions and semi-arid areas (mid-Asia, northern Africa, eastern USA, Australia) (Al-Snafi, 2016; Wang & Cui, 2011). Chicory has rich nutritional composition and is potentially a rich source of bioactive substances for human food fortification: inulin, sesquiterpene lactones (especially lactucin, lactucopicrin, 8-deoxy lactucin, guaianolid glycosides, including chicoroisides B and C, sonchuside C), caffeic acid derivatives (chiroric acid, chlorogenic acid, isochlorogenic acid, dicaffeoyl tartaric acid), fats, proteins, hydroxycoumarins, flavonoids, alkaloids, steroids, terpenoids, oils, volatile compounds, vitamins (α-tocopherol, γ-tocopherol), β-carotene, zeaxanthin and minerals (Al-Snafi, 2016; Petropoulos et al., 2017). In addition to its important nutritive profile, chicory shows many types of biological activity: hepatoprotective, anti-inflammatory, antioxidant, sedative, immunological, cardiovascular, hypolipidemic, antidiabetic, anticancer, gastro-protective, antimicrobial and many others (Bahmani et al., 2015; Al-Snafi, 2016).

The aim of this review is to consolidate the nutritional composition and bioactivity of the chicory plant, describe its health beneficial properties and demonstrate *Cichorium intybus* L. plant as a potential food ingredient. The importance of plant composition information is reflected in the ability to evaluate the intake of nutrients by consuming chicory enriched food products. Furthermore, this review collects literature regarding the relationship between nutritional components and their health-related bioactivity, which is the main point of food functionality.

2. Nutritional composition of chicory

Various nutritionally important compounds detected in chicory plant indicate its rich and versatile nutritional composition. Carbohydrates, phenolic compounds, flavonoids, fatty and amino acids, sesquiterpene lactones, vitamins, and minerals have been present in the *Cichorium intybus* L. Nutritional composition of raw chicory plant (*Cichorium intybus* L.) is presented in Table 1. Many scientific papers investigated the nutritional composition of individual chicory plant parts, and that information is summarized in Table 2.

Table 1

Nutritional composition of raw chicory (*Cichorium intybus* L.) per 100 g fresh weight (f.w.)

Nutrient	Amount
Proximates	
Water	94.52 g
Energy	17 kcal/ 71kJ
Protein	0.9 g
Total lipid (fat)	0.1 g
Ash	0.47 g
Carbohydrate	4 g
Total dietary fiber	3.1 g
Minerals	
Ca	19 mg
Fe	0.24 mg
Mg	10 mg
P	26 mg
K	211 mg
Na	2 mg
Zn	0.16 mg
Cu	0.051 mg
Mn	0.1 mg
Se	0.2 μg
Vitamins	
Vitamin C	2.8 mg
Thiamin	0.062 mg
Riboflavin	0.027 mg

Niacin	0.16 mg
Pantothenic acid	0.145 mg
Vitamin B-6	0.042 mg
Total folate	37 µg
Folic acid	0 µg
Folate, food	37 µg
Folate, DFE	37 µg
Vitamin B-12	0 µg
Vitamin A, RAE	1 µg
Retinol	0 µg
Vitamin A, IU	29 IU
Vitamin D (D2+D3)	0 µg
Lipids	
Fatty acids, total saturated	0.024 g
14:0	0.001 g
16:0	0.021 g
18:0	0.001 g
Fatty acids, total monounsaturated	0.002 g
18:1	0.002 g
Fatty acids, total polyunsaturated	0.044 g
18:2	0.037 g
18:3	0.006 g
Fatty acids, total trans	0 g
Cholesterol	0 mg
Amino acids	
Tryptophan	0.016 g
Threonine	0.025 g
Isoleucine	0.054 g

Leucine	0.039 g
Lysine	0.035 g
Methionine	0.005 g
Phenylalanine	0.022 g
Valine	0.041 g
Arginine	0.066 g
Histidine	0.015 g

DFE, dietary folate equivalents; RAE, retinol activity equivalent; IU, international unit; data adopted from *http://ndb.nal.usda.gov/ndb/search*; accessed on October 28th, 2019;

Table 2

Nutritional composition of chicory (*Cichorium intybus* L.) plant parts, per 100 g of dry weigh

Content g/100g	Dry mater	Moisture	Ash	Crude fiber	Insoluble dietary fiber	Soluble dietary fiber	Total dietary fiber	Carbo-hydrates	Total soluble sugar	Inulin	Crude protein	Crude fat	Ether extract	Nitrogen free extract	Reference
Root	96.08	58	8.12	27.32							5.54		1.04	57.98	Jan et al. (2011)
Root		75.63 ± 0.39	4.25 ± 0.11	5.12 ± 1.55	30.73 ± 0.33	0.42 ± 0.07	31.15	89.41 ± 1.07	11.06 ± 1.00	44.69 ± 0.88	4.65 ± 0.25		1.69 ± 0.71		Nwafor, Shale, and Achilonu (2017)
Root		87.57 ± 0.05	8.96 ± 0.07			66.93 ± 0.01		70.43 ± 0.05	12.33 ± 0.04		5.17 ± 0.17	3.01 ± 0.5			Zarroug, Abdelkarim, Dorra, Hamdaoui, Felah, and Hassouna (2016)
Root		76.32 ± 0.2	4.45 ± 0.32					90.77 ± 0.17			3.83 ± 0.35	0.95 ± 0.04			Khalaf, El-Saadani, El-Desouky, Abdeldaiem, and Elmehy (2018)
Leaf		83.06 ± 1.55	10.91 ± 1.86	16.78 ± 2.20				70.71 ± 3.08	7.80 ± 1.45	10.95 ± 2.56	14.70 ± 1.03		3.68 ± 0.19		Nwafor, Shale, and Achilonu (2017)
Leaf	95.1		18.6	22.4				38.2			14.0	1.9			Ereifej et al. (2015)
Leaf	93.0	22.64	18.65	17.61									0.33	49.31	Jan et al. (2011)
Leaf		85.77 ± 0.15	15.13 ± 0.74					72.11 ± 0.11			10.22 ± 0.26	2.54 ± 0.07			Khalaf, El-Saadani, El-Desouky, Abdeldaiem, and Elmehy (2018)
Seed		6.40 ± 0.16	6.91 ± 0.15	25.68 ± 0.19				31.66 ± 0.42			19.57 ± 0.17	22.89 ± 0.67			Wen Ying and Jin Gui (2012) Puna chicory
Seed		6.65 ± 0.23	6.80 ± 0.20	25.68 ± 0.17				34.72 ± 0.23			19.20 ± 0.13	22.56 ± 0.23			Wen Ying and Jin Gui (2012) Commander chicory

	95.0 ± 0.20		8.4 ± 0.05							1.79 ± 0.04	10.7 ± 0.3	14.4 ± 0.2			Jurgoński, Milala, Jusbkiewicz, Zduńczyk, and Bogusław (2011)
	94.74	5.26	11.55	36.63							18.55		13.58	19.69	Jan et al. (2011) Wild chicory seeds
	95.76	4.24	17.19	38.12							14.45		10.28	19.69	Jan et al. (2011) Chicory seeds from the market

2.1. Carbohydrates

Carbohydrates, proteins and lipids are structural units and the main reserve materials in plants. Furthermore, carbohydrates express important role in plant defense response. Their content depends on plant species, cultivation method, weather conditions and other conditions which will be discussed in the following paragraphs.

Carbohydrates content in chicory parts decreases in the following order: root (70.43 - 90.77%) > leaf (38.2 - 72.11%) > seed (31.66 - 34.72%) (Table 2). (Jan et al., 2011; Nwafor, Shale, & Achilonu, 2017; Zarroug, Abdelkarim, Dorra, Hamdaoui, Felah, & Hassouna, 2016; Khalaf, El-Saadani, El-Desouky, Abdeldaiem, and Elmehy, 2018; Ereifej et al., 2015; Wen Ying & Jin Gui, 2012; Jurgoński et al., 2011). Among them, the most present are fibers and sugars (Table 2). Some studies noted variations in soluble dietary fibers (0.42 - 66.93%) and crude fiber content (5.12 - 27.32%) in chicory root (Nwafor et al., 2017; Zarroug et al. 2016). Similar crude fiber content was found in chicory leaves (16.78-22.4 g/100g dry weight (d.w.)), while crude fiber content in seeds ranged from 25.68 to 38.12 g/100 g d.w. (Table 2). Slight differences in nutritional composition may be observed between various chicory varieties and cultivation technique such as organic or mineral fertilization or soil salinization (Wen Ying & Jin Gui, 2012; Jurgoński et al., 2011; Jan et al., 2011; Sinkovič, Demšar, Žindarčič, Vidrih, Hribar, & Treutter, 2015., Petropoulos et al., 2017.).

There is a lack of information about nutritive composition of chicory stem. Shad, Nawaz, Rehman, and Ikram (2013) reported presence of 2.12±0.10 g/100g d.w. of total sugar content in chicory stem. The similar content was reported in chicory root (2.03±0.02 g/100g d.w.) while leaves and seeds contained higher amounts of total sugars (4.50±0.37 g/100g d.w. and 3.05±0.06 g/100g d.w, respectively).

