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Review

Perspectives and utilization technologies of chicory (*Cichorium intybus* L.): A review

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Exploring and developing multiple utility technologies of plant resources is an alternative way for improving the efficiency of land used for food and fuel production. Chicory (*Cichorium intybus* L.) has a nutritional quality comparable to lucerne as it contains similar proportions of protein, lipid, minerals and other nutrients. Based on its chemical and biological activities, this research work evaluated and overviewed recent advances in utilization technologies and studies of chicory. It focuses on the biochemical compositions and physiological bioactivities of extractives from chicory and clearly states the promising potential utility technologies of the plant: Curative effect as a forage or vegetable with good digestibility, use of chicory in confectionery products and beverages, potential use in discovering new effective medicine and the development of new salubrious functional foods, additives and other profitable green bioproducts. However, a significant research gap still remains in these pharmacological actions and discoveries, and as such, the utilization of the health benefits of this plant should be put into practice. Thus, future research needs to be done in order to gain a better understanding and to further elucidate mechanisms of chicory and its extractives that are rationally suggested.

Key words: Chicory, biochemical composition, pharmacological activities, utilization technologies.

INTRODUCTION

As the competition for the finite resources on earth increases due to growth in population and affluence, agriculture is faced with intensifying pressure to improve the efficiency of land used for food and fuel production. In the past decade, researches have focused on scientific evaluation and advance of cropland efficiency: e.g. rotational and cover crops for increasing biomass production (Baumhardt et al., 2009; Po et al., 2009), winter wheat with grazing for increasing grain and beef production (Zhang et al., 2008), productivity and dynamics in bioenergy double-croping system for increasing cropland efficiency (Heggenstaller et al., 2008), water management under limited natural resources (Smade et al., 2010) etc. However, under extram limited cropland and resources, there is a renewed interest in developing alternate crops to meet the everlasting demand for fuels, chemicals, and industrial feedstocks (Augustus et al., 2000), and bioactivities of extractives from plants (Hussain et al, 2010; Idemudia and Ajibade, 2010; Tabatabaei et al, 2010; Chen et al, 2010; Thongrakard and Tencomnao, 2010; Anyasor et al, 2010). And based on the bioactives and pharmacological activities for health-promoting properties of plants, this has promoted the need to identify and evaluate potential plant species with multiple utilization technologies (Pugalenthi et al., 2005; Fu et al., 2006; Szajdek and Borowska, 2008), such as chicory (Wang and Cui, 2009a, b).

Chicory (*Cichorium intybus* L.), a perennial herb of the Asteraceae family, with blue, lavender, or occasionally white flowers, is also known as blue sailors, endive, succory, and coffeeweed, Kashen'na or Kasini (Uigur)(New Medical College of Jiangsu, 1977), is native to the Mediterranean region, mid Asia and northern Africa. Historically, chicory was grown by the ancient Egyptians as a medicinal plant, coffee substitute,

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Abbreviations: CP, Crude protein; **CL,** crude lipid; **EE,** ether extract; **CF,** crude fiber.

Table 1. Multi-utilizations of chicory.

Part of chicory	Utilization	Reference
Leaves and shoots	Salads, vegetable dishes	Herrmann, 1978; Hocking and Withey, 1987
	Forage	Hur and Park 1995; Wang and Cui, 2009a,b
Young and tender roots	Boiled and eaten	Zanner, 1988
Older roots	Dried and roasted and used as a coffee substitute and additive;	Bais and Ravishankar, 2001; Van Waes et al., 1998
	Sources of inulin	Herck and Baert, 1999
	For ethanol production by direct fermentation	Kyazze et al., 2008

vegetable crop, and occasionally for animal forage (Munoz, 2004; Deshusses, 1961; Grieve, 1971; Plmuier, 1972). Greeks and Romans also began to grow chicory as a vegetable crop 4000 years ago (Grieve, 1971; Plmuier, 1972). Today, it is cultivated in Europe and North America with many commercial uses (showed in table 1).

The US imports more than 2.3 million kilograms of chicons and 1.9 million kilograms roasted chicory roots for coffee according to 2002 US Department of Commerce tariff and trade data (Schmidt et al., 2007). Chicory is one of the commercially cultivated transgenic crops authorized by government of the US (Wang and Cui, 2010a). Naturally distributed in northern China, Chicory was originally used as a Uighurian and Mongolian traditional medicinal material or herb (Chinese Leechdom and Bioproduce Test Office, 1990; Uigur Pharmacopoeia Compile Committee, 1999). In China, based on the varieties of chicory, introduced abroad since 1980s, new broad leaf varieties of chicory are improvedly bred. They are prospective forages and cash crops with high production, multiple function and good quality, therefor, it can be use as both health care food and medicine, authorized by the Ministry of Health of the People’s Republic of China in 1998 (Wang and Cui, 2010a).

