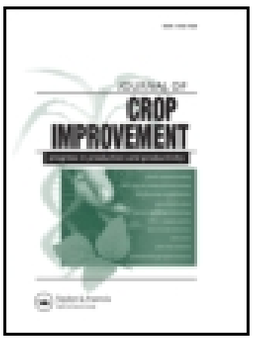

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Eating instead of managing it?–a systematic literature review on potential uses of creeping thistle as food and medicinal plant

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ABSTRACT

Creeping thistle, *Cirsium arvense* (L.) Scop, is one of the most common weeds in temperate climates. Frequently classified as an invasive species, it is the cause of massive herbicide and tillage use. Especially in organic systems, the plant is hard to manage. Little is known about creeping thistle being entirely edible and having diverse medicinal properties. Additionally, it has potential to be used as food preservative and provides essential ecosystem services. This systematic literature review provides evidence of creeping thistle uses from 56 peer-reviewed journals and 37 popular media references. It discusses potential uses and phytochemical properties of specific plant parts. Findings identify the stem as the most promising part for food use. Creeping thistle has elevated flavonoid (flower) and inulin (root) contents, with anti-inflammatory, antioxidant, and anti-diabetic properties respectively. The discussion contrasts the potential of creeping thistle of becoming a multi-purpose crop with its classification as a noxious weed.

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Canada thistle; ethnobotany; invasive species; neglected species; underutilized species

Introduction

Cirsium arvense (L.) Scop, Creeping, Canada, or California thistle, is a common weed of the *Asteraceae* family found in diverse cropping systems across temperate climates (Orhan et al. 2013). The plant is the cause of extensive weed control measures, including massive herbicide and tillage use. Its extensive horizontal and vertical root system stores considerable carbohydrate reserves, allowing the plant to resist diverse weed management techniques (Favrelière et al. 2020). Since creeping thistle also thrives in grazing areas and unmanaged (disturbed) environments (Tiley 2010), it is considered a noxious weed and invasive plant in the USA and numerous other countries (United States Department of Agriculture 2015).

However, *C. arvense* has been used as a food and medicinal plant for centuries. Numerous ethnobotanical studies have documented medicinal and health-promoting uses of the whole plant (Chhikara et al. 2020), and

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phytochemical analyses (Kenny et al. (2014) have built on this traditional ecological knowledge and identified plant metabolites of medicinal interest. Studies on edible uses are scarce, particularly outside ethnobotany. Thus, this review includes several online media sources discuss using creeping thistle as food, and information on its harvesting and food preparation.

The discrepancy between the potential of this plant, which is currently not exploited at a commercial scale, and the fact that farmers invest labor and resources to manage it, indicates the need for exploring evidence of uses of creeping thistle. Therefore, a systematic literature review – aligned with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) protocol (Moher et al. 2009) – was conducted to analyze evidence on human uses of *C. arvense*. This review aims to provide a baseline for assessing the question of whether reinterpreting the widespread notion of creeping thistle exclusively as a noxious weed is worthwhile (without neglecting its harmful role in different ecosystems).

Background

Creeping thistle botany and ecology

The creeping thistle is an herbaceous perennial *Asteraceae* native to temperate Eurasia (Guggisberg et al. 2012; Orhan et al. 2013). The species is characterized by considerable morphological variation, especially if derived from seed (Tiley 2010; Ackerfield et al. 2020). Five varieties have been identified, *C. arvense arvense, C. arvense maritimum, C. arvense horridum, C. arvense integrifolium*, and *C. arvense vestitum* (Tiley 2010).

Following human migration and agricultural activity, it has spread across the temperate northern hemisphere, South America, and Oceania. In the 17th century, it was introduced to North America from Europe, likely as contaminated hay (Tiley 2010). Seeds may have entered the USA in baled hay from Canada, which would explain its common designation in the USA, Canada Thistle (Spence 2016).

The latitudinal distribution of creeping thistle is limited by low winter and summer maximum temperatures, and by its long-day requirement for flowering. Creeping thistle grows on a wide range of soils but is sensitive to waterlogging. It is considered an indicator of "good land" since the plant grows best on nutrient- and organic-matter-rich substrate (Tiley 2010). As a long-day plant, creeping thistle is shade-intolerant (Chhikara et al. 2020).

Depending on the variety, stems can grow up to 180 cm above ground level (Tiley 2010). *C. arvense* is a rhizomatous thistle with a yellowish-green hollow slender stem (Chhikara et al. 2020). Yellowish to dark green sessile leaves are spiny, lobed, 15–20 cm long, 2–3 cm thick, and arranged alternately on the stem. Short-stalked, partially amplexicaul smaller leaves give

the appearance of a spiny stem (Chhikara et al. 2020). Creeping thistle is a diploid (2 n = 34), dioecious perennial that spreads both vegetatively by rhizomes and sexually (Guggisberg et al. 2012; Tiley 2010). Occasionally, plants have hermaphrodite nature. Flowers are lavender to pink. Female flowers lack pollen and have a peculiar vanilla-like scent. Commonly, there are 2–5 floral heads per branch and 100 florets per head, but favorable conditions may promote up to 100 heads per branch. Seeds are 4–5 mm long. Seed production varies depending on vicinity of male and female plants. Anemochory is facilitated by a feathery pappus (Chhikara et al. 2020). Seeds are generally produced by female flowers, but low seed production by males has been reported (Heimann and Cussans 1996). Creeping thistle has deep vertical roots, commonly located below the top 20 cm of the soil surface and with an extensive root system. Its creeping horizontal roots, up to 5 m long, can regenerate at considerable soil depth and develop axillary buds able to develop new aerial shoots (Nadeau and Vandenborn 1989; McAllister and Haderlie 1985; Favrelière et al. 2020; Tiley 2010). In early Spring, *C. arvense* uses carbohydrates stored in its root as an energy source to produce new shoots (Figure 1; McAllister and Haderlie 1985).

First-year shoots have a protein content of around 15% of the dry mass which doubles in mature shoots (Tiley 2010). It is remarkably high in leaves, almost equivalent to that of forage legumes (Harrington, Beskow, and Hodgson 2008). K, Ca, S, Fe, Mn, Cu, Zn, and B contents are also elevated (Harrington, Thatcher, and Kemp 2006).

