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REVIEW

Artichoke (*Cynara scolymus* L.): a review of its health-promoting properties

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Abstract

Cynara scolymus L., called artichoke or globe artichoke, is a perennial herbaceous plant cultivated worldwide. This plant is a common component of the Mediterranean diet and has been used as a remedy for health conditions since antiquity. The aim of this review is to find the health-promoting properties of artichoke, conducting a literature search in PubMed. The results show that 119 studies describe these effects and 17 health benefits of artichoke are reported in the scientific literature. Antioxidant activity and effects on the liver and lipid profile are the main health-promoting properties of this plant. We found that artichoke also improves cardiovascular and gastrointestinal health and exerts anticancer, antimetabolic and antiobesity, prebiotic and probiotic, renoprotective and antidiabetic activities. Only one or two research articles reported the positive effects of this plant on the immune system, arthritis, photoaging, the reproductive system, the nervous system, fungal infections and periodontal diseases. The health benefits are mainly exerted by phenolics. In conclusion, this review shows the health-promoting properties of artichoke. The main beneficial effects are antioxidant activity and effects on lipid profile and the liver, which are mainly mediated by phenolics. The results of the scientific articles described in this review and the molecular mechanisms related to the health benefits of artichoke should be confirmed by future experimental studies.

Keywords: *Artichoke, Cynara scolymus L., Antioxidant, Hepatoprotective, Lipid profile*.

Impact statement: Artichoke (*Cynara scolymus* L.) has many health benefits and the main properties are antioxidant activity and effects on the liver and lipid profile.

1. Introduction

Cynara scolymus L. is a plant species which belongs to the family Asteraceae (IPNI, 2023). This perennial plant, commonly known as artichoke or globe artichoke, is grown worldwide. Artichoke is endemic to the Mediterranean region and has probably been tamed in southern Italy. The Arabs brought it to other parts of the Mediterranean in medieval times (Pignone and Sonnante, 2004). Ancient populations did know artichoke for its nutritional and health-promoting properties (Sonnante *et al.*, 2007). The scientific name comes from the Latin word "*cinis*" and the Greek word "*skolymos*", which mean "ash" and "cardoon", respectively (Verotta *et al.*, 2015).

Artichoke is an herbaceous plant that can reach about 1.80 metres in height. The flower head is globe-shaped with green and violet external bracts. The receptacle is located in the lower part of the artichoke head and the "choke" made up of bristles is found above it. Many blue-purple flowers are arranged in the centre of the head (**Fig.1**). Artichoke buds are cut before blooming and the edible part includes the receptacle and the inner bracts (Basay, 2022; Grieve, 1931). This plant is a common ingredient of the Mediterranean diet and is widely utilised for health purposes. Artichoke leaves are mainly used in infusions and extracts for their health-promoting properties (Mulinacci *et al.*, 2004; Pereira *et al.*, 2015).

Figure 1. Artichoke. A botanical illustration of artichoke. ("*Cynara scolymus*" by Adriana Morgante Giornetti).

This plant contains minerals, vitamins, dietary fibres and bioactive compounds, which are responsible for its beneficial effects. Phenolics include: hydroxycinnamic acids, such as chlorogenic acid (**Fig.2**), caffeic acid and cynarine (**Fig.3**); anthocyanidins, such as cyanidin; flavones, such as apigenin and luteolin (**Fig.4**). Triterpenes and sesquiterpene lactones (e.g., cynaropicrin) (**Fig.5**) are also found in artichoke. Finally, this plant contains inulin, which is a fibre with health-promoting properties (Azzini *et al.*, 2007; Ceccarelli *et al.*, 2010; Lattanzio *et al.*, 2009; Panizzi and Scarpati, 1954; Rocchetti *et al.*, 2020).