Compering the carbohydrate contents in chicory to Jerusalem artichoke tubers (that varied from 55-65% depending on harvesting date) (Kocsis, Liebhard, & Praznik, 2007), and to cereals such as millet (total carbohydrates ranged 71.54-83.75 % depending on the set applied) (Chen, Ren, Zhang, Diao, & Shen, 2013), it can be concluded that chicory (especially root and leaves) may be considered as a rich and competitive source of carbohydrates. Leaves of *Cichorium intybus* L. showed higher content of crude protein, fiber, carbohydrates and lower fat content in comparison with some wild plants which could be considered as natural sources for antioxidants and valuable natural resources (Ereifej et al., 2015). Compared to chicory root, stem and seeds, leaves also showed higher contents of sugars (4.50 g/100g d.w.), and non-reducing sugars (4.27 g/100 g d.w.) (Shad et al., 2013). Fructose seems to be the most abundant sugar present in chicory seeds, 22.5% d.w. (Jurgoński et al., 2011). Some studies reported presence of saccharides in chicory flowers (*Cichorii flos*) (Judžentienė & Būdienė, 2008).

Chicory cultivar also showed a great impact on root yield and the amount of carbohydrates. Among the sugars, fructose was the most abundant compound with the content of 0.6-11.5%, then glucose (0.3-10.6%) and sucrose (2.6-11.1%) during three different experiments. Experiment 1 was devoted to determination of optimum planting and harvesting dates, experiment 2 was aimed to examine additional chicory cultivars harvested during a longer time period, while experiment 3 studied a chicory root development from the first of September through mid-November (Wilson, Smith, &Yonts, 2004). Fructan DP (degree of polymerization) was also influenced by different planting and harvesting dates, but the biggest share had fructans with DP 3-10 (28.4-60.3%), then DP 11-20 (11-31.9%) and DP>20 (1.9-25.3%) depending on planting date, cultivar, and harvest date (Wilson et al., 2004).

Robert, Happi, Wathelet and Paquot (2008) investigated yield of pectin and soluble sugars in chicory root. They concluded that extraction temperature, time, protease pretreatment, water purity, and water washing of pulps significantly affected yield and pectin composition with an increase of yield and purity of pectin in rough extraction conditions. Pectin and galacturonic acid yield varied due to extraction conditions from 35.0±03 to 242±1.0 mg pectin/g d.w. and 24-182 mg GAE/g d.w. The following sugar components dominated in the pectin extract: galacturic acid (671 to 782 mg/g d.w.), galactose (21-60 mg/g d.w.), rhamnose (10-24 mg/g d.w.), while xylose, arabinose and glucose were present in lower quantities (0-1 mg/g d.w., 5-18 mg/g d.w. and 0-3 mg/g d.w. respectively). Robert et al. (2008) also mentioned that harvest date caused the major changes in terms of neutral sugar content, while galacturonic acid content was constant during the harvest period.

According to results obtained by Jurgoński et al. (2011) chicory leaves contained 62.4 g of mono- and disaccharides on 100 g f.w., higher than in all other chicory plant parts (root, seed and peel).

2.1.1. Inulin

Chicory root is one of the major natural sources of inulin. This water-soluble storage polysaccharide belongs to a group of non-digestible carbohydrates called fructans. It is a fructose polymer with β-(2-1)-glycosidic-linkage which is a long-chain carbohydrate, consisting of 2–60 fructose molecules with a terminal glucose molecule. Inulin can play a role of fat and sugar replacer, texture modifier and as compound in functional food development due to its prebiotic properties. Many studies investigated inulin provided health benefits including: regulation of blood lipids (LDL-cholesterol and triacylglycerol) concentration, positive effect on constipation, bifidogenic effect with bacteria in the colon, decreasing the risk of many gastrointestinal diseases (ulcerative colitis, Crohn's disease, colon cancer), enhancing mineral absorption (especially Ca, Mg and Fe), regulates appetite by affecting gastrointestinal hormones, immune-modulating effects and others (Shoaib et al., 2016). Many studies reported different amounts of inulin presented in chicory root. That content varies from 11-20 g inulin/100 g in the fresh root (Figueira, Jin, Brod, & Honorío, 2004) to 44.69% inulin on dry root weight basis (Nwafor et al., 2017). Chicory root (11-20 g/100 g) possesses similar or higher amount of inulin compared to inulin rich plants: barley grains (18-20 g/100 g), Jerusalem artichoke tubers (12-19 g/100 g), asparagus roots (15 g/100 g), agave stem (12-15 g/100g), dandelion roots (12-15 g/100 g) and dahlia tuber (10-12 g/100 g) (Shoaib et al., 2016). Milala, Grzelak, Król, Juśkiewicz and Zduńczyk (2009) investigated inulin and total fructan content in chicory peel, root, leaves and seed. They obtained 14.5% inulin in the root (calculated on the dry matter) and 61.8% of total fructans. These values were the highest in comparison with other chicory plant parts. Chicory root yield and inulin content is significantly influenced by year's weather conditions, as reported in the study of Černý, Pačuta and Kovár (2008). They reported 18.13-22.93 % of inulin in dry chicory root. The main factors which affect root yield, the content of inulin and the length of the inulin chains are the sowing date, the harvest date and the genotype. The significant reduction of the average inulin chain length may be noticed in the autumn when degrading fructan enzymes are the most active. This leads to the conclusion that early harvested plants (in September) are rich in longer-chain inulin molecules (Roustakhiz & Majnabadi, 2017).

There are different reports about the DP of inulin from chicory root. Roberfroid and Delzenne (1998) stated that chicory inulin is a long chain fructan with DP 2-60. Vandoorne et al. (2014) investigated flooding stress impact on root growth, inulin content and inulin DP. Control samples showed 10.6 to 15.1

mean DP and 67.1 to 85.7 g inulin/ 100g d.w., depending on number of weeks after sowing. Samples obtained after flooding noted 10.1 to 12.3 mean DP and inulin amount of 76.4 to 85.0 g/100g d.w. in root. Monti, Amaducci, Pritoni and Venturi (2005) explained that the fructan average DP of single chicory root (commonly 10–20) is the average of short (fewer than 10 units) and long fructan chains (about 60). Chicory seeds contain the smallest amount of total fructans (1.9% d.w.) in relation to chicory root, peel and leaves (61.8% d.w., 47.7% d.w., 3.3% d.w., respectively), with inulin content of 0.3% d.w. (Milala et al., 2009).

2.2. Volatile compounds

The composition of volatile organic compounds in plants is species specific and affected by external conditions, including the availability of environmental factors such as light, nutrients and water (Kegge & Pierik, 2010). Their composition is also influenced by method of extraction. Extraction methodologies for volatile compound isolation from chicory applied organic solvents such as petroleum ether, chloroform, hexane and ethyl acetate (Nandagopal & Kumari, 2007). In the study of Judžentienė and Būdienė (2008), the volatile fractions from chicory root and chicory areal parts were isolated by hydrodistillation for 2 h with the Clevenger type apparatus with a mixture of pentane and diethyl ether (1:1). Solid-phase micro extraction (SPME) may also be used for isolation of volatile compounds from chicory according to Bais, Dattatreya, and Ravishankar (2003).

Volatile oils are found in all parts of the plant, with the highest concentration in the roots which have been found to be effective at eliminating intestinal worms in humans (Athanasiadou, Githiori, & Kyriazakis (2007). Gol, Noghani and Chamsaz (2014) reported 48 different compounds from chicory root essential oil with camphor (20.74%), cymene (15.06%), gamma-terpinene (13.24%) and cuminal (10.79%) as major components. It can be noted that chicory root contains higher amount of camphor, gama-terpinene and cymene (20.74%, 13.24% and 15.06%, respectively) compared to *Salvia officinalis* (11.25%, 0.08% and 0.07%, respectively) (Radulescu, Chiliment, & Oprea, 2004). Other volatile compounds found in chicory root are octane (34.3-69.8%), nonadecane (0.3-3.9%), aliphatic compounds and their derivates (64.1-81.3%) and tentatively identified compounds (4.8-22.7%) (Judžentienė &

Būdienė, 2008). Hexadecanoic acid (32.9%), nonadecane (26.1 %) and trans-α-bergamotene (14.0 %) were the most abundant volatile oil compounds from chicory areal parts reported in study of Rustaiyan, Masoudi, Ezatpour, Danaii, Taherkhani, and Aghajani (2011). Besides that, the oil contained also three sesquiterpene hydrocarbons, two oxygenated sesquiterpenes and nine aliphatic compounds with share of 17.1%, 4.8% and 78.1 %, respectively. Bais et al. (2003) identified volatile aromatic compounds (propyl isovalerate, undecanal, nonanol, isoamyl nonanoate and 2-decene-1-ol) in hairy chicory root after impact of fungal elicitors. *Cichorium intybus* L. leaves showed 7.43% oil yield, with better essential oil antifungal activity against *Ganoderma lucidum* than against *Bacillus subtilis* (Hanif, Bhatti, Jamil, Anjum, Jamil, & Khan, 2010). The *p*-cymol (17.12%), γ-terpinene (15.18%), cuminal (10.53%) and thymol (9.38%) were the most abundant compounds present in chicory leaves essential oil in study of Gol et al. (2014).