Creeping thistle as weed and invasive plant

The creeping thistle is an effective colonizer of both agricultural and unmanaged environments (Guggisberg et al. 2012), mainly due to its vegetative propagation. Plants originating from rhizome fragments grow faster than those developing from seeds (Favrelière et al. 2020; Tiley 2010). A single seedling or root fragment leads to a clumped distribution of aerial shoots with widely varying densities (Tiley 2010).

In agricultural production, the extensive and persistent underground root system of *C. arvense* is difficult to manage because carbohydrate reserves provide such plants with the ability to resist diverse weed-management techniques (Favrelière et al. 2020). The presence of *C. arvense* not only causes yield losses in crops but some authors also claim that it can interfere in pastures due to a deterrent effect of the leaf spines on grazing animals (Tiley 2010) while others state that livestock can be trained to feeding on creeping thistle and considerably benefits from it (Voth 2021). This has led to a long history of investigation into control measures (mechanical, chemical, biological, cultural, and integrated). However, despite more than a century of research on creeping thistle control, the management of this weed has met

Figure 1. Young creeping thistle roots and shoots, ready for human consumption.

with limited success (Cripps et al. 2011). It is now the most frequently listed harmful weed in the USA and Canada (Skinner, Smith, and Rice 2000). Systemic herbicides are considered most effective against creeping thistle, especially in the long-term, since they are capable of affecting the root (Government of Saskatchewan 2022). However, even abundantly applied herbicides cannot hinder the creeping thistle's long-term survival (Davis et al. 2018). Despite herbicides being the most common control methods used in conventional and integrated agriculture, cultural practices (e.g., mowing, hoeing, or repeated cultivations) have also been effective but are often expensive and time-consuming (Favrelière et al. 2020). Combinations of herbicides and cultural practices are most effective (Davis et al. 2018). While integrated weed management is a promising strategy, controlling creeping thistle in organic systems is most challenging (Orloff et al. 2018).

Creeping thistle also effectively colonizes non-agricultural environments (Figure 2), usually through seeds, which is most common on bare or disturbed ground, mirroring the plant's ecology as an opportunist pioneer (Tiley 2010). Hence, creeping thistle is listed as noxious invasive species in 27 US

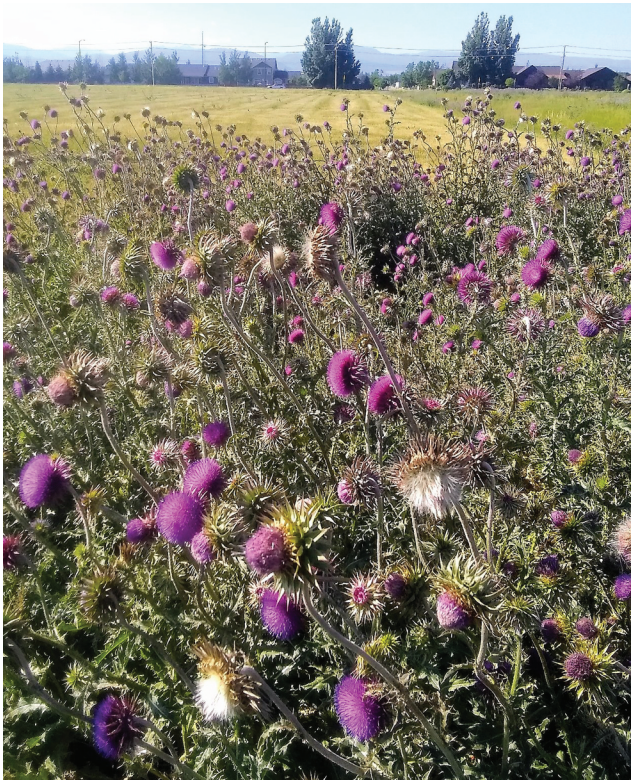

Figure 2. Creeping thistle not only colonizes farmland but also urban areas, for example construction land. Growth in patches is most common.

states (United States Department of Agriculture 2022) and terrestrial invasive at the federal level (United States Department of Agriculture 2015). Creeping thistle and other plants designated "invasive" impose enormous financial costs on agriculture, challenge biodiversity, and degrade the functioning of native ecosystems (Vilà et al. 2011).

Methods

Systematic literature review approach and study question

This systematic literature review was conducted to collect and analyze published evidence on the following closed-frame study question: What evidence exists of human uses of creeping thistle (*Cirsium arvense*)? Emphasis was on using creeping thistle as a source of food and medicine. The literature research was conducted by the author between September 2020 and May 2022.

The review process was aligned with the PRISMA protocol (Moher et al. 2009). This procedure involves four essential steps: (1) search term definition

and article search, (2) title and abstract screening, (3) full-text screening, and (4) data systematization and analysis.

The literature review centered on peer-reviewed academic publications. Given the relatively low number of academic publications on creeping thistle as a food, an additional online popular media review was conducted, exploring contemporary movements such as "plant foraging." The protocols of both reviews were identical, but slightly different search terms were used. The data synthesis of the popular media review also covers fewer parameters than the academic publication review because little expertise in areas such as phytochemistry was expected in popular media. The outcomes of each review, academic versus popular media, are presented separately in the results section.

Academic publication review

The overall research question determined the search terms used in the PRISMA protocol. To specify the search, different search term combinations were tested in five different publication databases (Web of Science, ScienceDirect, Wiley Online Library, Scopus, and Google Scholar). The initial search terms were confirmed and used as the final set of search terms (Table 1). Web of Science and Google Scholar were selected as the only consulted databases due to low outputs in the other ones. Based on this decision, 66 academic articles were identified for the review process as at least one search term combination appeared in their title, abstract, keywords, or full text.

Next, the abstracts of the 66 articles were reviewed to select publications for the full-text reading. The respective *a-priori* inclusion criteria were: (i) evidence of elevated academic quality control (peer-review) without restriction of publication year; (ii) article is published in English; (iii) article is a journal article, book, or book chapter, and (iv) the abstract addresses the research question directly. If criterion (iv) was not met, the full text was searched for a potential section on uses of creeping thistle. The exclusion criteria included (i) reports, manuals, maps, newspaper articles, and non-print media; (ii) articles without abstract; (iii) abstracts written in poor English or a language other than English; and (iv) articles published by

Table 1. Final search terms, peer-reviewed academic publications.