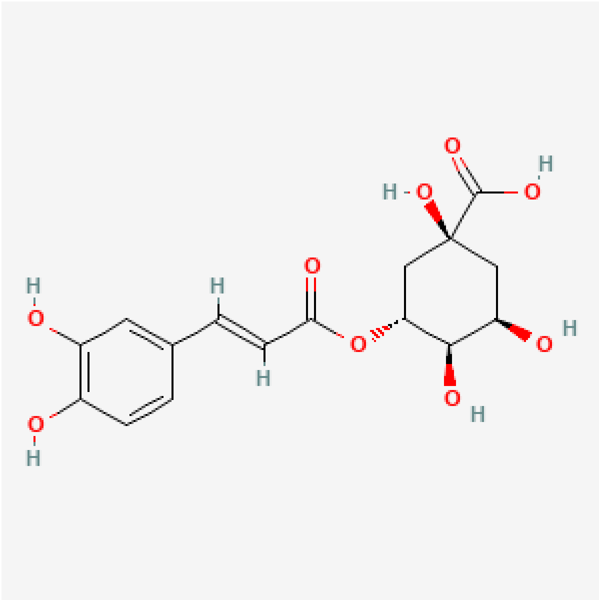

Figure 2. Chlorogenic acid. A chemical structure image of chlorogenic acid (Retrieved from: https://pubchem.ncbi.nlm.nih.gov/compound/1794427#section=2D-Structure).

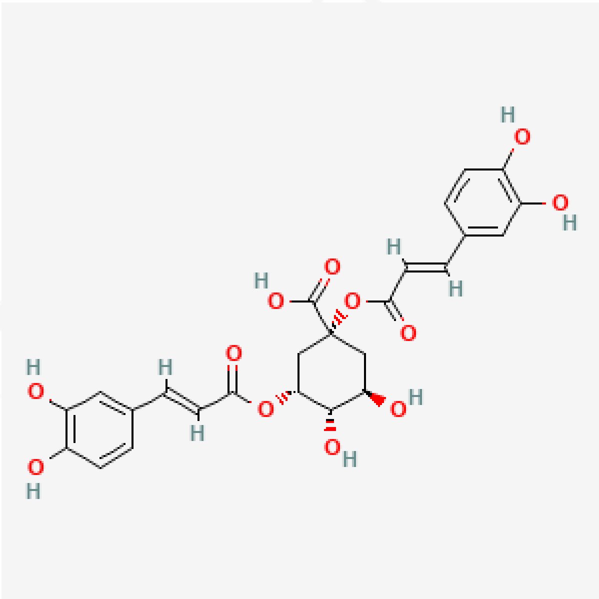

Figure 3. Cynarine. A chemical structure image of cynarine (Retrieved from: https://pubchem.ncbi.nlm.nih.gov/compound/5281769#section=2D-Structure).

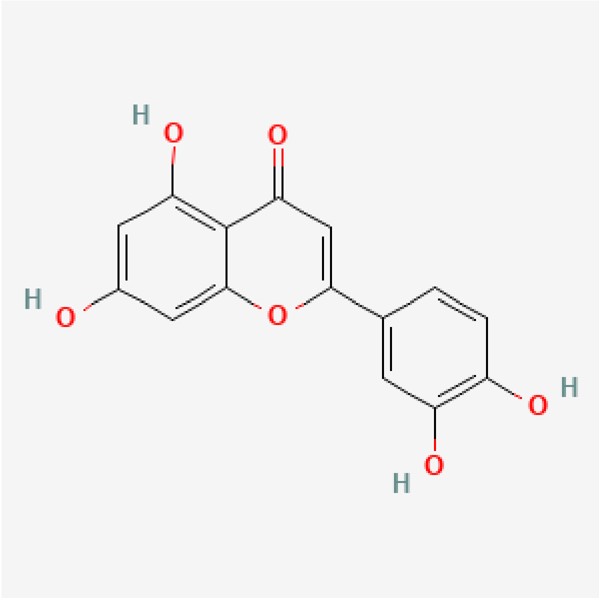

Figure 4. Luteolin. A chemical structure image of luteolin (Retrieved from: https://pubchem.ncbi.nlm.nih.gov/compound/5280445#section=2D-Structure).