2.3. Phenolic compounds

Phenolic compounds are one of the most important groups of compounds responsible for various plant bioactivities. With its great morphological diversity, chicory presents the rich source of phenolic compounds, especially phenolic acids and flavonoids. Phenolic composition of chicory is highly influenced by cultivar and fertilizer administration. Moreover, the content of phenolic components varies depending on the part of the plant, with chicory seed and leaf as the richest parts.

2.3.1. Total phenolic content

Total phenolic content of 20.0±0.90 mg gallic acid equivalent (GAE)/g for dry methanolic chicory root extract was reported by Nwafor et al. (2017). Denev, Petkova, Ivanov, Sirakov, Vrancheva, and Pavlov (2014) noted different amounts of total phenolic content depending on the chicory culture, the harvest date and extraction solvent. According to these data total polyphenolic content varied from 3.7 to 7.9 mg GAE/ g d.w. Total phenolic contents were significantly different for wild and cultivated chicory root (22.4 and 35.1 mg GAE/100 g, respectively) (Spina et al., 2008). Total phenolic content seems to be noticeable higher in chicory leaves, compared to other plant parts. According to Khalaf et al. (2018), total phenolic content in chicory leaves was 865.91 mg GAE/100 g (d.w.). Heimler, Isolani, Vignolini and

Romani (2009) determined contents of total phenolics in chicory leaves and noted amounts of 404.6 to 696.3 mg GAE/100 g f.w. By comparing results obtained by Lin and Tang (2007) and previously mentioned studies devoted to the determination of total phenolic content in chicory leaves, it seems that chicory leaves contain a higher amount of total phenolics when compared to different fruits (strawberry, oriental plum, loquat) and vegetables (green, yellow, and red paper, red and white onion, ceylon spinach, bitter melon, beetroot). In study of Milala et al. (2009), lyophilized extract obtained from chicory seeds was the richest in polyphenol compounds compared to root, peel and leaves, and contained more than 10% of total phenolics.

2.3.2. Phenolic acids

Milala et al. (2009) determined 0.3% (d.m.) caffeoylquinic acids and 0.2% (d.m.) dicaffeoylquinic acids in root of *Cichorium intybus* L. Juśkiewicz, Zduńczyk, Żary-Sikorska, Król, Milala, and Jurgoński (2011) stated content of caffeoylquinic acids (0.50 g/100 g), monocaffeoylquinic acids (0.30 g/100 g) and dicaffeoylquinic acids (0.20 g/100 g) in lyophilized chicory root. By analyzing ethanol extract of chicory seeds, Jurgoński, Juśbkiewicz, Zdunczyk and Bogusław (2012) determined 9.6 g phenolic compounds/100 g fresh mass including mono- and dicaffeoylquinic acids (caffeoylquinic acids (CQA) , 2.8 g/100 g f.w. and 6.8 g/100 g f.w. respectively), with antioxidant activity of 505.1 nmol Trolox equivalent (TE)/g. They also confirmed that CQA-rich extract from chicory seeds in improving diet-induced metabolic disturbances. Pandino, Courts, Lombardo, Mauromicale, and Williamson (2010) reported total caffeoylquinic acid content in wild cardoon (0.0021% d.w.) and in globe artichoke (0.0071-0.2514% d.w.), which indicates that chicory possesses higher contents of these acids. On the other side, leaves of *Acanthopanax trifoliatus* (Asian vegetable and medical plant), harvested at different seasons contained mono and dicaffeoylquinic acids varied from 0.25-0.90% and 0.10-1.36% (Sithisarn, Muensaen, & Jarikasem, 2011).

Willeman et al. (2014) reported the presence of chlorogenic acid in chicory root, flour and roasted grains at levels of 100.2 μg/g of d.w., 1547 μg/g, and 822.5 μg/g, respectively. Khalaf et al. (2018) reported 272.48 mg/100 g d.w. chlorogenic acid, while Bahri et al. (2012) quantified hidroxycinnamic acids in leaf tissue of *Cichorium intybus* L. and noted average concentrations of 130 mg/kg f.w. for chlorogenic acid. In study of Nwafor et al. (2017), chlorogenic acid content was 17.84% in chicory root.

According to results obtained by Jurgoński et al. (2011) fresh chicory contained 2.13 g/100 g of chicoric acid. *Cichorium intybus* L. leaves are also rich in chicoric acid with content of 370 mg/kg f.w. reported by Bahri et al. (2012). Moreover, chicoric acid in leaves (0.87 to 6.14 mg/g) was determined by Heimler et al. (2009).

Caffeic acid is present in chicory root with content of 35.22% (Nwafor et al., 2017), as well as 1.27 mg/100 g d.w. in leaves (Khalaf et al., 2018).

Protocatechuic (2.50%, 7.98 mg/100 g d.w.), *p*-hydroxybenzoic (11.04%), iso vanillic (1.97%, 30.66 mg/100 g d.w.) and *p*-coumaric acids (9.65%, 22.84 mg/100 g d.w.) were also present in chicory root and leaves, respectively (Nwafor et al., 2017; Khalaf et al., 2018). Khalaf et al. (2018) identified some phenolic acids in chicory leaves including gallic acid (1.52 mg/100 g d.w.), 4-amino-benzoic (8.61 mg/100 g d.w.), *p*-OH-benzoic (11.93 mg/100 g d.w.), caffene (68.76 mg/100 g d.w.), ferulic acid (5.85 mg/100 g d.w.), iso-ferulic acid (49.10 mg/100 g d.w.), e-vanilic acid (131.02 mg/100 g d.w.), benzoic acid (77.50 mg/100 g d.w.), ellagic acid (91.19 mg/100 g d.w.), alpha-cumaric (7.58 mg/100 g d.w.), 3,4,5-methoxy-cinnamic (6.37 mg/100 g d.w.), salycilic acid (15.76 mg/100 g d.w.) and cinnamic acid (0.70 mg/100 g d.w.). Bahri et al. (2012) quantified hidroxycinnamic acids in leaf tissue of *Cichorium intybus* L. and noted average caftaric acid concentrations of 246 mg/kg fresh weight (f.w.).

Shad et al. (2013) determined total phenolic acids in chicory stems, and reported content of 2.09±0.21g/100g d.w.

2.3.3. Flavonoids

The flavonoid content in leaves was found at 112.38 mg quercetin equivalent (QE)/100 g d.w. in study of Khalaf et al. (2018), apropos 4.96 to 21.80 mg catechin/100g f.w. (Heimler et al., 2009). The range of these values was conditioned by first and second sampling, as well as the way of chicory farming (conventional or biodynamics). Total flavonoids (0.08±0.03 g/100g d.w.) were also determined in chicory stems (Shad et al., 2013). In their study of weed seeds, Abbas, Rana, Shahid, Mahmood-ul-Hassan and Hussain (2012) reported the presence of flavonoids in *Cichorium intybus* L. seeds, in content of 14.13%).

By comparing total flavonoid content in strawberry (14.6 mg QE/100 g f.w.), oriental plum (37.6 mg QE/100 g f.w.), mulberry (250.1 mg QE/100 g f.w.), loquat (14.2 mg QE/100 g f.w.), green (7.5 mg QE/100 g f.w.), yellow (4.1 mg QE/100 g f.w.), red (10.4 mg QE/100 g f.w.) paper, red (36.5-56.4 mg QE/100 g f.w.) and white (30.6 mg QE/100 g f.w.) onion, ceylon spinach (133.1 mg QE/100 g f.w.), bitter melon (15.0 mg QE/100 g f.w.), beetroot (62.8 mg QE/100 g f.w.), with total flavonoid content in different parts of chicory plant, it may be concluded that chicory leaves are promising source of flavonoids (Lin & Tang, 2007).

Quercetin glucuronide (0.74±0.02 g/100g f.w.) as well as luteolin glucuronide (0.98±0.216 to 3.33±0.05 mg/g) were detected only in chicory leaves (Jurgoński et al., 2011, Heimler et al., 2009).

According to Mulabagal, Wang, Ngouajio, and Nair (2009) the most abundant anthocyanin (>95) in leaves from five different *Cichorium intybus* L. cultivars was cyanidin-3-O-(6”-malonyl-β-glucopyranoside). They also noted that anthocyanin from chicory leaf in its pure form presents *in vitro* activities similar to aspirin and may show anti-inflammatory activity *in vivo*. Nørbæk, Nielsen, and Kondo (2002) investigated anthocyanins from flowers of *Cichorium intybus* L. and reported the presence of four anthocyanins: delphinidin 3,5-di-O-(6-O-malonyl-β-D-glucoside), delphinidin 3-O-(6-O-malonyl-β-D-glucoside)-5-O-β-D-glucoside, delphinidin 3-O-β-D-glucoside-5-O-(6-O-malonyl-β-D-glucoside) and delphinidin 3,5-di-O-β-D-glucoside. 3-O-*p*-coumaroyl quinic acid has been identified also, for the first time.