Term 1	AND	Term 2
"Cirsium arvense"		Edible OR Medicinal OR Use(s)

a potentially predatory publisher based on beallslist.net (Google Scholar only). A total of 57 articles that met the inclusion criteria were considered for full-text screening. The identified articles were critically appraised to ensure they provided evidence to address the study question and met the *a-priori* inclusion criteria. Fifty-six articles were included in the quantitative synthesis of the systematic literature review.

The specific parameters of evidence extracted from each article included: (i) uses of creeping thistle (in general categories, such as edible or medicinal), (ii) field of study, for example ethnobotany or weed science, that contributed to the development of the article, (iii) country or region where the study was conducted, (iv) plant parts used as food and all respective specifications, (v) food uses and food preparation, (vi) plant parts used as medicine and all respective specifications, (vii) therapeutic effects, (viii) method of application as human medicine, (ix) phytochemical properties per plant part, (x) other uses (articles that exclusively dealt with uses of creeping thistle other than as food or medicine were not considered, but additional uses, for example as forage or pollinator plant, were recorded for reviewed articles). Using the software NVivo Release 1.6.1 (QSR International, Doncaster, Australia), the evidence from each text was then synthesized using the aforementioned parameters as codes and establishing sub-codes where appropriate, for example one for each plant part (Edwards-Jones 2014).

Popular media review

Different search-term combinations were tested in the Google search engine (Table 2). For each search term, only the first one-hundred hits were reviewed. Eliminating duplicates, 176 web pages (including links to videos) were identified for further review.

The inclusion criteria for full review were: (i) media published in English and (ii) media containing text about creeping thistle or video that dealt with this topic. The exclusion criteria included (i) social media, (ii) media using poor English or another language, (iii) media with an exclusively commercial context (without facts about creeping thistle), and (iv) media that appeared to reproduce third-hand content only. A total of 41 media were considered for full-text screening. They were converted into formats accessible for coding in

Table 2. Final search terms, popular media.

Term 1	AND	Term 2
"Cirsium arvense"		Edible
OR		OR
"Canada Thistle"		Medicinal
OR		OR
"Creeping Thistle"		Use(s)

NVivo using NCapture. After full review, 37 media were considered for data extraction.

The specific parameters for the qualitative data extraction in NVivo (same procedure as for academic publications) included: (i) uses of creeping thistle (in general categories), (ii) plant parts used as food and respective specifications, (iii) food uses and food preparation, (iv) plant parts used as medicine and respective specifications, (v) therapeutic effects, and (vi) other uses.

Findings and discussion

Identified full texts

Available peer-reviewed literature mainly deals with two areas: (1) Phytochemical studies, analyzing the presence of plant metabolites with potential medicinal properties in specific plant parts, and (2) ethnobiological studies about traditional uses of creeping thistle as medicine or food. The 56 reviewed academic publication full texts (Appendix 1) involve 53 studies conducted in 17 different countries or regions, with most studies coming from Pakistan, Turkey, the USA, and Canada (Figure 3). Three publications are of global scope. Half of the reviewed studies are from the field of ethnobotany, and 29% deal with plant physiology or phytochemistry. The review further includes studies in botany, ecology, crop and weed science, and microbiology (Figure 4). The popular media review encompasses 37 websites (Appendix 2). While 66% of reviewed academic papers deal with medicinal uses of creeping thistle, most popular media emphasize its food use (Table 3).

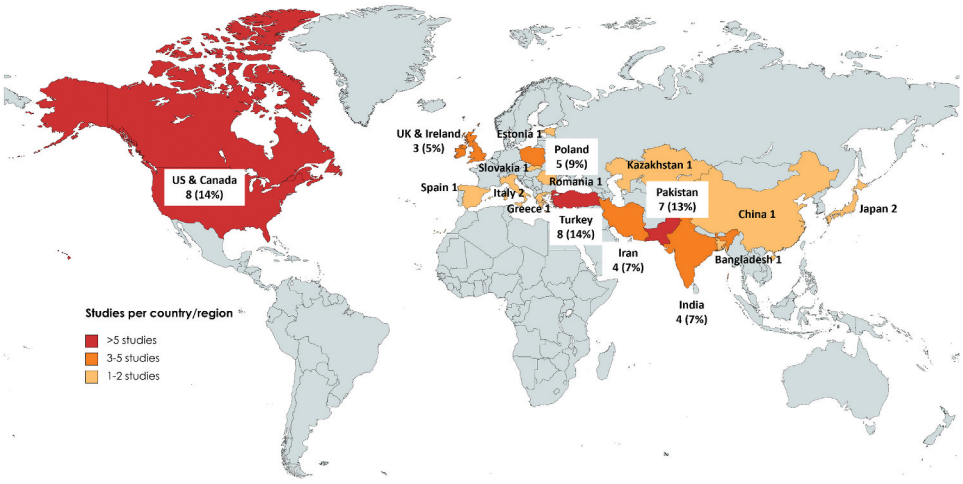

Figure 3. Countries and regions where reviewed academic publications were conducted, number of publications per area.

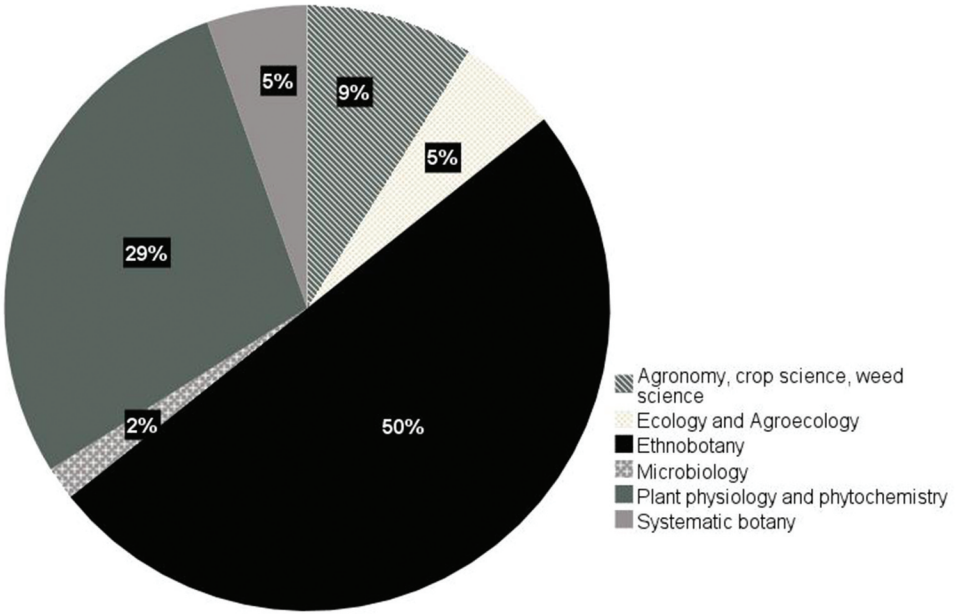

Figure 4. Scientific disciplines related to studies on creeping thistle uses percentage of all reviewed academic publications.