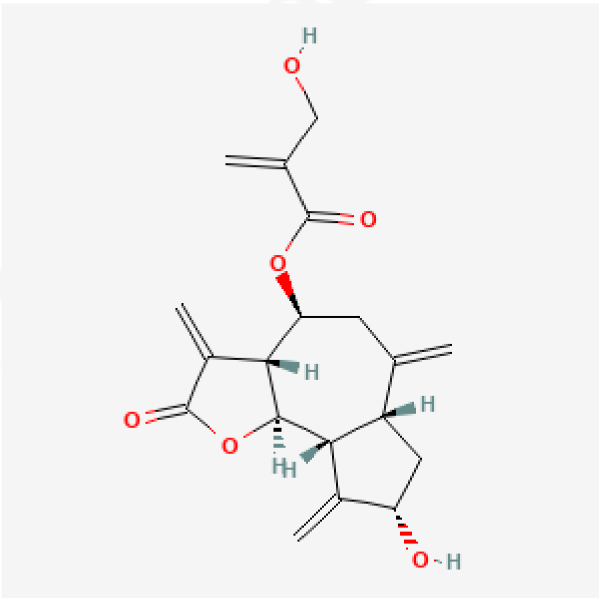

Figure 5. Cynaropicrin. A chemical structure image of cynaropicrin (Retrieved from: https://pubchem.ncbi.nlm.nih.gov/compound/119093#section=2D-Structure).

In this review, we search the scientific literature to identify the health benefits of artichoke. This plant has been used for treating health conditions since ancient times and is still largely utilised by healthcare and herbal practitioners. Research has focused on its properties and there is increasing interest in the different beneficial effects and the molecular mechanisms involved in these activities. Our work has great significance, as it includes the latest research findings on this topic.

2. Methods

We investigated the beneficial effects of artichoke on human health, searching for scientific articles in the PubMed database (https://pubmed.ncbi.nlm.nih.gov/). The following keywords were used: "artichoke", "*Cynara scolymus*", "artichoke therapeutic effects", "*Cynara scolymus* therapeutic effects", "artichoke properties", "artichoke health benefits", "artichoke health-promoting properties", "artichoke phytotherapy", "*Cynara scolymus* phytotherapy", "artichoke disease treatment" and "*Cynara scolymus* disease treatment". The article types selected in PubMed were: clinical trials, randomized controlled trials, books and documents. We included only previous studies relating to the topic of this review and written in English. We excluded reviews, systematic reviews, meta-analyses and articles which show only negative results or adverse effects of artichoke. We chose the scientific studies through an initial screening by reading titles and abstracts. In a second moment, we read the whole texts to find the proper scientific articles.

3. Results and Discussion

The results of literature search indicate that 1374 articles are included in PubMed. We chose 119 studies after article screening and we identified 17 health-promoting properties of artichoke (**Table 1**).