Khalaf et al. (2018) identified some phenolic compounds in chicory leaves including catechein (96.41 mg/100 g d.w.), catechol (5.13 mg/100 g d.w.), epicatachin (13.12 mg/100 g d.w.) and coumarin (11.10 mg/100 g d.w.). In the study of Spina et al. (2008) the content of epigallocatechin gallate in wild and cultivated chicory root was similar (16.5 µg/g and 17.53 µg/g respectively). Tannins are also present in *Cichorium intybus* L. seeds in percent of 14.53±0.02 (Abbas et al., 2012).

2.4. Amino acids and proteins

Amino acids are organic compounds containing amino and carboxyl functional groups, that are building blocks of life. They are present in plants, animals and humans and they have an important role in human health maintenance. The levels of amino acids vary and many plant defense responses against biotic or abiotic stress involve metabolic adjustments in amino acid metabolism and their presence. Some of them are determined in chicory and their presence is described.

Foster, Fedders, Clapham, Robertson, Bligh, & Turner (2002) reported different amounts of amino acids present in chicory rossete leaves differed by cultivation date and cultivar. They noticed similarities in amino acid composition among the cultivars and decrease of cisteine and hydroxyproline as well as decrease in total N concentration with latter harvested period. The major amino acids contained in rossete leaves were glycine (72.2-91.7 µmol/g d.w.), alanine (61.6-84.7 µmol/g d.w.), leucine (64.0-93.2 µmol/g d.w.), aspartate plus asparagine (60.9-83.5 µmol/g d.w.) and glutamate plus glutamine (69.5-96.2 µmol/g d.w.).

Glutamine, glutamate, asparate, asparagine, glycine, serin and arginin are the main amino acids in chicory root and leaves, while ornithin, proline, threonine, isoleucine, valine, leucine, alanine, histidine, lysine, phenylalanine and γ-butiric acid are present in lower amounts (Druart, Goupil, Dewaele, Boutin, & Rambour, 2000). Salty soil conditions may improve proline accumulation both in wild chicory root and leaves as plant response to stress (Sergio et al., 2012).

Total content of amino acids in two varieties of chicory seeds was in the range of 10.61-14.91 %, with glutamic acid (2.14-3.58%), aspartic acid (1.11-1.58 %), arginine (1.04-1.54%), glycine (0.79-0.99 %) and leucine (0.63-0.99 %) as the most abundant acids (Wen Ying & Jin Gui, 2012). Chicory seeds may be considered as good source of amino acids when compared to oil seeds and legumes such as sunflower (4.889-5.083% glutamic acid, 2.201-.3.002% aspartic acid, 1.586-2.194% arginine, 0.934-1.332% glycine and 1.490-1.511% leucine), safflower (0.021-0.363% glutamic acid, 0.201-0.247% aspartic acid, 1.559-1.665% arginine, 0.857-1.022% glycine and 1.002-1.023% leucine) and ground nut (1.397% glutamic acid, 3.459% aspartic acid, 2.795% arginine, 1.232% glycine and 1.622% leucine) (Ingale & Shrivastava, 2011).

The water-soluble proteins are the most abundant in chicory, followed by approximately similar contents of a salt soluble protein and free amino acids. Leaves have higher content of free amino acids and water-soluble protein content while roots contain appreciable amount of salt soluble protein content, taking into account their contents in chicory root, leaves, stem and seeds (Al-Snafi, 2016).

Water soluble proteins in stems (9.43±1.77 g/100g d.w.) where higher than in chicory roots and seeds (5.57±0.58 g/100g d.w. and 8.35±1.82 g/100g d.w, respectively), while chicory leaves contained 14.13±1.50 g/100g water soluble proteins. Salt soluble proteins were abundant in stems at amount of 6.85±0.38 g/100g d.w., similar as in leaves and seeds (6.91±0.53 g/100g d.w. and 6.81±0.51 g/100g d.w, respectively), while root contained 7.94±0.30 g/100g d.w. Free amino acids in stems were present in content of 5.98±0.31% g/100g d.w more than in roots and seeds (a 1.23±0.07 g/100g d.w. and 2.03±0.05 g/100g d.w, respectively) while leaves were the richest in free amino acids content (8.46±0.24) (Shad et al., 2013).

According to Table 2, chicory seeds are the richest source of crude protein (11.26 to 19.57%), followed by leaves (10.22 to 14.70%) and root (3.83 to 5.54%). In the study of Akeel, Al-Sheikh, Mateen, Syed, Janardhan, and Gupta (2014) concentration of protein in *Cichorium intybus* L. seeds was reported to be in the range 110.8-146.6 μg/ml depending on pH (6.5 and 7.4). When compared to crude protein content in *Datura innoxia* (17.21, 13.90, 2.09% in leaf, seed and root respectively) (Ayuba, Ojobe, & Ayuba, 2011), and buckwheat (22.7, 13.1, 5.6% in leaf, seed and root respectively) (Vojtíšková, Kmentová, Kubáň, & Kráčmar, 2019), chicory plant represents good source of proteins.

The RDA (Recommended Daily Allowance) for adult men and women is 0.80 g of protein/ kg of body weight/day. According to this statement a 70-kilogram woman should eat 56 grams of protein each day. The intake range of 10 to 35 percent set for protein provides a reasonable guideline for how much protein should be part of a balanced and healthy diet (Lupton, 2002). Due to this recommendation, chicory seeds and leaves containing more that 10% of crude proteins are good sources of proteins from a dietary point of view.

2.5. Minerals

Minerals are needed for growth, metabolic functioning, and normal plant life cycle. Additionally, environmental stresses (salinity, drought, extreme temperatures, light conditions) affect mineral content in different way, depending on the species or cultivar, and the specific plant organ. Furthermore, minerals are essential in human metabolism and body functions. *Cichorium intybus* L. mineral diversity is detailed in Table 3.

Chicory root is a good source of minerals including calcium, potassium, sodium and magnesium which are distinguished by content compared to other minerals in the root (Nwafor et al., 2017; Jan et al. 2011; Harrington, Thatcher, & Kemp, 2006; Foster, Clapham, Belesky, Labreveux, Hall, & Sanderson, 2006). Harrington et al. (2006) noticed the benefits of mineral composition of chicory root along with some common pasture weeds such as perennial ryegrass, white clover, and dandelion, due to the content of P, S, Mg, Na, Cu, Zn and B.

Rosa et al. (2017) reported also the presence of Cr (0.0736 mg/100 g), Al (14.602 mg/100 g), Cd (0.019 mg/100 g), Ni (0.0574 mg/100 g), Co (0.0149 mg/100 g) and Si (6.78 mg/100 g), in chicory leaves. Abbas, Saggu, Sakeran, Zidan, Rehman, and Ansari (2015) noted high amount of mineral elements especially Ca (3.5%) and Mg (0.28%), while Se content was 3.2 mg/100 g. Reported silicon content is within limit of the daily intake from the British diet, even though a safe recommended dietary allowance as well as tolerable upper intake level for Al, Cd, Ni, Co and Si hasn't been set yet for human diet.

Wen Ying and Jin Gui (2012) compared chemical composition of two varieties of chicory seeds (Puna chicory and Commander chicory) with alfalfa and corn seeds. Chicory seeds proved to be more dominant in the appearance of the mineral composition with higher contents of K (5.92 to 6.49 mg/g), Ca (19.52 to 20.09 mg/g), P (9.43 to 9.45 mg/g), Mg (3.59 to 3.96 mg/g), Cu (22.33 to 23.00 µg/g), Zn (55.50 to 60.83 µg/g) and Mn (32.83 to 37.66 µg/g).

By comparing wild and cultivated chicory seeds offered at the markets, Jan et al. (2011) noted slight differences in Mn and Ca content, as it is shown in Table 3. They reported that seeds are especially rich in Ca, K, Mg and Na.

The mineral composition of the flower was not much studied. According to Szentmihàlyi, Marczal and Then (2006), chicory flower is rich in Fe (15.52 mg/100 g d.w.), Al (10.26 mg/100 g d.w), Mn (4.316 mg/100 g d.w), Zn (4.20 mg/100 g d.w) and B (3.66 mg/100 g d.w), as presented in Table 3. Compared to leaves, shoots root and herb, flowers seem to contain the smallest content of mineral elements. Al, As, B, Ba, Cr, Cu, Fe, Mn, Ni, Ti and Zn were present at significantly different concentrations in these plant parts.