Table 3. Reported core uses of *C. arvense* per group of reviewed publications (% of publications reporting a specific use per total number of reviewed publications).

	Edible Use	Medicinal Use	Other Uses
Academic publications (n = 56)	39%	66%	27%
Popular media (n = 37)	78%	49%	30%

In reviewed academic publications, essential background is lacking to assess the potential of *C. arvense* to become a future food source or crop. For example, precise information on its mineral or vitamin content could not be identified. Furthermore, no information is available on how specific traits (e.g., phytochemical properties, yield, harvestability, or flavor) vary due to plant age, sex, environmental conditions, and variety. Likewise, information on crop management, yield, harvesting, storage, shelf life, contemporary culinary uses, or consumer preferences has not been found. Finally, no information is available on potential market demand. The popular media review provided relevant additional insight into food uses, covering culinary uses of fresh creeping thistle, strategies for foraging, and preparation recommendations. Ethnoculinary and historic uses are also discussed. Some popular media offer information on food products made from the plant.

Concerning medicinal use, most academic publications deal with potential uses in contemporary medicine or therapeutic uses in traditional medicine. Thus, important technical information, for example on extraction methods,

is missing. Neither is evidence from clinical studies available. Reviewed popular media do not add considerably to the body of knowledge on medicinal uses of creeping thistle, as they frequently refer to peer-reviewed studies.

As for uses other than as food or medicine, uses reported in academic media encompass creeping thistle as an organic pesticide (insecticide, fungicide), food preservative, forage plant, veterinary medicine, potential ingredient of perfumes, source of nanoparticles, pollinator plant, and providing further ecosystem services such as erosion prevention. Popular media additionally discuss the plant as a source of oil and tinder and as an ornamental plant.

Overall, the reviewed sources provide evidence of multiple human uses of creeping thistle. The available information is a starting point, outlining research needs, but does not go beyond that.

Phytochemistry

Sixteen peer-reviewed publications deal with the phytochemistry of creeping thistle, 15 of which include analytical studies, mainly about plant compounds and their potential uses in fields such as food processing and safety, medicine, pest and weed control. Antimicrobial properties (for food preservation and health) are a common topic. Table 4 contains an overview of primary and secondary plant metabolites (by plant part) of creeping thistle that have been identified in these studies. The table only lists compounds that contribute to potential uses of *C. arvense*.

Food uses

Overview

In academic publications, human consumption of creeping thistle is evidenced from India, Italy, Kazakhstan, Pakistan, Romania, Russia, Slovakia, Spain, Turkey, the UK and Ireland, and North America (USA and Canada, specifically Native American communities). Out of 22 academic publications dealing with food uses of creeping thistle, 64% include edible uses of the stem, 41% of roots, 41% of leaves, and 5% of the flower. Of 29 reviewed popular media articles about creeping thistle as food, 86% report edible uses of the stem, 45% of roots, 52% of leaves, and 17% of the flower.

Stem

Most reviewed (academic and popular) sources recommend the internal aerial stem of young plants as the most appropriate part for human consumption: First, because the young stem is described as easiest to clean, and second, because the taste is perceived as palatable, specifically tender,

Table 4. Primary and secondary plant metabolites with medicinal properties identified in reviewed academic publications, number of studies providing evidence per plant part.

	Flower	Leaf	Root	Stem	Whole plant	Not specified
Alkanes						
Docosane	1					
Heneicosane				1		
Heptacosane	1					
Hexacosane	1					
Nonacosane	1					
Nonadecene			1			
Octadecane	1					
Tetracosane	1					
Flavonoids						
Flavonoids (unspecified)	2	1		2		4
Acacetin	1					
Apigenin	1					1
Apigetrin	1					
Kaempferol	1					
Linarin		1				
Luteolin	1					
Rutin		1				
Glycosides						
Glycosides (unspecified)				1		1
Saponins (unspecified)			1			
Quercimeritrin						1
Phenolic acids						
Phenolic acids (unspecified)	2	2		1		2
Chlorogenic acid		1			1	
Coumaric acid		1				
Ferulic acid		1				
Vanillic acid		1				
Saccharides						
(chiro-, myo-) Inositol					1	
Inulin			3			
Steroids						
Steroids (unspecified)			1			1
Lanosterol acetate	1					
gamma-Sitosterol	1					
Stigmasterol	1					
Terpenes						
alpha-Amorphene		1				
Bisabolol	1	1		1		
delta-Cadinene	1	1		1		
Carene	1	1				
Caryophyllene	1	1		1		
Germacrene				1		
Humulene	1	1		1		
Phytol	1			1		
alpha-Pinene		1				
beta-Selinene		1		1		
Terpenoids						
Terpenoids (unspecified)				2		2
Amyrin	2					
Borneol	1			1		
Camphor	1	1	1	1		
beta-Citronellol		1				
delta-Elemene		1		1		

(*Continued*)

Table 4. (Continued).

	Flower	Leaf	Root	Stem	Whole plant	Not specified
Eucalyptol	1	1		1		
Fenchyl acetate	1					
Nerol	1					
Oplopenone				1		
Other compounds						
Alkaloids (unspecified)				2		1
Coumarins (unspecified)			1	1		2
Tannins (unspecified)				1		3
2 H-1-Benzopyran						1
Estragole	1					
Mannitol						1
2-Pentaadecanone						1
Quinic acid	1	1		1	1	
Quinone			1			

resembling celery (for its appearance) and asparagus (for its use) (Rogers 1928; Lawanda's Garden 2021).