Chicory is a relatively new forage crop (Ryder, 1999). Much of the breeding for improved forage characteristics has been done in New Zealand, where the variety Puna was developed under grazing conditions (Hume et al., 1995). Chicory produces leafy growth which, if managed properly, is similar in nutritive value to Lucerne (*Medicago* sativa L.) (Moloney and Milne, 1993), but the mineral content is superior for copper and zinc (Li et al., 2006). Liveweight gains of young farmed deer can be as high as those obtained with perennial ryegrass/white clover mixtures (Hoskin et al., 1999b). Its forage is highly palatable to livestock (Gao and Ma, 1991; Li et al., 2006). Currently, forage chicory is being studied for its bioactive compounds, such as tannins or sesquiterpene lactones, which can reduce nematode and helminth parasites infection in animals (Athanasiadou et al., 2007; Hoskin et al., 1999a; Hoskin et al., 2003; Marley et al., 2003). Usually grazed, chicory can also be used to improve the quality of a silage mixture (Gao and Ma, 1991; Li et al., 2006). For optimum performance and persistence, it should be rotationally strip grazed, or machine harvested (Li et al., 1997).

Over the past decades, a number of publications have reported on the biochemical composition (Ablimit et al., 2008; Francke and Majkowska-Gadomska, 2008; He et al., 2002; Heimler et al., 2009; Luo and Wu, 2009; Mao et al., 2009b; Wu and Luo, 2009; Yang et al., 2009b; Yang, 2009)，effects of the biological activities (Jiang et al., 2008a, b; Jurgonski et al., 2008; Lavelli, 2008; Li et al., 2008b; Nessrien et al., 2007; Pool-Zobel, 2006; Qi et al., 2008; Ren et al., 2008; Ripoll et al., 2007; Talip et al., 2006; Tursunay et al., 2009; Yang et al., 2009a; Zheng et al., 2008) and utilization technologies (Athanasiadou et al., 2007; Calabrese and Damato, 2007; Devacht et al., 2008; Koyazounda, 2008; Robert et al., 2006; Schulten, 2004) of chicory and its extractives. However, no comprehensive review has been performed to summarize the state-of-the-art, especially in light of the recent focus on the developing bioproducts in sustainable world economy. Thus, in the current work, we critically review the scientific literature about the phytochemistry and bioactivity of extracts from chicory, potential utility technologies, and also suggest future research avenues.

CULTIVARS (VARIETIES) AND PRODUCTIVE PERFORMANCE

There are a large amount of chicory cultivars or varieties in the world. For example, there are 51 cultivars of chicory registered by the Italian agriculture ministry alone (Giolo, 2003; Tosini, 2004). They are roughly classified three types on the basis of size and the shape of the leaf, viz. big broad vertical leaves type, little decumbent leaves type and ‘medium type’; Most forage chicory cultivars are classed in the first type (Li and Kemp, 2005; Wang and Cui, 2010a).

One of the most popular cultivated cultivar of forage chicory is *Cichorium intybus* cv. Puna (Grasslands Puna, or Puna chicory) in the world, developed in New Zealand. It is well adapted to different climates, being grown from Alberta, Canada, to New Mexico and Florida and in China. It is resistant to bolting, which leads to high

Table 2. The agronomy characteristics and productive performances of the 8 cultivars of chicory in China.