Table 3

Mineral composition of chicory plant parts

Mineral mg/ 100g	Ca	K	N	P	S	Mg	Na	Fe	Cu	Mn	Zn	Pb	Co	Se	Mo	Reference
Root	181.26 ± 4.40	103.7 ± 4.62				20.14 ± 1.69	67.42 ± 2.45	1.77 ± 0.21	0.36 ± 0.02	0.31 ± 0.10	0.39 ± 0.03	0.04 ± 0.003				Nwafor, Shale, and Achilonu (2017)
	360	1700				300	50		2.7	7.5	4					Jan et al.(2011)
	540 ± 0.00	380 ± 0.00					140 ± 0.00	0.74 ± 0.01	0.07 ± 0.01	0.26 ± 0.01	0.17 ± 0.1	0.79 ± 0.01	0.09 ± 0.01			Zarroug, Abdelkarim, Dorra, Hamdaoui, Felah, and Hassouna (2016)
	1180	3800	4350	663	627	393	591	16.7	1.86	16.1	5.77		0.027	0.004	0.042	Harrington, Thatcher, and Kemp (2006)
	1280	2860		280	410	270		17100	1100	8700	3100					Foster, Clapham, Belesky, Labreveux, Hall, and Sanderson (2006)
Leaf	248.16	4550.96		842.82		124.02	51.08	19.18	1.045	6.28	2.28		0.0149		0.0152	Rosa et al. (2017)
	3500					280	80.0		3.2	7.1	4.72			0.032		Abbas, Saggu, Sakeran, Zidan, Rehman, and Ansari (2015)
	2500	2500				750	60		2.5	10.0	5.0					Jan et al. (2011)
	292.61 ± 13.35	166.57 ± 3.43				6.94 ± 5.86	88.84 ± 2.58	9.17 ± 0.85	0.60 ± 0.06	0.90 ± 0.01	0.91 ± 0.03	0.03 ± 0.01				Nwafor, Shale, and Achilonu (2017)
Seed	2000	1170				500	560		1.5	2.5	6.5					Jan et al.(2011) Wild seed

	3000	1100				650	510		1.3	6.5	6.0					Jan et al.(2011) Market seed
Flower								15.52 ± 1.2	2.23 ± 0.2	4.316 ± 0.14	4.20 ± 0.44					Szentmihàlyi, Marczal, and Then (2006)

2.6. Fatty acids and derivatives

Lipids are mostly present in plant cell membranes and may act as plant energy stores. Applied cultivation practice may affect lipid profile of plant. Fatty acids, especially omega-3, 6, 9 express important health benefits in human body. Many fatty acids and their derivatives were described in chicory.

Average total lipid content in chicory leaves was 0.13 g/100g wet weight (w.w.), lower than in other three wild edible Mediterranean *Asteraceae* plants: *Taraxacum obovatum, Chondrilla juncea* and *Sonchus oleraceus* (García-Herrera et al., 2014). Chicory plant contains significant quantities of the next fatty acids in descending order: linoleic, palmitic, linolenic, stearic, behenic and eicosanoic acids, and 2.5 % of oil (Kam & Kanberoglu, 2019).

Fathalla, Bishr, Singab, and Salama (2015) investigated fatty acid methyl esters of *Cichorium intybus* L. seeds and reported the presence of lauric acid methyl ester (0.13 %), myristic acid methyl ester (0.06 %), palmitoleic methyl ester (0.38 %), palmitic acid methyl ester (19.77%), methyl dihydromalvalate (0.44 %), 9,12- linoleic methyl ester (58.98 %), stearic acid methyl ester (9.07 %), methyl linolelaidate (0.59 %), linolenic acid methyl ester (0.81 %), 11-eicosenoic acid methyl ester (0.65 %) and eicosanoic acid methyl ester (1.69 %). Najib, Ahamad, Ali and Mir (2014) reported the presence of five fatty acid esters in methanolic extract of the seeds of *Cichorium intybus* L.: *n*-hexadecanyl hexadecanoate, *n*-pentadecanyl octadec-9-enoate, *n*-hexadecanyl octadec-9-enoate, *n*-hexadecanyl octadecanoate and *n*-octadecanyl octadecanoate.

The total fatty acid content in leaves of nine chicory cultivars ranges from 104 to 644 mg/100 g f.w., where α-linolenic acid (64%) is dominant. Chicory leaves are not so rich in fatty acids when compared to coriander (*Coriandrum sativum* L.) where the highest total fatty acid content was found in basal leaves with 61.21 mg/g d.w., followed by upper ones (41.8 mg/g d.w.) depending on different salt conditions during cultivation (0, 25, 50 and 75 mM of NaCl) (Neffati & Marzouk, 2008). The most abundant fatty acid in chicory leaves seems to be α-linolenic acid, followed by linoleic and palmitic acids. An n-6/n-3 polyunsaturated fatty acids ratio of forced chicory is 1.38 and differs among cultivars. Among unsaturated fatty acids, oleic acid is the only one determined in chicory samples. Significant differences in content of fatty acids present in wild and cultivated chicory leaves was reported, while chicory leaves contains more α-linoleic acid than lettuce (20%) and spinach (40%) (Elgersma, Søegaard, & Jensen, 2013; Sinkovič, Hribar, Vidrih, Ilin, & Žnidarčič, 2015; Jančić, Todorović, Basić, & Šobajić, 2016).

2.7. Sesquiterpene lactones

Sesquiterpene lactones are secondary plant metabolites mostly known from the *Asteraceae* family. *Cichorium intybus* L. is a rich source of sesquiterpene lactones, which have role in plant defense (Rees & Harborne, 1985). They are also considered as potential carriers of functionality with many positive bioactivities reported.

Chicory root is a rich source of bitter-tasting sesquiterpene lactones, which promote appetite and digestion. Sesquiterpene lactones are soluble accumulating metabolites in *Asteraceae*, especially in chicory, mainly present in the latex (Wulfkuehler, Gras, & Carle, 2013; Willeman et al., 2014). The most abundant sesquiterpene lactones isolated from the root of *Cichorium intybus* L. are lactucin, 8-deoxylactucin, 11(S),13-dihydro-8-deoxylactucin, lactucopicrin, 11(S),13- dihydrolactucopicrin, jacquinelin, crepidiaside B, lactuside A (Ripoll et al., 2007b; Beharav et al., 2010; Wulfkuehler et al., 2013; Willeman et al., 2014). Kisiel and Zielińska (2001) reported that lactucin-like guaianolides and their glycosides are the most abundant lactones present in roots and aerial parts of *Cichorium* species. Furthermore, roots of the plants produce a small number of germacrane- and eudesmane-type sesquiterpene lactones and their glycosides. Poli et al. (2002) mentioned that sequiterpene lactone content depends on the harvest date. Despite the bitter taste, sesquiterpene lactones derived from chicory root have many important activities such as: anti-inflammatory, anti-tumour, anti-leukaemic, cytotoxic, antimicrobial, allergenic, antioxidant, antibiotic, anti-cancerigenous, antiprotozoal, anthelmintic, antimalarial, sedative and anti-diabetic activity, inhibits egg hatching of *Haemonchus contortus*, promots appetite and digestion in humans, protects plants against herbivore attacks and helps signaling between plants (Schmidt, Ilic, Poulev, & Raskin, 2007; Ferioli & D’Antuono, 2012; Ferioli et al., 2015; Verma et al., 2013; Zhang, Yan, Wang, & Liu, 2016; Fan et al., 2017; Peña-Espinoza, Williams, Thamsborg, Simonsen, & Enemark, 2017; Giambanelli, D’Antuono, Ferioli, Garrido Frenich, & Romero-González, 2018).

Ferioli and D’Antuono (2012) detected various sesquiterpene lactones in leaves of two different cultivars of chicory. They quantified the presence of free and bounded forms of sesquiterpene lactones, and their content was: 11(S), 13-dihydrolactucin (437.4 mg/kg d.w.), lactucin (350.3 mg/kg d.w.), 8-deoxylactucin (598.8 mg/kg d.w.), 11(S),13-dihydro-8-deoxylactucin (613.9 mg/kg d.w.), 11(S),13-dihydrolactucopicrin (69.5 mg/kg d.w.) and lactucopicrin (315.7 mg/kg d.w.). According to Ferioli et al. (2015) chicory is richer in total sesquiterpene lactones (383–2497 mg/kg d.w.) when compared to endive (128–2045 mg/kg d.w.). Foster, Cassida and Sanderson (2011) investigated variation in sesquiterpene composition and concentration in chicory leaves during growth. They stated that concentration of total sesquiterpene lactone generally decreases or remains constant, while composition of sesquiterpene lactones during the growing period varied among the forage chicory cultivars.

2.8. Vitamins

Only a few studies mentioned vitamin content in chicory. Chicory leaves are rich in B_1, B_2, B_6 and C, with average amounts of 133,4 to 156.7 μg/ 100 g f.w., 112.4 to 116.1 μg/100 g f.w., 162.8 to 168.7 μg/ 100 g and 3.5 to 4.0 μg/ 100 g f.w. in wild and cultivated chicory plants, respectively, while the content of vitamin A in leaves was reported to be 0.45 mg/100 g f.w. (Jančić et al., 2016).