Three academic publications specifically point to the young stem and another three to young developing shoots. One paper refers to Rogers (1928), who suggests consuming "the shoots before emerging from the soil," which are described as "tender and tasty when used in the same way as asparagus."

Several popular media add that stems should be peeled, removing the ectoderm, for raw or cooked intake and that their processing is like the one of asparagus or rhubarb. Following DeGroot (2019), the best time to harvest stems is when the buds are forming but not yet open and stems are 1–2 cm thick. Lawanda's Garden (2021) recommends steaming them in salted water. Creeping thistle stems are presented as a celery substitute (Landes 2022), part of salads, stir fries (Lawanda's Garden 2021), or soups (Raya Garden 2022).

Leaves

While one academic publication suggests the exclusive consumption of young leaves (Kenny et al. 2014), others are less specific. In popular media, it is strongly recommended to remove the leaf margins before consumption, wearing gloves. One online video suggests eating only the midribs of leaves harvested in the Spring (Edible Wild Food 2019). Raw or cooked consumption of leaves is most recommended. Leaf flavor is described as slightly sweet and salty, recalling the flavor of the globe artichoke (Un Mondo Ecosostenibile 2022). Leaves can also be eaten fresh like spinach. They can be used in sandwiches (DeGroot 2019), soups, stews, and pot roasts (Alberta Wild Craft 2022), or fried with other herbs, garlic, and oil (Un Mondo Ecosostenibile 2022). According to Lawanda's Garden (2021), leaves can be frozen for future use.

Roots

Three academic publications refer to raw consumption of the roots, and two of them also mention cooking them. Numerous popular media specify that only first-year roots should be consumed. Several also indicate that eating the roots may result in flatulence due to their high content of inulin (starch-like soluble fiber; anti-diabetic and prebiotic; is not digested and enhances beneficial bowel microflora). Soaking roots for 24 hours before cooking them is said to decrease this effect (Lawanda's Garden 2021). Popular media recommend roots being cooked in a mixture with other vegetables (Wild Edibles Database Australia 2021). Their taste is described as between Jerusalem artichoke and parsnip (Landes 2022).

Flower

The only academic publication discussing creeping thistle flower as a food recommends using its capitula for an infusion (Şenkardeş et al. 2019). In popular media, edible flower uses are discussed in more detail. One article points to eating the inner part of the petioles (after stripping all spines off) raw, as a pickle or cooked (Hope 2022), another one recommends the consumption of the buds similar to the globe artichoke (Neverman 2021). One source articulates that thistle flowers can be used as chewing gum (Lawanda's Garden 2021). The flower may also be part of herbal teas (Alberta Wild Craft 2022). According to Honey Traveler (2022), single flower thistle honey (from *Carduus, Cirsium*, and *Centaurea* species) is an acknowledged specialty and produced in Italy, North America, Argentina, and Australia.

Culinary use

Regarding the preparation of meals with creeping thistle, 27% of academic publications on food uses (n = 22) suggest raw consumption (of stems and leaves) in snacks or salads, 18% point to cooked, stewed, or boiled preparation (mostly of stems), 14% feature stuffing of leaves, 7% fried processing (of the stem after boiling), 4% each mention creeping thistle as an ingredient of a soup (stem), bread (stem), or infusion (flower), and 32% do not include details on culinary use.

Accordingly, in Turkey and the Middle East, the thistle is part of traditional sarma (cooked leaves rolled around a filling made of rice and/or minced meat, and other vegetables), one of the most widespread feasting dishes of the Middle Eastern and South-Eastern European cuisines (Dogan et al. 2015). For this purpose, leaves of *Arctium, Centaurea, Cirsium, Petasites, Lactuc*a, *Solanum*, or *Tussilago* spp. are traditionally used, providing a sour, lightly astringent, or bitter taste. Further use of creeping thistle in this region is to boil leaves stuffed with rice or bulgur (pounded and boiled wheat) (Doğan and Tuzlacı 2015; Dogan et al. 2004, 2015). In Italy, creeping

thistle is fried in fat, often with beaten eggs (Ranfa and Bodesmo 2017). Historic use as soup, porridge, or bread ingredient, especially during food shortages, is reported from Estonia (Kalle and Sõukand 2012).

Popular media offer a variety of food uses of *C. arvense* (n = 28): 39% describe raw consumption (of stems and leaves, seldomly roots), and 32% cooked, steamed, or braised preparation (of leaves, stems, and roots). Furthermore, roasted, fried, baked, and stuffed preparation of stems and leaves is reported.

[The author of this review has self-experimented with eating (fresh and boiled) stems and roots. I found both, the texture and flavor, of stems appealing and would describe their taste as "fresh," closer to lettuce than asparagus. The texture resembles celery. The roots are palatable, but their taste needs getting used to. It reminded me of Jerusalem artichokes.]

Medicinal uses

Overview

Human consumption of creeping thistle for medicinal purposes is reported from Bangladesh, China, Estonia, Greece, India, Iran, Italy, Kazakhstan, Japan, Pakistan, Poland, Romania, Turkey, the UK, and the USA. Therapeutic effects of creeping thistle are discussed in peer-reviewed studies about the plant's phytochemistry and ethnobotany. Of all respective studies (n = 37), 24% report medicinal effects of thistle roots, 19% of the flower, 16% of leaves, 5% of stems, and 14% of the whole plant, while one-third does not specify the effective plant part.

Phytochemical studies and therapeutic effects

Anti-inflammatory properties of creeping thistle (leaves, roots) are most reported, followed by hemostatic (leaves) and diuretic effects (leaves, roots, stem) (see Table 5). The elevated inulin content, an anti-diabetic (Li et al. 2019; Tiley 2010), of creeping thistle roots indicates a promising area of opportunity for medicinal use (or as a food supplement). Hepatic and hepatoprotective root compounds are discussed in four ethnobotanical studies (Table 5). Hepatoprotective effects can be ascribed to bioactive compounds found in *C. arvense* roots, such as chlorogenic acid (Das et al. 2022).

Phytochemical studies further indicate that *C. arvense* flowers are rich in flavonoids (Dehjurian, Lari, and Motavalizadehkakhky 2017), including luteolin that has anti-inflammatory effects (Aziz, Kim, and Youl Cho 2018) and is discussed in the cure of cardiovascular disease (Aziz et al. 2021) and cancer (Lin et al. 2008). Flavonoids found in the flowers, such as kaempferol, also have strong antioxidant properties (Dehjurian, Lari, and Motavalizadehkakhky 2017; Silva Dos Santos et al. 2021).