Cultivar of forage chicory	Fresh leaf yield per year (10^4 kg/hm^2)	Utilization and agronomic characteristics in China	Derivation of the cultivar or variety	Reference
cv. Grassland Puna	9～15 (in Southwest and northern of China)	Forage chicory, wide range of adaptation capacity with tolerance to drought, disease and pests, and high uptake of mineral elements; and growth well in soil with 0.2% salinity	Commercially released and has been frequently used in the world since 1985, registered in China via Forage crop examine and approve committee of People's Republic of China in November 1997.	(Wang and Cui, 2010a; Yang, 2008)
cv. Europe	22.5 (in plain of Mid China)	Can be used both as forage and vegetable, high yield of the matured taproot with weight about 1 kg per fresh root	Introduced and began to plant in eastern China in 1980, registered in China via Forage crop examine and approve committee of People's Republic of China (№ 182).	(Wang and Cui, 2010a)
cv. Commander	17.88 (in Shicuan province of China)	Forage chicory, have a high content of crude protein at 26.88% of dry matter in rosette of foliage leave stage	Base on a variety of chicory introduced from Australia, breeding improvement by Animal Husbandry Institute of Sichuan Province of China and Barenbrug (Beijing) International Co. Ltd., registered in China via Forage crop examine and approve committee of People's Republic of China (№ 351) in 2007.	(Wang and Cui, 2010a)
cv. Oubao	27.45~38.40 (in Eastern and Southern China)	Quadplex chromosome type forage chicory, high fresh leaf yield	By Minquan county special animal and plant breeding trial garden in Henan province of China introduced to China from Canada.	(Wang and Cui, 2010a)
cv. Kuoye	11~16 (in Southeastern China)	Forage chicory, long yearly persistence of 230d growth in most areas of China	New cultivar chicory in China of breeding improvement base on a variety of forage chicory introduced from New Zealand	(Wang and Cui, 2010a)
cv. Yifeng	15~23 (in Mid and Northeast of China)	Can be used as both forage and vegetable, growing and being used long life up to 15 years if managed properly	New big leaf cultivar chicory in China of breeding improvement base on a variety of forage chicory introduced from Europe	(Wang and Cui, 2010a; Shang, 2008)
F_1 hybrids Barckoria	25~40 (in Yangtse river drainage area)	Forage chicory, high fresh leaf yield	F_1 hybrids of chicory breeding by Barenbrug (the US) International Co. Ltd.	(Wang and Cui, 2010a; Qing, 2009)
cv. Chicory OG02	15~20 (in Yangtse river drainage area)	Forage chicory, with broad leaf of length 28～42cm and width 12～17cm	Big leaf type, introduced from Italian TAVAZZANO Co. Ltd.	(Ge,2006; Wang, 2006)

nutrient levels in the leaves in spring. It also has high resistance to grazing (Answers.com, 2010). Then, are cv. Puna II (Rumball et al., 2003a), cv. La Certa Forage Feast (Zobel et al., 2006), cv. INIA LE Lacerta (Labreveux et al., 2006), cv. Accalai (Sulas, 2004), cv. Marrubiu (Sulas, 2004), cv. Choice (Rumball et al., 2003b), cv. Nausica and cv. Arancha (Thonar et al., 2006), and varieties Brow Tyne, Six Point, and Oasis (David and Sears, 2007). etc., whereas most common varieties (or cultivars) of forage chicory available in China are 8 chicory cultivars currently (table 2), viz. *Cichorium intybus* cv. Puna, cv. Europe, cv. Commander, cv. Oubao, cv. Kuoye, cv. Yifeng, cv. F_1 hybrids Barckoria originally from the US (Qing, 2009) and cv. Chicory OG02 from Italy (Wang, 2006).

The agronomy characters and productive performances of the 8 chicory cultivars in China are list in table 2. Grassland Puna chicory has a wide range of adaptation

Table 3. The nutritional components of cultivars of forage chicory and average of 10 alfalfa varieties.

Forage chicories, phenological stage	Puna chicory*					Qikeli*		Yifen*	Alfalfa*
	Rosette leaves	Elongation stage	Start in bloom	Blooming stage	Average of all stages	Rosette leaves	Start in bloom	Rosette leaves	Average of 10 varieties
CP (%)	24.77	21.56	18.25	16.75	20.33±3.58	22.87	14.73	22.90	18.11±1.53
CL (%)	3.15	3.52	4.01	4.43	3.78±0.56	4.46	2.10	5.01	2.94±0.55
CF (%)	26.83	32.61	35.98	38.97	33.60±5.21	12.90	36.81	13.14	28.89±1.52
NFE (%)	21.25	24.35	26.89	28.82	25.33±3.28	30.34	24.92	30.02	43.10±1.70
Ash (%)	21.19	15.62	13.07	9.74	14.91±4.83	15.28	8.01	16.11	6.93±0.38
Ca (%)	1.49	1.12	1.08	1.01	1.18±0.21	1.50	1.18	1.50	-
P (%)	0.55	0.37	0.31	0.25	0.37±0.13	0.42	0.24	0.24	-