3. Biological activity

In recent years, many studies reported diverse bioactivity of compounds isolated from the chicory. Phenolic compounds including gallic acid, protocatechic acid, chicoric acid, chlorogenic acid, caftaric acid, (Heimler et al., 2009), hexoside (Dalar & Konczak, 2014), flavonoids (Khalaf et al., 2018), inulin (Shoaib et al., 2016), sesquiterpene lactones (Schmidt et al. 2007), coumarins (Khalaf et al., 2018) or other compounds present in chicory extracts were considered as responsible for positive impact on human health. Some of the proven bioactivities from compounds detected in chicory are antiradical (Kagkli, Corich, Bovo, Lante, & Giacomini, 2016), antimicrobial (Verma et al., 2013), antioxidant (Abbas et al., 2015), hepatoprotective (Neha et al., 2014), antibacterial (Liu, Wang, Liu, Chen, & Cui, 2013), antidiabetic (Abdel-Rahim, Rashed, El-Hawary, Abdelkader, Kassem, & Mohamed, 2016), anthelmintic (Peña-Espinoza, Williams, Thamsborg, Simonsen & Enemark, 2017) and anti-parasitic activity (Peňa-Espinoza, Boas, Williams, Thamsborg, Simonsen, & Enemark, 2015). Bioactivity of chicory compounds is presented in Table 4.

Table 4

Summarized bioactivity of *Cichorium intybus* L.

Bioactivity/Health condition	**Plant part**	**Extract type**	**Compound/s**	**Reference**
Anti-hepatotoxic activity	Chicory plant	Ethyl-acetate extracts		Li, Gao, Huang, Lu, Gu, and Wang (2014)
	Leaf	Water extract	Cichoric acid	Zhang et al. (2014)
	Leaf	Ethanolic extract	Flavonoids	Neha et al. (2014)
	Seed	Alcoholic extract	Phytoconstituents from extract such as flavonoids, saponins and their glycosides	Fathalla, Bishr, Singab, and Salama (2015)
Anti-diabetic	Plant (root, leaves, and stems)	Ethanolic extract	Potentially inulin	Pushparaj, Low, Manikandan, Tan, and Tan (2007)
	Leaf		Potentially fibers (inulin)	Abdel-Rahim, Rashed, El-Hawary, Abdelkader, Kassem, and Mohamed (2016)
	Seed	Aqueous extract	Phytochemicals such as anthocyanins, tannins, coumarins, chicoric acid, chlorogenic acid, and caffeic acid	Ghamarian, Abdollahi, Su, Amiri, Ahadi, and Nowrouzi (2012)
Antimicrobial	Root	Ethyl acetate extract		Koner, Ghosh, and Roy (2011)
	Root and leaf	Methanolic extract	Potentially inulin, sesquiterpene lactones, coumarins, flavonoids.	Verma et al. (2013)
	Root		Sesquiterpenoid lactones from chicory root: cichoralexin, 10 α-hydroxycichopumilide and 8 α-angeloyloxycichoralexin; terpenoids and phenolics.	Nishimura and Satoh (2006)
	Leaf		Phenolic compounds - gallic acid, protocatechic acid, chicoric acid and chlorogenic acid.	Kagkli, Corich, Bovo, Lante, and Giacomini (2016)

	Leaf and root	Ethanolic and methanolic extracts of γ-irradiated chicory	Phenolic compounds and flavonoids	Khalaf, El-Saadani, El-Desouky, Abdeldaiem, and Elmehy (2018)
	Seed	Methanolic extract and ethylacetate fraction	Alkaloids, flavonoids, saponins, tannins, steroids, anthraquinone.	Mehmood, Zubaır, Rızwan, Rasool, Shahid, and Ahmad (2012)
	Seed	Aqueous and organic (ethanol and ethyl acetate) extracts	Watersoluble compounds (inulin, flavonoids, etc)	Shaikh, Rub, and Sasikumar (2016)
	Flower	Ethyl acetate extract		Petrovic, Stanojkovic, Comic, and Curcic (2004)
Antioxidant	Root	Ethanolic extract	Caffeoylquinic acid	Liu et al. (2013)
	Flower	Methanolic extract	Phenolic compounds	Derakhshani, Hassani, Pirzad, Abdollahi, and Dalkani (2012).
	Leaf	The ethanolic and methanolic extracts of γ-irradiated chicory	Phenolic compounds and flavonoids	Khalaf, El-Saadani, El-Desouky, Abdeldaiem, and Elmehy (2018)
	Seed	The methanolic extract and ethylacetate fraction	Alkaloids, flavonoids, saponins, tannins, steroids, anthraquinone.	Mehmood, Zubaır, Rızwan, Rasool, Shahid, and Ahmad (2012)
Anti-inflammatory	Root	Polar solvent extract	Sesquiterpene lactones	Ripoll, Schmidt, Ilic, Poulev, and Raskin (2007a) Ripoll et al. (2007b)
Antihyperglycemic	Root	Water extract Methanolic extract partitioned with ethyl acetate	Chicoric acids: Caffeic and ferulic acids Caffeic acid moiety, di-O-caffeoylquinic acids suppressed and derivates (3-caffeoylquinic, caffeic, and quinic acids)	Azay-Milhau et al. (2013) Jackson, Rathinasabapathy, Esposito, and Komarnytsky (2017)
Antimalarial activity	Root	Aqueous root extracts further extracted with Et_2O or EtOAc	Sesquiterpene lactons: lactucin and lactucopicrin	Bischoff, Kelley, Karchesy, Laurantos, Nguyen-Dinh, and Arefi (2004)
Antifungal activity	Root	Aqueous phase of acetone extract purified with hexan	Sesquiterpene lactons from root: 8-deoxylactucin and 11β,13-dihydrolactucin.	Mares, Romagnoli, Tosi, Andreotti, Chillemi, and Poli (2005)
Anti-cancer activity	Root	Methanolic extract	Lactucin, β-sitosterol, quinic acid, succinic acid and polyphenols like	Mehrandish, Mellati, Rahimipour, and Nayeri (2017)

			flavonoids.	
Tumour inhibitory activity	Root	Ethanolic extract	Inulin, cichoriin, esculin, esculetin, caffeine, polyacetylenes, organic acids, gums, proteins and vitamins	Hazra, Sarkar, Bhattacharyya, and Roy (2002)
Antiradical activity	Leaf	Hydroalcholic extracts	Phenolic compounds and flavonoids	Heimler, Isolani, Vignolini and Romani (2009)
			Gallic acid, protocatechic acid, chicoric acid and chlorogenic acid.	Kagkli, Corich, Bovo, Lante, and Giacomini (2016)
Antiosteoporotic effect	Leaf	Aqueous extract	Saccharides and flavonoids	Hozayen, El-Desouky, Soliman, Ahmed, and Khaliefa (2016)
Enzyme (α-glucosidase, α-amylase, pancreatic lipase and angiotensin converting enzyme) inhibitory activities, prevention of metabolic syndrome.	Leaf	Lyophilised hydrophilic extract	Hydroxycinnamic acids and flavonoids, with isomers of chlorogenic acid, caftaric acid, cichoric acid,and luteolin hexoside	Dalar and Konczak (2014)
Anti-parasitic activity (*Ostertagia ostertagi*)	Leaf	Ethyl acetate extract of primal methanol/water extract	Sesquiterpene lactones: lactucin, 11β, 13-dihydrolactucin, 8-deoxylactucin, 11β, 13-dihydro-8-deoxylactucin, lactucopicrin, 11β, 13-dihydro-lactucopicrin.	Peňa-Espinoza, Boas, Williams, Thamsborg, Simonsen, and Enemark (2015)
Anthelmintic effects	Leaf	Methanol extract	Sesquiterpene lactones	Peňa-Espinoza, Williams, Thamsborg, Simonsen, and Enemark (2017)
Radioprotective effect	Seed	Methanolic extract	Phenolic compounds such as chlorogenic acid which act as antioxidant agents.	Hosseinimehr, Ghaffari-Rad, Rostamnezhad, Ghasemi, Pourfallah, and Shahani (2015)
Improvement of glycemia, atherogenic index and antioxidant status	Seed	Ethanolic extract	Caffeoylquinic acid-rich extract	Jurgoński, Juśbkiewicz, Zdunczyk and Bogusław (2012)

3.1. Anti-hepatotoxic activity

Li et al. (2014) noted the hepatoprotective effect of ethyl-acetate extract of chicory plant against carbon tetrachloride-induced hepatic fibrosis in rats. Oral doses of 6, 18, and 54 g/kg per day were investigated for hepatoprotective effect in Wistar albino rats, with a dose of 54 g/kg per day as the most effective. Significant decreasing of serum levels of aspartate aminotransferase (149.04±34.44, $P<0.01$), alanine aminotransferase (100.72±27.19, $P<0.01$), hexadecenoic acid (548.50±65.09, $P<0.01$), laminin (28.69±3.32, $P<0.01$) and hydroxyproline (263.33±75.82, $P<0.01$) in liver was noted. Fathalla et al. (2015) suggested that defatted extract showed lower hepatoprotective activity than total extract, and connected this with potential bioactivity of lipid fraction from chicory seed extract. Zhang et al. (2014) linked anti-hepatitis B effect of chicory leaves with chicoric acid and its anti-hyaluronidase, phagocytosis stimulatory and antioxidative properties. Dose of 10–100 µg/ml chicoric acid from chicory leaves reduced significantly the hepatitis B surface and envelope antigen levels with the maximum inhibition rates of 79.94% and 76.41%, respectively. Flavonoids present in hydroalcoholic leaf fractions also may be responsible for hepatoprotective role of chicory (Neha et al., 2014). Kostic et al. (2013) mentioned the role of chicory flower in treatment of skin diseases, diabetes and anti-hepatotoxic activity.