Table 5. Reported therapeutic uses of *C. arvense* in humans, number and percentage of academic studies reporting a specific effect out of all reviewed publications dealing with medicinal plant uses (n = 37).

Therapeutic effect	Number of publications	Percentage out of 37 reviewed publications	Listed effective plant partsi
Antidiabetic	3	8%	R
Antifungal	2	5%	W
Anthelminthic	1	3%	R
Anti-inflammatory	11	30%	L, R
Antimicrobial	4	11%	W
Antioxidant	4	11%	W
Antiproliferative & anti-cancerous	4	11%	W
Antiseptic	1	3%	W
Appetizing	2	5%	R
Astringent	4	11%	R
Cholesterol-lowering	1	3%	
Diaphoretic	1	3%	W
Diuretic	6	16%	L, R, S
Emetic (after intoxications)	2	5%	F, L
Emmenagogue	1	3%	R
Generally vulnerary	1	3%	
Hemostatic	9	24%	L
Hepatic & hepatoprotective	4	11%	F, R
Laxative	1	3%	
Tonic	3	8%	L, R
Vasorelaxant	1	3%	

i F: Flower; L: Leaves; R: Root; S: Stem; W: Whole Plant

Ethnobotanical studies

Mentions of curing infections and inflammations of different body parts are most abundant (Table 6). Out of 28 reviewed ethnobotanical studies, 18 mention illnesses that have been treated with *C. arvense*. Using roots to cure mouth diseases is the most frequently mentioned single traditional use, followed by leukemia (where the effective plant part is not specified). Hemostatic (to check bleeding) effects are also prominently reported. They may be attributed to flavonoids and other phenolic compounds of the leaves (Lamponi 2021; Nazaruk et al. 2008). Noteworthily, ethnobotanical studies provide evidence of traditional plant use for specific therapeutic purposes but not of their effectiveness.

Methods of application

Topical applications, frequently poultices and bandages containing leaf juice, are most reported in peer-reviewed publications, especially in the context of healing wounds and infections (28% of considered publications, n = 18). Oral therapies (22%) involve the consumption of raw edible plant parts, chewing the leaf, and leaf extracts as a mouth wash. Oral uses are most mentioned in

Table 6. Human diseases treated with *C. arvense* in traditional medicine, number and percentage out of all reviewed ethnobotanical studies (n = 18).

Illness/disease	Number of publications	Percentage out of 18 Ethnobotany publications dealing with diseases	Effective plant part (if specified)i
Abdominal pain	3	17%	L
Arthritis	1	6%	
Bleeding piles	1	6%	
Bronchitis	2	11%	L, S
Cancer	1	6%	L
Cough	1	6%	
Diabetes	2	11%	R
Dry skin	1	6%	
Eye infections	3	17%	
Gastritis	1	6%	R
Gonorrhea	2	11%	
Headache	2	11%	L
Healing of wounds	1	6%	L
Inflammation	3	17%	L, R
Ingestion	2	11%	F, L
Leukemia	4	22%	
Metrorrhagia	3	17%	
Mouth diseases	6	33%	R
Pain	1	6%	
Rheumatism	1	6%	
Skin sores & Dermal inflation	3	17%	R
Sore throats	1	6%	L
Syphilis	3	17%	
Toothache	3	17%	L, R
Treating poison ivy	1	6%	R
Tuberculosis	3	17%	L, R
Ulcer	3	17%	
Vomiting	1	6%	L
Worms	3	17%	R

i F: Flower; L: Leaves; R: Root; S: Stem; W: Whole Plant

the context of mouth and teeth infections (17%). Decoction of leaves is listed as a strategy to cure abdominal pain (6%).

Popular media include several additional methods of application:

- Paste of the roots, combined with an equal quantity of the root paste of *Amaranthus spinosus* (spiny pigweed) as treatment of indigestion;
- Leaf tea to cure tuberculosis;
- Root tea or decoction to treat diarrhea and intestinal worms in children;
- Juice of the roots against intestinal parasites;
- Decoction of the whole plant, internally and externally, to heal bleeding piles;
- Creeping thistle (plant part not specified) simmered in milk as a remedy for diarrhea after the acute symptoms have subsided; and
- Root syrup for coughs.

Other uses

Academic and popular media suggest diverse creeping thistle uses other than as food and medicine (Table 7). Prominently, the plant's antibiotic properties are discussed in the context of uses as a food preservative, biopesticide, and veterinary medicine.

Table 7. Evidence of *C. arvense* uses other than as human food and medicine in reviewed academic (n = 56) and popular (n = 37) media.

Use	Academic publications (n = 56)	Popular media (n = 37)
Antibiotic (diverse contexts)	**4%**[i] Strong inhibitory activities of methanolic extract of *C. arvense* flower and leaves against *Escherichia coli* and *Klebsiella pneumonia* (Dehjurian, Lari, and Motavalizadehkakhky 2017).Antimicrobial properties against strains of *Staphylococcus aureus, Pseudomonas aeruginosa, Bacillus subtilis*, and *Candida albicans* (Kenny et al. 2014).	
Biofungicide	**4%** Leaves have highest antifungal properties, followed by stems and roots (Banaras et al. 2017).Especially to control *Macrophomina phaseolina* in beans (Banaras et al. 2017).	
Ecosystem services (food source)	**4%** Source of nectar for honeybees (Sheley and Petroff 1999).Food source for birds (Duke 2001).	**19%**[ii] Food source for pollinators (Helzer 2022).Fall honey plant (Raya Garden 2022).Attract honeybees (United States Department of Agriculture 2022).Food source for goldfinches (Smith 2022).
Ecosystem services (soils)	**4%** Erosion prevention (Sheley and Petroff 1999). Soil aeration and decompaction (Tiley 2010).	**3%** As a chelator of heavy metals in the soil (All About Heaven 2022).Carbon sequestration. (All About Heaven 2022).
Food preserving	**2%** Due to antimicrobial and antioxidant properties (Kenny et al. 2014).	
Food processing	**4%** To coagulate milk. (Uphof 1968).As a dye (Tiley 2010)	**13%** To coagulate milk. (Smith 2022).Extract is component of a Scottish gin (The Botanist 2021).
Forage	**6%** Senescent *C. arvense* as forage for deer (Khan et al. 2019).Forage for cattle and horses [historic] (Tiley 2010).	**6%** Forage for hogs (Raya Garden 2022). Forage for cattle, used similar to alfalfa (Smith 2022).
Fuel	**2%** For heating [historic] (Tiley 2010).	**3%** As oil and tinder (Wild Edibles Database Australia 2021).
Insect repellent	**2%** Due to its content of nonadecene beta-citronellol, and camphor (Amiri, Yadegari, and Hamedi 2018).	