Note: 1 CP: crude protein; CL: crude lipid; CF: crude fiber; NFE: nitrogen free extract.
2 **Data from:** Puna chicory, Yang Yali (Yang, 2008); Qikeli chicory, Cai Wanjiu (Wang and Cui, 2009b); Yifen chicory, Shangwu zaixian (Wang and Cui, 2009 a; Shang, 2007); Alfalfa, Zhou Yanchun (Zhou et al., 2008a).
3 10 **Alfalfa cultivars are:** Gongnong №1, №2 come from Jiling province; Longmu 801, 803 come from Heilongjiang province; Hybrid bear 1 come from Nongxia Hui autonomous region; Big leaf alfalfa, Magna601, Nongbao and Hopulord come from the U.S.; Victorian come from Canada (Zhou et al., 2008a).

A comparison of the biochemical composition with alfalfa

Crude protein

Crude protein. Crude protein (CP) content in chicory is more valuable than in alfalfa. In table 3, at rosette of foliage leave growth stage of the chicory cultivars, they has contains higher crude protein than alfalfa, e.g. cv. Puna at 24.77%, cv. Yifen at 22.90% and cv. Qikeli at 22.87%; Whereas the average CP of whole growth stage of Puna chicory at 20.33% higher than the average CP of 10 alfalfa varieties at 17.85% of the shoots and leaves in bloom stage. The protein in chicory is in high quality, e.g. 17 kind of amino-acid, including 9 needs of amino-acid for animal and human beings in chicory; lysine content at 1.2% in chicory is similar to it in alfalfa (1.05~1.38%) (Zhang et al., 2005b; Zhang et al., 2006), and 9 kind of amino-acid contents amongst them in chicory, which is harvest in rosette of foliage leave growth stage, are higher than those in alfalfa (Wang and Cui, 2010b). The fresh leaf of forage chicory can be used as a substitute for condense feedstuff, e.g. CP contains in fresh leaf yield of 1m^2 chicory field (cv. Oubao), which is content of CP up to 31~35% in the leaf，is similar to CP in 12 kg maize grain, therefore, it can be increase farming benefit 70% (Wang and Cui, 2010b); whereas decrease feeding cost 50% when with a substitute fresh leaf of cv. Kuoye chicory for in cattle farm (Wang and Cui, 2010b).

Crude lipid

It contain Crude Lipid (CL) at 3.78% in forage chicory of whole growth stage, higher than at 2.99% of the average of 10 varieties in alfalfa shoots and leaves in bloom stage (table 3); especially, in rosette of foliage leaf growth stage, when chicory mostly been used as forage or grazing, the contents of EE at 4.46% and 5.0% in cv. Qikeli and in cv. Yifen, respectively (showed in table 3).

Crude fiber

In rosette of foliage leave growth stage of forage chicory, crude fiber (CF) which is contains in cv. Puna chicory is similar to in alfalfa, whereas CF in cv. Qikeli and in cv. Yifen at 12.9% and at 13.0%, respectively, lower than in the average of 10 alfalfa varieties (at 28.89%) with ratios of 55.22% and 54.87%, respectively (table 3).

Mineral composition

Forage chicory is rich in mineral Composition, highly palatable with good digestion and assimilation to poultry and livestock (Sanderson et al., 2003; Scharenberg et al., 2007), e.g. rich in carotene, ascorbic acid and mineral Ca, P, K, Mg, S, Fe, Mn, Zn, Cu, Na, Se and Sr etc. (Wang and Cui, 2010b), is good feedstuff substitute for condense feedstuff (e.g. grain in China) with highly palatable to cow, cattle, swine, sheep, deer, horse, rabbit, chook, goose, duck, fish and ostrich etc. (Foster et al., 2002; Moloney and Milne, 1993). E.g. it was reported that suits rabbit's palate and makes the hairs polished and fine quality after weeks feeding (Wang and Cui, 2010b), also, can cure rabbit and swine of diarrhoea when with 2 days feeding (Liu, 2004).