3.2. Anti-diabetic effect

Daily administration of 125 mg/kg ethanolic chicory plant extract for 14 days to Sprague–Dawley diabetic rats reduced serum glucose by 20%, triglycerides by 91% and total cholesterol by 16%. Inulin potentially express anti-diabetic effect in tested animals. The possibility that this extract induces insulin secretion from pancreatic β-cells was also highlighted in the study of Pushparaj, Low, Manikandan, Tan, and Tan (2007). Aqueous extract of chicory seed prevented body-weight loss and decreased fasting blood sugar in four-week trial in rats. Chicory appeared to have short-term (about 2 hours) and long-term (28 days) effects on Type 2 diabetes mellitus as well as to be a natural dietary supplement for slowing down the pace of diabetes progress (Ghamarian et al., 2012). Chicory seed ethanolic extract containing 9.6% of caffeoylquinic acids improved glycemia, decreased the atherogenic index and increased blood antioxidant status during 28-day treatment of Wistar rats (Jurgoński et al., 2012).

3.3. Antimicrobial effect

Ethanolic, methanolic, ethyil-acetate and aqueous extracts of chicory root, leaves and seeds expressed antimicrobial activity due to presence of phenolic compounds, flavonoids and sesquiterpene lactones depending on the plant part (Table 4). Koner et al. (2011) tested ethyl acetate extract of chicory root for anti-bacterial and anti-fungal properties and stated that chicory root has great ability to inhibit both Gram-positive and Gram-negative bacteria (*Staphylococcus aureus, Bacillus subtilis, Pseudomonas fluorescens, Rhizobium leguminosarum, Escherichia coli, Vibrio cholera),* yeast (*Sachharomyces cerevisiae*) and *Aspergillus niger*. Verma et al. (2013) reported *in vitro* antibacterial activity of *Cichorium intybus* L. against some pathogenic bacteria as well as antibacterial activity of chicory leaves extract against Gram-negative pathogenic bacteria (*Escherichia coli* and *Pseudomonas aeruginosa*) considering inulin, sesquiterpene lactones, flavonoids and coumarins responsible for this activity. Petrovic, Stanojkovic, Comic and Curcic (2004) connected antibacterial activity of areal parts of chicory with presence of cichorin in its flowers. Shaikh, Rub and Sasikumar (2016) proved antimicrobial activity of chicory seed extract against *Staphylococcus aureus, Pseudomonas aeruginosa, Candida albicans* and *Escherichia coli.* Sesquiterpene lactones isolated from chicory leaves using ethyl-acetate and methanol showed important anti-parasitic activity against *Ostertagia ostertagi* and anthelmintic effect against free-living and parasitic stages of *Cooperia oncophora* (Peňa-Espinoza et al., 2015; Peña-Espinoza, Williams, Thamsborg, Simonsen, & Enemark, 2017).

3.4. Antioxidant activity

Antioxidant activity of chicory plant was the subject of investigation in numerous scientific studies. Liu et al. (2013) linked antioxidant and antibacterial activities of chicory root extracts with the bioactive substances primarily identified as caffeoylquinic acids. Rub, Siddiqui, Ali, Shaikh, and Mukadam (2014) investigated the antioxidant activity of the polyphenol rich fraction of chicory roots and also reported its strong hypoglycemic potential. Dalar and Konczak (2014) studied the antioxidative activity of roots, stems, leaves, flowers, and the whole plant of *Cichorium intybus* L. As it is reported in their study, the leaves contained the highest level of total phenols (22.6 mg GAE/g d.w.) and exhibited the highest antioxidant capacities. The FRAP (ferric reducing antioxidant capacity) value of leaf was 251.6 μmol Fe^{+2}/g d.w. The

ORAC (oxygen radical absorbance capacity) value of chicory plant parts was reported to decline in the following order: flower ≥ leaf > root > stem. They also identified many important phenolic compounds in ethanol based lyophilized extract of *Cichorium intybus* L. leaf: apigenin, hydroxybenzoic acid-O-hexoside, caftaric acid, isorhamnetin, 4-O-caffeoylquinic acid, 5-O-caffeoylquinic acid, apigenin glucoside, luteolin hexoside, quercetin/hesperitin glucoside, cichoric acid and quercetin rutinoside (rutin). Heimler et al. (2009) reported 19.30 to 48.60 mg sample f.w./mg DPPH, for antiradical activity IC50 (the antiradical dose required to cause a 50% inhibition) in chicory leaves. Khalaf et al. (2018) found that irradiation treatment was superior for improving the phytochemical, antioxidant and antimicrobial activities and the most indicated doses to maintain phytochemicals content, and to increase antioxidant activity, as well as antimicrobial, were 4 and 12 kGy for roots and leaves of chicory, respectively. They also reported that DPPH (1,1-diphenyl-2-picrylhydrazyl radical) radical scavenging activity of leaves was 80.95 ± 0.39%. Antioxidant capacities of chicory flower expressed as FRAP (240.8 μmol Fe^{+2}/g d.w.) seem to be stronger than for root or stem. Furthermore, flowers expressed the highest ORAC (1307.7 μmol TE/g d.w.) compared to leaf, root and stem. Jurgoński et al. (2011) reported that chicory leaves extract showed higher antioxidant activity (210.1 nmol/g of f.w.), compared to the seed extract (505.1 nmol/g of f.w.). Chicory leaves and flowers possess valuable oxygen radical scavenging and total reducing capacities, comparable to those of Chinese medicinal plants (Dalar & Konczak, 2014). According to the results obtained by Montefusco et al. (2015) who investigated the hydrophilic and lipophilic antioxidant activities, contents of lutein (8.0 to 30.1 μg/g f.w.), β-cryptoxanthin (0.13 to 0.41 μg/g f.w.) and β-carotene (3.3 to 14.1 μg/g f.w.) varied in cultivated and wild chicory cultivars. Antioxidant activities in chicory cultivars ranged between 352 and 1056 μmol TE/100 g f.w., depending on the varietal and environmental factors, related to growing, soil, and climatic conditions. Total phenolic content from 30.1 to 101.7 mg GAE/100 g f.w. was reported in edible parts of cultivated and wild chicory. The flavonoid content evaluated from 11.1 to 66.2 mg catechin equivalents (CE)/100 g f.w., correlated with total antioxidant activity in chicory leaves. They also concluded that the hydrophilic antioxidant activity was higher than the lipophilic antioxidant activity in different chicory varieties. Comparing dietary supplementation with rutin and extract of chicory seeds rich in caffeoylquinic acid in rats, Jurgoński et al. (2012) concluded that chicory seed extract decreases serum atherogenicity and increases blood antioxidant status, contrary to rutin.

3.5. Other bioactivities

Many studies investigated and demonstrated a wide range of different chicory bioactivities.

Sesquiterpene lactones rich alcoholic extract of chicory root showed anti-inflammatory effect in rats and mouses. Inflammation was reduced for 76% at 100 mg/kg dose in rats, and 71% for 200 mg/kg dose in mouses (Ripoll et al., 2007b).

Chicoric acids, especially caffeic and ferulic acids, promote a decrease in hepatic glycogenolysis, increase insulin release and reduce hepatic glycogenolysis. From the other side, natural chicoric acid aqueous extract from chicory root improve intraperitoneal glucose tolerance in a dose-dependent manner considering *Cichorium intybus* L. as an antihyperglycemic agent (Azay-Milhau et al., 2013). Similar conclusions were noted in study of Jackson, Rathinasabapathy, Esposito, and Komarnytsky (2017), where the caffeic acid moiety was responsible for antihyperglicemic effect.

Sesquiterpene lactones (lactucin and lactucopicrin) from chicory root cause antimalarial activity against HB3 clone of strain *Honduras-1* of *Plasmodium falciparum* (Bischoff, Kelley, Karchesy, Laurantos, Nguyen-Dinh, & Arefi, 2004). On the other hand, sesquiterpene lactones 8-deoxylactucin and 11*β*,13-dihydrolactucin, showed antifungal activity against zoophilic and anthropophilic dermatophytes (Mares, Romagnoli, Tosi, Andreotti, Chillemi, & Poli, 2005).

A pilot work of chicory anti-cancer activity has been conducted. In the study of Mehrandish, Mellati, Rahimipour, and Nayeri (2017), methanolic extract of chicory root showed cytotoxic effect on human breast cancer SKBR3 cell line with IC50 value of 800, 400 and 300 after 24, 48 and 72 hours of treatment.