Health-promoting effects	References
Effects on the liver	Ahmadi *et al.*, 2019; Ben Salem *et al.*, 2017b; Ben Salem *et al.*, 2019; Celepli *et al.*, 2022a; Celepli *et al.*, 2022b; Colak *et al.*, 2016; Deng *et al.*, 2022; El-Boshy *et al.*, 2017; El Morsy and Kamel, 2015; Elsayed Elgarawany *et al.*, 2020; Frigerio *et al.*, 2021; Gebhardt, 1997; Gebhardt, 2001; Gebhardt, 2002a; Gebhardt, 2002b; Gebhardt and Fausel, 1997; Heidarian and Rafieian-Kopaei, 2013; Kirchhoff *et al.*, 1994; Küçükgergin *et al.*, 2010; Kurt *et al.*, 2014; Kwon *et al.*, 2018; Lee *et al.*, 2021b ; Liao *et al.*, 2021; Majnooni *et al.*, 2021; Mehmetçik *et al.*, 2008; Menghini *et al.*, 2010; Metwally *et al.*, 2011; Miccadei *et al.*, 2008; Nasef *et al.*, 2022; Panahi *et al.*, 2018; Qiang *et al.*, 2012; Rangboo *et al.*, 2016; Saénz Rodriguez *et al.*, 2002; Sharaf El-Deen *et al.*, 2017; Speroni *et al.*, 2003; Sümer *et al.*, 2020; Tang *et al.*, 2017; Wang *et al.*, 2021; Wauquier *et al.*, 2021
Effects on lipid profile	Ben Salem *et al.*, 2017b; Ben Salem *et al.*, 2019; Ben Salem *et al.*, 2022a; Bogavac-Stanojevic *et al.*, 2018; Bundy *et al.*, 2008; Deng *et al.*, 2022; Englisch *et al.*, 2000; Frigerio *et al.*, 2021; Gebhardt, 1998; Heidarian and Rafieian-Kopaei, 2013; Ibrahim *et al.*, 2022; Küçükgergin *et al.*, 2010; Küskü-Kiraz *et al.*, 2010; Kwon *et al.*, 2018; Liao *et al.*, 2021; Majnooni *et al.*, 2021; Panahi *et al.*, 2018; Qiang *et al.*, 2012; Qinna *et al.*, 2012; Rangboo *et al.*, 2016; Rondanelli *et al.*, 2013; Rondanelli *et al.*, 2014; Rondanelli *et al.*, 2019; Shimoda *et al.*, 2003; Tang *et al.*, 2017; Wauquier *et al.*, 2021
Effects on the cardiovascular system	Ben Salem *et al.*, 2022a; Bogavac-Stanojevic *et al.*, 2018; Crevar-Sakac *et al.*, 2016; Juzyszyn *et al.*, 2008; Küçükgergin *et al.*, 2010; Li *et al.*, 2004; Lupattelli *et al.*, 2004; Roghani-Dehkordi and Kamkhah, 2009; Wang *et al.*, 2021; Xia *et al.*, 2014; Zapolska-Downar *et al.*, 2002
Effects on the gastrointestinal system	Bundy *et al.*, 2004; Emendörfer *et al.*, 2005; Holtmann *et al.*, 2003; Ishida *et al.*, 2010; Marakis *et al.*, 2002; Nassar *et al.*, 2013; Sabater *et al.*, 2019; Verspohl *et al.*, 2008; Walker *et al.*, 2001
Antimetabolic and antiobesity activity	Ardalani *et al.*, 2020; Ben Salem *et al.*, 2019; Ben Salem *et al.*, 2022a; Ebrahimi-Mameghani *et al.*, 2018; Kwon *et al.*, 2018; Rezazadeh *et al.*, 2018a; Rezazadeh *et al.*, 2018b; Rondanelli *et al.*, 2014; Wauquier *et al.*, 2021
Anticancer activity	Abdel-Moneim *et al.*, 2021; Ding *et al.*, 2021; Islam *et al.*, 2021; Lepore *et al.*, 2019; Liu *et al.*, 2019; Menghini *et al.*, 2010; Metwally *et al.*, 2011; Miccadei *et al.*, 2008; Mileo *et al.*, 2012; Mileo *et al.*, 2015; Mileo *et al.*, 2020; Muti *et al.*, 2022; Pulito *et al.*, 2015; Villarini *et al.*, 2021; Yang *et al.*, 2022
Probiotic and prebiotic activities	Costabile *et al.*, 2010; Fissore *et al.*, 2015; López-Molina *et al.*, 2005; Riezzo *et al.*, 2012; Valerio *et al.*, 2010; Van den Abbeele *et al.*, 2020; Zeaiter *et al.*, 2019