A comparative study was conducted in Guizhou province in China, with alfalfa and Barckoria chicory on growth performance of 48 New Zealand white rabbits, which are age of 35d (24 animals, divided into 3 groups in random) and 45d (24 animals, divided into 3 groups in random), respectively. The different experimental group I (alfalfa group), group II (Barckoria chicory group) were fed adlib item diets with addition of 20% alfalfa, 20% Barckoria chicory and control group lasted for 30ds, respectively. The results showed that: daily liveweight gain in the experimental group I were 36.88g (35 day), 37.18g (45 day), group II were 35.40g, 35.65g and control group were 33.63g, 34.39g, respectively, group I, II were significantly higher than that of the control group (P <0.01); by comparing with the control group, feed/gain ratio in the group I decreased 4.60%, 4.68% respectively and in the group II decreased 8.59%, 7.89% respectively. After profit per animal analyzing, the profit in group II (Barckoria chicory group) was the highest of the three groups, and in group I was higher than the control group significantly (Huang et al., 2008). Another example, fresh forage *Panicum maxiumum* in mixtures with *Cichorium intybus, Neonotonia wightii, Stylosanthes guianensis* cv. Reyan No.2 and *Ipomoea batatas* respectively, was examined over 40 d in a trial rotationally grazed by rabbits, the result indicated that grazed frequency orderly are *Cichorium intybus* (91.5%) > *Ipomoea batatas* (83.0%) > *Neonotonia wightii* (76.2%) > *Stylosanthes guianensis* cv. Reyan No.2; and *Panicum maxiumum* in mixtures with *Cichorium intybus* is at the highest profit of the mixtures groups (Jin et al., 2007).

Growth chicory for swine feeding can be both lower cost and higher porky quality (Byrne et al., 2008; Hansen et al., 2006; Rideout and Fan, 2004), e.g. it is productive to plant chicory 3,700 hm^2 for 1.325 million commercial swines in Zhongyi contry, Guizhou province of China in 2006, make a production value at 795 million Yuan (about US $117 million) (Wang and Cui, 2010b). Also, Puna chicory may result in improved goat productivity in terms of growth rate and chevon production if used as a summer pasture (Lema et al., 2008).

UTILIZATIONS TECHNOLOGIES AND PERSPECTIVES

Chicory can grow well in temperate zone with moderately well-drained soils. However, it is tolerant of torrid and cold climate also, e.g. cv. Yifeng chicory grow well in sweltering southern China, and keep grow greenery at －8°C air temperature in chilly northern China as well (Wang and Cui, 2010a; Shang, 2007); cv. Europe chicory can be naturally winter-dormant and live through the winter at －30°C air temperature in northern China (Wang and Cui, 2010a). It can be cultivated in a variety of soil types as a wild plant, viz. in wasteland, grassland, cropland, space in orchard, sloping field, roadsides, side of conduit and ditch, e.g. cv. Kuoye chicory is suited to soils with a pH of 5.0-8.2; therefore, it is planted in most areas of China (Wang and Cui, 2010a). So, it is getting more and more development multiple functional utilization technologies as following (Wang and Cui, 2010b).

Pasture use of chicory

Its popular pasture or forage uses have focused research so far and the last few decades that have been carried out on chicory. Chicory is a highly productive forage under midsummer conditions in the eastern USA, often has higher concentrations of minerals relative to grasses and legumes (Belesky et al., 2001). It could be a good complement to Pennlate orchard grass in grass-based feeding systems (Labreveux et al., 2006) and offer a productive high quality forage crop for Mississippi's grazing livestock producers (Parish, 2006). And, adding chicory to pasture, mixtures improved forage yield, root growth, and soil moisture extraction under drought (Skinner, 2008). Chicory and sulla (*Hedysarum coronarium* L) mixture maintained high quality during the growing season in a dairy sheep system in Sardinia Italy (Sitzia et al., 2006). It is reported that P availability in the soil mineral content may influence sesquiterpene lactone composition of chicory herbage (Foster et al., 2006).

Forage chicory is a valuable pasture component because it exhibits more tolerance to adverse environmental conditions such as drought (Kemp et al., 2002), low soil fertility, and disease and pests’ resistance (Ge, 2006) ; And it is highly palatable, persistent and high-yielding plant that can improve seasonal distribution of high-quality herbage to both poultry and livestock (Foster et al., 2002; Kemp et al., 2002). As pasture or herbage, forage chicory has a longer period of utilizable time than common succulence because of being greenery earlier in spring and dormancy later in winter, e.g. in mid areas of China, it can provide excellent forage for harvest or grazing livestock as long as 8 months (from Apr. to Nov.), whereas in southern China, can be used round yearly without dormancy with 12-13 times leaf harvests (cut with a stubble of 4-5 cm usually) per year and a rest period of 22 (in summer) to 40 (in winter) days between harvests, if in moderately well-drained soils and providing moderate to high fertility after each harvest for optimal vegetation growth, and for preventing the plant from matures and reaches the reproductive growth stage, e.g. cv. Barckoria and cv. Oubao chicory have fresh leaf yields as high as 40×104 kg/hm^2 and 38.4×104 kg/hm^2 per year (table 2), respectively. And, it can be used for up to 15 years of leaf harvests or grazing forage when planted with grass or legume mixtures if managed properly. Also, because of caffeinic acid and alkaloid in the leaf, forage chicory is highly resistant to plant disease and pests, except rotting root when in not well-drained soils, after conducted a 10 year (1989-1999) trial in China (Ge, 2006; Shang, 2007; Shang, 2008; Wang and Cui, 2010a; Xie et al., 2007).