Ethanolic (80%) extract of chicory root was studied in terms of tumour-inhibitory effect against Ehrlich ascites carcinoma in Swiss mice and showed significant results at doses from 300 to 700 mg/kg/day (Hazra et al., 2002).

Phenolic compounds from chicory seed, such as chlorogenic acid, are well-known as antioxidant agents, but may act as radioprotective agents also. Methanolic extract of chicory seeds was investigated against genotoxicity induced by ionizing radiation in human lymphocytes. All doses of chicory extract (10, 50, 100, and 200 µg/mL) significantly reduced the frequency of micronuclei in binucleated lymphocytes from human peripheral blood samples (Hosseinimehr, Ghaffari-Rad, Rostamnezhad, Ghasemi, Pourfallah, & Shahani, 2015)

Aqueous chicory leaves extract rich in inulin and flavonoids may be considered as bone protection agent against glucocorticoid-induced osteoporosis in rats, more than parsley and basil extracts. These results were obtained during 8-week long treatment and indicated antiosteoporotic effect of chicory (Hozayen, El-Desouky, Soliman, Ahmed, & Khaliefa, 2016).

Dalar and Konczak (2014) evaluated the ability of lyophilized hydrophilic leaf extract to inhibit selected digestive enzymes related to metabolic syndrome (α-amylase, α-glucosidase, pancreatic lipase and angiotensin converting enzyme).

In traditional medicine, chicory flowers were used for curing common ailments, as a tonic and appetite stimulant, and in treatment of gallstones, gastro-enteritis, sinus problems, cuts and bruises (Judžentienė & Būdienė, 2008). According to Bahmani, Zargaran and Rafieian-Kopaei (2014), chicory root, leaves and flowers were traditionally used for aiding the function of the gallbladder. Zolfaghari, Adeli, Mozaffarian, Babaei and Habibi Bibalan (2012) reported laxative and anticholesterol effect of chicory. Kratchanova, Denev, Ciz, Lojek and Mihailov (2010) summarized utilization of areal chicory parts in treatment of liver diseases, cholagogue, and digestive tract.

4. Safety and Health claims

Chicory extract, as well as inulin, is Generally Regarded as Safe (GRAS) by the FDA and appears on the Everything Added to Food in the United States (EAFUS) list (Food and Drug Administration, 2018). The safety of a chicory root extract was confirmed in study of Schmidt et al. (2007), during Ames test and four-weeks sub-chronic toxicity study in male and female Sprague–Dawley rats. They reported that chicory root extract containing sesquiterpene lactones is non-toxic and non-mutagenic at 70, 350, or 1000 mg/kg/day, administered orally. Toxicological profiling (subacute and chronic toxicity) of aqueous chicory seed extract has been confirmed that has no ill effect and the dose of 200 mg/kg body weight resulted in significant reduction in serum glucose (52.7%) and triglycerides levels (65.3%) and decreased the oxidative burden in high-fat-diet-induced diabetic rats (Chandra, Khan, Jettey, Ahmad, & Jain, 2018).

The claim of chicory products short-term and/or long-term effects on diabetes has been proven by the glucose tolerance test and HbA1c measurement (Nowrouzi, Mazani, Rezagholizadeh, & Banaei, 2017). Furthermore, there are some clinical studies on human subjects which have demonstrated potential role of bioactive chicory root extract in the management of osteoarthritis (Olsen, Branch, Jonnala, Seskar, & Cooper, 2010), a positive effect of chicory inulin or oligofructose to reduce the postprandial blood glucose response (Lightowler, Thondre, Holz, & Theis, 2018), as well as oligofructose-enriched chicory inulin positive effects on the improvement of the glucose and calcium homeostasis, liver function tests, blood pressure and reduction in hematologic risk factors of diabetes in female patients with type 2 diabetes mellitus (T2DM) (Farhangi, Javid, & Dehghan, 2016).

EFSA (European Food Safety Authority) confirmed health claim that non-digestible carbohydrates from chicory (fructo-oligosaccharides (FOS, oligofructose) obtained from chicory inulin), which should replace sugars in foods or beverages reduce post-prandial glycemic responses (EFSA Panel on Dietetic Products Nutrition and Allergies, 2014). EFSA and Commission Regulation (EU) 2015/2314 confirmed that the effect on bowel function demonstrated by the intake of native chicory inulin is a beneficial physiological effect with dosage of 12 g/day for this claim (Theis, 2018).

5. Current and potential applications

Currently, there are several known chicory applications: baked and ground chicons or roots for coffee substitute and supplement, utilization of leaves as a vegetable and cultivation of chicory as a forage plant for poultry and animal feed (Saeed et al., 2017). Chicory, as a great source of dietary fibers such as inulin and FOS and many functional food ingredients can assist in maintaining good health and in preventing diseases. Inulin is mostly applied into food as low-calorie sweetener, fat substitute and texture modifier, in order to increase dietary fiber content, improve technological and sensory value of the products (Drabińska, Zieliński, & Krupa-Kozak, 2016). Many studies investigated inulin bioactivity: tumor inhibitory, antidiabetic, anti-hepatotoxic and antioxidative activity (Table 4). Chicory powdered roots finds another application in successfully replacing wheat flour (10%) and fat (25%) in cracker production after debittering by soaking the roots in water or citric acid solution (Massoud, Amin, & Elgindy, 2009). Chicory fibers were also incorporated in restructured sausages in order to replace fat, with conclusion that addition of chicory fiber significantly reduced the moisture, fat, hardness and pH values of sausages (Choi et al., 2016). Bossard, Leveque, and Marboutin (2006) obtained flour from dehydrated chicory root in order to prepare food dough for baking. Wang & Cui (2011) also mentioned utilization of chicory for tea production, such as tea for keeping fit. Also, implementation of chicory root extracts (1, 2 and 3%) in yogurt due to health promoting effect of chicory inulin as well as its ability to form creamy emulsions with aqueous liquid were investigated (Jeong et al., 2017). Dried chicory root extract (2-6 %) was implemented into yogurt-ice cream formulation with intention to decrease production costs by replacing dairy ingredients with other low cost alternatives, such as inulin and buttermilk. By increasing the amount of dried chicory root extract in yoghurt-ice cream formulation increased the textural and flavor properties and overall acceptability score while melting rate was decreased (Kumar, DC, Alam, & Sawant, 2018). Future research should be devoted more closely to the application of chicory in food products on an industrial scale, according to its important benefits and potential.

6. Conclusive remarks

Cichorium intybus L. is a valuable source of bioactives for new food products especially because of the presence of inulin, sesquiterpene lactones and phenolic compounds in roots, leaves, seeds, and flowers. Among them, inulin as the most abundant compound determines chicory as one of the richest source of this prebiotic which can be used for development of added value food products.

The health-promoting characteristics of the chicory-derived applications are well backed by the experimental data available from bioactivity studies especially anti-inflammatory, anti-diabetic, anti-hepatotoxic, antihyperglycemic and antimicrobial activity. This data suggest that food enriched with chicory can provide a potential health effect determining it as a desirable ingredient in the diet.

Chicory root seems to be a promising raw material for the enrichment of functional food products according to its high mass yield and diverse and rich composition of biologically important compounds (inulin, sesquiterpene lactones, and minerals) compared to other parts of the plant. Chicory root inulin possesses wide application possibilities in food industry: as prebiotic, fat replacer, sugar replacer, texture modifier and for the development of innovative foods in order to improve health due to its beneficial role in gastric health. Also, sesquiterpene lactones from the chicory root could be utilized as a source for the development of functional foods with anti-inflammatory activity. Additionally, the utilization of all parts of chicory may contribute to reducing food waste and improvement of food system sustainability.

Usually, processing practices of chicory plant includes roasting for production of coffee substitutes or surrogates (Oliveira et al., 2012), slicing and drying for tea production (Lee, Kang, & Hsieh, 2004), as well as hot water continuous extraction for inulin isolation (Zhu, Bals, Grimi, & Vorobiev, 2012) at industrial utilization. Inulin-containing waste may be reused in industrial fermentations to produce biofuels and bio-based chemicals, as well as for production of single-cell protein, single cell oil, citric acid, and other chemicals (Hughes et al., 2017). On the other side, the industrial processing of chicory uses mainly the roots, resulting in large amounts of unused chicory by-products (leaves and peels) which may be investigated as a source for isolation of bioactive compounds such as sesquiterpene lactones and polyphenols. Future developments in the optimization of the extraction of economically important bioactive compounds from chicory and their implementation from pilot to industrial scale are needed in order to supply industry and ensure the valorization of chicory plant parts and the sustainability of the final products enriched in the nutritional and functional bioactives of chicory.

In summary, chicory plant may be considered as rich and promising raw material in terms of carbohydrates, proteins, phenolic compounds, flavonoids, and minerals content, making chicory as a desirable ingredient in the development of innovative and functional food products.

This review clearly reveals chicory as a good potential valuable resource for food ingredients and functional foods, beverages and dietary supplements.

Conflicts of interest

The authors have declared no conflict of interest.

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