Antioxidant activity	Abdel-Moneim *et al.*, 2021; Ahmadi *et al.*, 2019; Ben Salem *et al.*, 2017a; Ben Salem *et al.*, 2017b; Ben Salem *et al.*, 2019; Ben Salem *et al.*, 2022a; Ben Salem *et al.*, 2022b; Biel *et al.*, 2020; Bogavac-Stanojevic *et al.*, 2018; Brown and Rice-Evans, 1998; Carpentieri *et al.*, 2022; Celepli *et al.*, 2022a; Celepli *et al.*, 2022b; Cicek *et al.*, 2022; Colak *et al.*, 2016; Crevar-Sakac *et al.*, 2016; D'Antuono *et al.*, 2018; Deng *et al.*, 2022; Durazzo *et al.*, 2013; El-Boshy *et al.*, 2017; El Morsy and Kamel, 2015; Elsayed Elgarawany *et al.*, 2020; Gebhardt, 1997; Gebhardt and Fausel, 1997; Gurel *et al.*, 2007; Heidarian and Rafieian-Kopaei, 2013; Ibrahim *et al.*, 2022; Jiménez-Escrig *et al.*, 2003; Juzyszyn *et al.*, 2008; Khattab *et al.*, 2016; Kostić *et al.*, 2021; Küçükgergin *et al.*, 2010; Küskü-Kiraz *et al.*, 2010; Lee *et al.*, 2021a; Lee *et al.*, 2021b; Liao *et al.*, 2021; Lin *et al.*, 2022; Liu *et al.*, 2019; Magielse *et al.*, 2014; Matsumoto *et al.*, 2021; Mehmetçik *et al.*, 2008; Menghini *et al.*, 2010; Metwally *et al.*, 2011; Miccadei *et al.*, 2008; Mohammed *et al.*, 2020; Nasef *et al.*, 2022; Nassar *et al.*, 2013; Pérez-García *et al.*, 2000; Rezazadeh *et al.*, 2018a; Sarawek *et al.*, 2008; Skarpanska-Stejnborn *et al.*, 2008; Speroni *et al.*, 2003; Takei *et al.*, 2015; Tang *et al.*, 2017; Wang *et al.*, 2021; Xia *et al.*, 2014; Zapolska-Downar *et al.*, 2002
Antidiabetic effects	Ben Salem *et al.*, 2017b; Deng *et al.*, 2022; Ebrahimi-Mameghani *et al.*, 2018; Fantini *et al.*, 2011; Ibrahim *et al.*, 2022; Kwon *et al.*, 2018; Rondanelli *et al.,* 2014
Antiarthritic effects	Masutani *et al.*, 2016; Wauquier *et al.*, 2021
Renoprotective activity	Ben Salem *et al.*, 2022b; El-Boshy *et al.*, 2017; Khattab *et al.*, 2016; Sümer *et al.*, 2020; Wang *et al.*, 2021
Neuroprotective effects	Cicek *et al.*, 2022; Ibrahim *et al.*, 2022
Effects on the reproductive system	Gurel *et al.*, 2007; Mohammed *et al.*, 2020
Effects on the immune system	El-Boshy *et al.*, 2017; Hueza *et al.*, 2019
Antiphotoaging effects	Takei *et al.*, 2015; Tanaka *et al.*, 2013
Antifungal effects	Zhu *et al.*, 2005
Prevention of periodontal diseases	Hayata *et al.*, 2019

Table 1. Health-promoting properties of artichoke. The table shows the beneficial properties of artichoke and the scientific articles which report these effects.