A comparative trial was conducted in Grassland Science Institute of Guizhou Province of China in successive 2 years (2006-2007), planted cv. Puna chicory mixed with *Rutagaga*, maize and *Beta vulgaris* var. cicla, respectively, compared the yields with growth Puna of monoculture. The overall results show that, the mixtures of Puna-*Rutagaga* and Puna-maize produced fresh leaf yields, which are not significantly different from the monoculture Puna chicory, and gained additional harvests of fresh leaf 40,920kg/hm^2 together with fresh root 3,4684kg/hm^2 of *Rutagaga*, and fresh maize stalk and leaf 21,400kg/hm^2 together with dried corn grain 7,615kg/hm^2, respectively, therefore, increased the cropland use efficiency and gained additional profits from the 2 mixtures for herdsman (Tan et al., 2008). Forage chicory is usually leafy harvest or rotationally strip grazed with a rest period of 25-30 days, but can also be used to improve the quality of a silage mixture for milch cow in later winter and early spring when mixed with alfalfa or brome grass in mid or northern China (Wang and Cui, 2010b). In addition, grazing chicory can decrease some internal parasites in livestock, and therefore has potential to reduce the use of anthelmintics (Athanasiadou et al., 2005; Wang and Cui, 2010b).

An over three years trial for evaluation of Ninety-one perennial legumes and herbs from 47 species in 21 genera was conducted to identify species with high herbage production and persistence in mixed farming zones in southern Australia showed that Chicory, T. *fragiferum* and L. *corniculatus* were identified as species, other than lucerne, with the most immediate potential for further selection to increase the diversity of perennial legumes and herbs adapted to southern Australian environments (Li et al., 2008a).

Leafy vegetable

Though its has been used in European countries for hundreds of years as a leafy vegetable, chicory is a relatively new hardy vegetable crop in China (Wang and Cui, 2010b; Groenwold, 1979). Both forage and vegetable used chicory, e.g. cv. Europe and cv. Yifeng chicory, provide fresh green leaf, which are used as a salad green or mixtures with blander-flavored lettuce, but also used cooked, grown for its chicons, obtained by forcing roots in the dark in winter, viz. the roots are harvested in the fall before hard freezing occurs, and planted upright in moist sand and forced to grow a new head by keeping the air temperature near 18℃ degrees (Wang and Cui, 2010b). The chicons salad, for its chemical compositions of esculetin, cichoriin and lactucopicrin, has a effect of purifying liver, regulating gallbladder, relieving (detoxicating) ebriety and keeping fit (Wang and Cui, 2009a, b). Either used as a salad or cooked, chicory is a health care vegetable (Yin et al., 2008), for its rich in mineral content and amino-acid, and curative effect (Wang and Cui, 2009a). Also, growing without any insecticide or pesticide, it can be a raw material for growing edible fungus (Wang and Cui, 2009a, b). Therefore, chicory is ranked a functional vegetable in 21st century (Wang and Cui, 2009a, b).

Natural products extraction and further developments

Historically, the majority of new drugs have been generated from natural products (secondary metabolites) and from compounds derived from natural products (Li and Vederas, 2009). For its special chemical compositions and physiological bioactivities, natural products extraction from chicory has been preparing and developing for natural medicine (drugs), salubrious beverages, functional foods and additives (Wang and Cui, 2009a, b).