(*Continued*)

Table 7. (Continued).

Use	Academic publications (n = 56)	Popular media (n = 37)
Veterinary medicine	**6%** Antimicrobial activity, treatment of endo- and ectoparasites in rabbits and poultry (whole plant) (Lans and Turner 2011).Performance, egg quality, nutrient digestibility and antioxidant status in quail (Orhan et al. 2013).	
Further uses	**6%** Source of bioactive, phyto-generated nanomaterials (Barbinta-Patrascu et al. 2020). Pappus used to fill mattresses [historic] (Tiley 2010).	**3%** As ornamental (DeGroot 2019).

i Number of peer-reviewed articles referring to use type (examples below do not cite all respective publications); ii Number of popular media referring to use type.

Evidence of antibiotic and fungal properties (of the whole plant) is available in a total of four academic publications (Table 7). These properties are widely related to alkenes and flavonoids in the creeping thistle flower and, to a lesser extent, in other plant parts (Chhikara et al. 2020). Uses as food preservatives, biopesticides, and veterinary medicine are discussed. The plant's antibiotic and -fungal properties indicate a viable use of creeping thistle. While other "thistles" have been identified as oil-rich plants (Ghiasy-Oskoee et al. 2020), this use of creeping thistle is not discussed in reviewed academic media.

Several ethnobotanical publications describe creeping thistle as a historic source of forage (for cattle, horses, hogs, and deer). A high nutritional value is cited (Tiley 2010).

Apart from direct human and animal uses, *C. arvense* is frequently mentioned as a plant that provides significant ecosystem services. It is characterized as a host to numerous insects, especially honeybees, attracted by copious and accessible nectar and strong flower fragrance (Tiley 2010).

Like other weeds, creeping thistle fulfills additional ecological functions such as providing habitat for insects and other fauna, preventing erosion, increasing soil organic matter, recycling soluble nutrients and avoiding their leaching, as well as sequestering carbon dioxide from the atmosphere (Schonbeck 2022).

Outlook

Creeping thistle as a future crop?

The available literature stresses the potential of creeping thistle as a multipurpose plant (whether as a crop or obtained through foraging) – a source of food, medicine, and preservative among other potential uses highlighted here. Foremost, being one of the most competitive weeds in countless

production systems and ecosystems in temperate climates (Davis et al. 2018; Sheley and Petroff 1999), *C. arvense* promises abundant growth (and possibly high yields) in diverse environments, while simultaneously providing important ecosystem services (Sheley and Petroff 1999; Duke 2001).

Converting a weed into a crop species would certainly be a contribution to diversifying available food crops: Today, only 30 crop species provide more than 90% of plant-based calories and nutrients consumed by humans (Hammer, Arrowsmith, and Gladis 2003), and it would not be the first time in human history that a weed plant is reinterpreted as a crop. Historically, the classification of a plant as a crop or weed has been a continuum as it is determined by a subjective decision based on the plant's usability for an individual producer or stakeholder (Randall 1997; Holzner 1982).

Weed manuals and herbicide promotional literature list numerous weed species such as clovers (*Trifolium* spp.), orchard grass (*Dactylis glomerata* L.), or Jerusalem artichoke (*Helianthus tuberosus* L.), plants that many farmers value as forage, cover, or food crops when grown in the right context. Instead, crops such as buckwheat (*Fagopyrum esculentum* L.) or winter rye (*Secale cereale* L.) can become weeds (Schonbeck 2022).

Several existing weeds are crop descendants, and numerous existing crops are weed descendants (Ellstrand et al. 2010; Filatova et al. 2021; Doebley 2006). Apart from historic examples of former weeds reinterpreted as crops, including oats and barley (Filatova et al. 2021), there are also contemporary examples, such as pennycress (*Thlaspi arvense* L.), still classified as a weed but currently, an emerging oil plant (DeMartini 2022; Zanetti et al. 2019). Weeds are also increasingly identified as a source of biomass for biofuels (Kataki and Kataki 2022). In conclusion, creeping thistle may be a promising future crop for certain producers, while still maintaining its classification as a harmful weed for others.

Since *C. arvense* is a strong competitor within and outside agroecosystems (Tiley 2010), its common classification as a noxious invasive species will be an obstacle to exploring its potential as a crop, not only from an ecological but also from a legal perspective. However, classifying species as "native" or "alien" is debated in academia (Warren 2021), because anthropogenic factors are sometimes behind invasive tendencies. Climate change is just one example of this (Zhang et al. 2020).

Research needs

Conversions of formerly wild "thistles" into crops have occurred (Gominho, Fernandez, and Pereira 2001; Domínguez et al. 2017). If someone decided to explore creeping thistle as a crop, research would be necessary for plentiful fields. First of all, Guggisberg et al. (2012), aligned

with numerous other studies, identified a high genetic diversity within this species, and it seems evident that the potential, for example as a food or medicinal plant, varies considerably among varieties. Core parameters to be assessed include nutritional value, mineral, and vitamin content of specific varieties and morphotypes, along with other phytochemical properties in the case of medicinal use.

Next, crop management for creeping thistle needs to be developed, encompassing almost all aspects from seeding dates to harvesting. This would be pioneer work. Although other *Cirsium* spp., such as cabbage thistle (*Cirsium oleraceum* L.), have been identified as edible and may have been cultivated historically (Del Vitto and Petenatti 2015), no information about modern production systems for *Cirsium* spp. exists. However, there are established cropping systems for other "thistles" and thistle-like plants. Cultivation of milk thistle (*Silybum marianum* L. Gaertn) or blessed thistle (*Cnicus benedictus* L.) could be a reference point (Karkanis, Bilalis, and Efthimiadou 2011; Ghiasy-Oskoee et al. 2020). Inputs may also be identified from other *Asteraceae*. As for harvesting creeping thistle roots, black salsify (*Scorzonera hispanica* L.) and Jerusalem artichoke cultivation could serve as examples. Further inputs may come from findings related to weed management of creeping thistle. It is, for example, well established that carbohydrate storage in the roots and the emergence of new shoots are strongly impacted by physical soil management (Orloff et al. 2018; Nadeau and Vandenborn 1989).