In addition to an important sources of inulin, fructans, polyphenols and cichoric acid (Milala et al., 2009; Zhang et al., 2005a) in food industry, natural products extracting from chicory, which contains saccharides, organic acid, polyphenol (Heimler et al., 2009; Yang, 2009), alkaloid, triterpenes, sesquiterpenes, coumarins, flavone (Ablimit et al., 2008; Mao et al., 2009; Wu and Luo, 2009; Yang et al., 2009b), etc., have many physiological bioactivities and remedial (therapeutic) effects (Board of Health of Xinjiang Uigur Autonomus Region Revolution Committee, 1976; Li et al., 2005; Ramalakshmi et al., 1994; Rees and Harborne, 1985; Trdan et al., 2004; Xinjiang Army Logistic Hygeian Unit, 1970). e.g. a number of studies report the effects of chicory extractive in lowering the blood glucose and lipid of rats (Zheng et al., 2008), in decreasing uric acid of mice (Li et al., 2008b), of quail (Yang et al., 2009a), and hepatoprotection of mice (Talip et al., 2006; Zheng et al., 2008). And it can be sorbefacient calcium, enhancing immunity via antioxidant activity in experimental rats (Jurgonski et al., 2008; Lavelli, 2008; Nessrien et al., 2007).

It is also reported chicory extractives have the effects on antifatigue (Zheng et al., 2004), antiaging (Qi et al., 2008) and anticancer activities (Chen et al., 2004; Hazra et al., 2002; Pool-Zobel, 2006) of rats and mice, etc.. Furthermore, the ethanol extract from chicory stem have antiallergic, antibacterial activities (Nishimura et al., 2000; Tursunay et al., 2009), antivirus (Ni et al., 2005; Ren et al., 2008) and anti-inflammatory effects (Ripoll et al., 2006; Ripoll et al., 2007) in vitro and vivo.

And the root extraction of chicory have a herbicidal activity on *Trifolium repens* L., *Lolium perenne* L, *C.intybus*, and *Abutilon theophrasti* Medic in a newly report (Sun, et al, 2010).

In addition, the shoot, root and seed of chicory are components or ingredients of traditional Chinese medicine, and it is evacuant and appetitive (Mimistry of Health of the People's Republic of China Pharmacopoeia Committee, 2005; New Medical College of Jiangsu, 1977) with better cardiovascular effect (Jiang et al., 2008b).

Almost half of the chemicals, which are popular used medically nowadays, are come from natural products compounds or its ramifications. More than 90% of new chemicals, developing in last five decades in China, are related to natural products (Hu and Xu, 2009), e.g. about 60% of anticancer drugs are getting from plant natural products, and been expecting more effective drugs for infection, immunity and metabolize diseases from natural products (Qi et al., 2007). In the point of this view, it must have a bright prospect on discovering new medicine (drugs) with research and development on the peculiar physiology function of the natural products extraction from chicory, e.g. a method of manufacturing medicine (drug) for treating coronary heart disease with cichoric acid (Jiang et al., 2008a, b) and a method of manufacturing medicine (drug) for treating dementia disease with cichoric acid (Jiang et al., 2008a) and anti-edema drugs (Ripoll et al., 2005; Ripoll et al., 2006). In addition, Chicory feeding be considered to have the potential for utilization as part of a strategy for boar taint reduction in intact male pork (Byrne et al., 2008).

A functional foods market's increase at a speed of 12% per year in last five years in China, whereas 10% in the world (Patel et al., 2008; Yang, 2008), chicory is developing for salubrious beverage, functional foods and additives, e.g. chicory tea (Liu, 2001), chicory tea for keeping fit (Jiang et al., 2007), chicory additives for livestock and poultrly feedstuff (Zhang et al., 2009), though developed in some other countries, e.g. chicory beverage (Guyot, 2000; Leroux, 1987; Nakhmetov et al., 1991; Vonasek et al., 1986), chicory powders and chicory pastes (Magomedov et al., 2003), functional food and pet food (Fone, 1998a; Fone, 1998b; Fone, 2002; Montagner, 2003) etc..

Raw material for industry

Chicory inulin has been identified as an effective prebiotic to promote active fermentation and lactobacilli proliferation in the large intestine, and to enhance calcium (Ca) digestive absorption and deposition in bones of rats (Demigne et al., 2008). As inulin is the highest component of chicory, about 70% of dried matter, chicory is valuable raw material for industrialized producing inulin, fructooligosaccharide and high fructose corn syrup for foodstuff manufacture (Kikuchi et al., 2009), e.g. confectionery products and beverages. Inulin as a dietary fibre is getting more and more popular used in food industry in European countries, e.g. inulin is produced (from chicory and Jerusalem artichoke) about 1×10^6 ton per year for further processing to manufacture functional food and salubrious food etc. in Europe (Yin and Lin, 2008). As inulin is in great demand in the world market, a first plant for producing inulin from chicory (usually from in Jerusalem artichoke in China) is founded and put into produced 6×10^4 ton per year in Liaoning province in China (Li et al., 2009). Furthermore, crude protein, ether extract, crude fiber and nitrogen free extract, which are contain in the residua after industrialized extraction of chicory shoot and root, are higher than those in corn grain. So, in terms of value in use, chicory is quality industrial material and valuable cash crop (Hu et al., 2006; Wu et al., 2008).

In addition, the essence and spice extracting from chicory flowers can be manufacture cosmetic. Also, it can be abstract and epurate edible pigment (Haito and Saito, 2004; Haito and Saito, 2006), dispersed bitter substances suitable for use in the food industry (Binder and Wolf, 1985) and neutralization of bitterness of foods and its use for manufacture of functional foods based on chicory or other bitter raw materials (Koyazounda, 2007; Koyazounda, 2008) etc.

Potential use of biomonitor for entironment

In Kayseri, Turkey, Forty-five sites (industrial, urban, roadside, suburban and rural) in and around Kayseri were investigated for testing chicory as a possible biomontor of heavy metal pollution. The results indicated that mean heavy metal concentrations in industrial site and roadside were significantly higher than rural sites in washed and unwashed leaves of chicory concentrations of Pb, Cd, Cu and Zn were determined in unwashed and washed leaves and soils collected from a wide range of sites with different degrees of metal pollution. The mean Pb, Cd, Zn and Cu concentrations in industrial site were significantly higher than rural sites in soil. Significant correlations were obtained between the heavy metal concentrations in surface soils and washed leaf samples. This demonstrated that chicory is a useful biomonitor of the investigated heavy metals (Aksoy, 2008); As indicator plant, chicory can accumulate the heavy metal (cadmium, Cd; chromium, Cr; copper, Cu; nickel, Ni; lead, Pb and zinc, Zn), sodium (Na) and sulphur (S) contamination of roadside topsoils (Scotti et al., 1999; Simon, 2001).

Since bloomming stage of chicory is last out 3-4 months in temperate zone, it is a good honey fountain plant, and a quality water and soil conserving plant with being deep top root, drought-tolerant and can reduce nitrate leaching, deep drainage, thereby reducing the rate of soil acidification and the occurrence of dryland salinity (Han et al., 2009; Li and Kemp, 2005; Sun et al., 2009; Zhao et al., 2009).

CONCLUSION AND SUGGESTIONS FOR FUTURE RESEARCH

The research efforts on the biochemical compositions and physiological bioactivities of extractives from chicory clearly states some promising potential utility technologies of the plant: Curative effect as a forage or vegetable with good digestibility, use of chicory in confectionery products and beverages, the potential for use in discovering new effective medicine and the development of new salubrious functional foods, additives and other profitable green bioproducts. However, a significant research gap span still remains in these pharmacological actions and discoveries, and as such, profitable and efficient utilization of the health benefits of this plant should be put into practice. Thus, further researches are urgently required to gain a better understanding and definite knowledge of chicory and its extractives in various protections against diseases.

Concentrated shoot or root extracts and purified chemical can be found in various herbal preparations. As it is cheap and easily available in developing countries, chicory preparations are getting more and more available in China, as well as the rest of the world, to employ or assist-remedy by practitioners of natural health in treating a number of diseases or chronics, for example, diabetes mellitus, coronary heart disease, chronic liverish disease, allergic or infective disease, inflammation and even cancer. However, the structure property of the physiological bioactivities and the relation between the structure and function are not quite clear, and thus, further work is obviously needed to prove more controlled clinical trials.

Towards industrialized utilization of chicory products, integrative and systemic studies are imperatively needed from concentration and extraction to industrial end-uses through process development and optimization of technologies, including environmentally benign solvents (for example, ethanol and water) and other global green technology (for example, sub- and super-critical liquids, ionic liquids, enzyme-assisted and ultrasound treatment) that are involved in the extraction mechanisms and in the residue processing for complete biomass conversion.

Though chicory is a beneficial herb and it contains high amount of proteins, carbohydrates, mineral elements, good agronomic characters and high biomass production, the research on developing more effective green processing techniques could further disseminate the wider utilizations as feed, food or medicinal materials. Nonetheless, further extensive research work focusing on *in vitro* and *in vivo* experiments related to biological activities evaluation and health-promoting properties are fundamentally needed.

As it is reported to accumulate the heavy metal contamination of roadside topsoil and industrial site, chicory has the potential to be used as biomonitor for entironment, especially for heavy metal pollution. However, further studies of critical demonstration are presently needed.

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