Once there is a baseline for crop management, follow-up studies may include economic feasibility assessments, ecological questions, farmer perceptions, socio-cultural issues, processing as food, medicine, or for another purpose, and last but not least, consumer demand and preferences.

Conclusions

This literature review provides evidence that creeping thistle is a source of food and medicine, among other potential uses. If creeping thistle were not a successful weed, identifying its human uses might not be pertinent since hundreds of underutilized species likely have similar or even superior traits. However, the fact that *C. arvense* already grows abundantly in different cropping systems and environments without depending on external resources, such as irrigation and fertilizers, providing important ecosystem services, for example as a pollinator plant, justifies further research on the potential of creeping thistle. For crop improvement, genetic variability studies regarding economic traits will be needed.

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Appendices

Appendix 1: Reviewed academic media and creeping thistle uses discussed in these papers

Reference	Edible Use	Medicinal Use	Other Uses
Akhtar, Ihsan ul, and Mirza (2018)		X	
Akihisa et al. (1998)		X	
Alda et al. (2014)	X		
Allen and Hatfield (2004)		X	
Amiri, Yadegari, and Hamedi (2018)		X	Repellent (Pesticide)
Aziz et al. (2021)	X		
Bahmani, Zargaran, and Rafieian-Kopaei (2014)		X	
Banaras et al. (2017)		X	Antifungal
Barbinta-Patrascu et al. (2020)		X	Source of nanoparticles
Borawska et al. (2010)		X	
Çakır (2017)	X		
Chhikara et al. (2020)		X	Ecosystem services
Coffey (1994)		X	
Dehjurian, Lari, and Motavalizadehkakhky (2017)		X	
Demirtas et al. (2017)		X	
Doğan and Tuzlacı (2015)	X		
Dogan et al. (2004)	X		
Dogan et al. (2015)	X		
Duke (2001)	X	X	Source of pollen for honeybees
Facciola (1990)	X		Food processing: Coagulation of milk
Ferdosi et al. (2021)		X	
Gairola, Sharma, and Singh Bedi (2014)		X	
Guarrera (2005)			
Kalle and Sõukand (2012)		X	
Kang et al. (2012)		X	
Kenny et al. (2014)	X	X	Food processing: Conservation of food
Khan et al. (2013)		X	Forage
Khatun and Rahman (2018)		X	
Koc et al. (2015)		X	
Končeková, Halmová, and Fehér (2020)	X		
Kumar and Ahmed Hamal (2009)	X		
Lans and Turner (2011)		X	Antiparasite (poultry)
Lim (2015)	X		
Lym and Christianson (1996)		X	

(*Continued*)

(Continued).

Reference	Edible Use	Medicinal Use	Other Uses
MacKinnon and Pojar (2016)		X	
Nazaruk (2008)		X	
Nazaruk et al. (2008)		X	
Nusipali and Bazhykova (2019)	X	X	
Orhan et al. (2013)		X	Antiparasite (poultry)
Rajaei and Mohamadi (2012)		X	
Ranfa and Bodesmo (2017)	X		
Rehman et al. (2015)		X	
Şenkardeş et al. (2019)	X		
Shaheen, Ahmad, and Haroon (2017)	X		
Sheley and Petroff (1999)	X		Ecosystem services
Skrajna (2010)		X	
Spence (2016)		X	Forage
TardÍo, Pardo-De-Santayana, and Morales (2006)	X		
Thakur and Chander Dutt (2020)	X		
Tiley (2010)	X	X	Source of pollen for honeybees; food processing; ecosystem services; forage
Travlos et al. (2016)		X	
Umair, Altaf, and Mehmood Abbasi (2017)		X	
Uphof (1968)	X		Food processing: Coagulation of milk
Viegi et al. (2003)		X	Veterinary medicine
Yasukawa et al. (1998)		X	
Yeşil and İnal (2019)	X		
Number of publications addressing creeping thistle use	**22**	**37**	**15**

Appendix 2. Reviewed popular media and creeping thistle uses discussed in these media

Reference	Edible Use	Medicinal Use	Other Uses
Alberta Wild Craft (2022)	X		
All About Heaven (2022)	X		Environmental services
Bates (2012)	X		
Canada Responsible Forager (2022)	X		
DeGroot (2019)	X		Ornamental
Edgerton (2021)	X		
Edible Wild Food (2021)	X		
Edible Wild Food (2019)	X		
Elpel (2021)	X	X	
Georgetown University Medical Center (2021)		X	
Global Invasive Species Database (2020)	X	X	
Health Benefits Times (2021)	X	X	Food processing: Coagulation of milk
Helzer (2022)			Forage
Honey Traveler (2022)			Source of pollen for honeybees
Hope (2022)	X		
Kress (2022)		X	
Landes (2022)	X		
Lawanda's Garden (2021)	X	X	
Lower (2021)		X	
Montana Department of Agriculture (2017)	X		Source of pollen for honeybees
Native American Ethnobotany Database (2022)		X	
Natural Medicinal Herbs (2021)	X	X	
Neverman (2021)	X		
Plants for a Future (2021)	X	X	Food processing: Coagulation of milk
Raya Garden (2022)	X	X	Forage
Smith (2022)	X		Source of pollen for honeybees, ecosystem services, forage
Survival (2015)	X	X	
The Botanist (2021)	X		
The Holistic Homestead (2015)	X	X	
The Homegrown Herbalist (2021)	X	X	
The Nature Niche (2021)	X		
Un Mondo Ecosostenibile (2022)		X	
United States Department of Agriculture (2022)	X	X	Source of pollen for honeybees
Waddington (2022)	X		
Wandering Botanist (2021)		X	
Wild Edibles Database Australia (2021)	X	X	Oil, tinder
Wild Plant Guides (2022)	X		
Number of media addressing creeping thistle use	29	18	11