3.1. Effects on the liver

Several research studies examined the effects of artichoke consumption on the liver, performing *in vivo* and *in vitro* experiments. Two studies showed the beneficial effect of artichoke leaf extract (ALE) alone (Panahi *et al.*, 2018) or in combination with metformin or vitamin E (Majnooni *et al.*, 2021) in individuals with non-alcoholic fatty liver disease (NAFLD). Artichoke extracts also improve NAFLD in rodents (Deng *et al.*, 2022; Lee *et al.*, 2021b). Rangboo and colleagues (2016) showed that ALE exerts hepatoprotective activity in a sample of 60 individuals with non-alcoholic steatohepatitis (NASH), while Tang and colleagues (2017) found that an artichoke extract has a beneficial effect on alcoholic liver disease (ALD) in mice. Previous studies demonstrated that ALE exerts hepatoprotective effects *in vivo* (Ahmadi *et al.*, 2019; Ben Salem *et al.*, 2017b; Ben Salem *et al.*, 2019; Celepli *et al.*, 2022a; Celepli *et al.*, 2022b; El-Boshy *et al.*, 2017; El Morsy and Kamel, 2015; Elsayed Elgarawany *et al.*, 2020; Heidarian and Rafieian-Kopaei, 2013; Küçükgergin *et al.*, 2010; Kurt *et al.*, 2014; Kwon *et al.*, 2018; Liao *et al.*, 2021; Mehmetçik *et al.*, 2008; Nasef *et al.*, 2022; Sharaf El-Deen *et al.*, 2017), *in vitro* (Menghini *et al.*, 2010) and *ex vivo* (Wauquier *et al.*, 2021). Stem and receptacle extracts have this effect in rats (Sümer *et al.*, 2020) and an extract with high phenolic content exerts hepatoprotective and choleretic effects in rats (Speroni *et al.*, 2003). Previous scientific articles reported that artichoke has hepatoprotective effects in these laboratory animals (Colak *et al.*, 2016; Metwally *et al.*, 2011; Wang *et al.*, 2021). Qiang and colleagues (2012) found that ALE increases bile acid secretion in hamsters. Artichoke extracts exert choleretic activity *in vivo* (Kirchhoff *et al.*, 1994; Saénz Rodriguez *et al.*, 2002) and *in vitro* (Frigerio *et al.*, 2021). Previous studies demonstrated that this plant extracts have hepatoprotective (Gebhardt, 1997; Gebhardt and Fausel, 1997; Miccadei *et al.*, 2008) and anticholestatic (Gebhardt, 2001; Gebhardt, 2002b) effects *in vitro*, which are mainly exerted by phenolics. Gebhardt (2002a) showed that liver cholesterol synthesis can be inhibited by ALE *in vitro* and flavones are the bioactive compounds mainly involved in this effect.

3.2. Effects on lipid profile

The effects of artichoke consumption on lipid profile are well documented in the scientific literature. ALE intake alone (Panahi *et al.*, 2018) or in association with metformin or vitamin E (Majnooni *et al.*, 2021) improves lipid profile in individuals with NAFLD. A study by Rangboo *et al.* (2016) showed that ALE consumption is effective in lowering triglycerides, total cholesterol and low-density lipoprotein cholesterol (LDL-C) in a cohort of 60 individuals with NASH. Shimoda and colleagues (2003) demonstrated that the beneficial effect of artichoke on lipid profile is exerted by sesquiterpenes. Another study by Bundy *et al.* (2008) showed that ALE can be effective in reducing total cholesterol in individuals with hypercholesterolemia. Englisch and colleagues (2000) demonstrated that ALE can lower LDL-C and total cholesterol in a cohort of 143 individuals with hyperlipoproteinemia. A previous study by Rondanelli *et al.* (2013) found that ALE intake reduces total cholesterol and LDL-C and raises high-density lipoprotein cholesterol (HDL-C) in a sample of 92 patients with hypercholesterolemia, while other scientific articles reported that artichoke extracts can decrease triglycerides, total cholesterol and LDL-C and improve HDL-C in rats (Ben Salem *et al.*,2017b; Deng *et al.*, 2022). Rondanelli and colleagues (2019) demonstrated that ALE improves HDL-C and lowers total cholesterol/HDL-C ratio in a cohort of 20 individuals with mild hypercholesterolemia. Another study found that consumption of an artichoke extract ameliorates lipid profile in a sample of 55 overweight individuals with impaired fasting glycaemia (Rondanelli *et al.,* 2014). Two articles reported the beneficial effect of ALE on cholesterol homeostasis, performing *in vitro* (Frigerio *et al.*, 2021) and *ex vivo* (Wauquier *et al.*, 2021) experiments. Many research studies found the beneficial effect of artichoke extracts on lipid profile in rodents (Ben Salem *et al.*, 2019; Ben Salem *et al.*, 2022a; Bogavac-Stanojevic *et al.*, 2018; Heidarian and Rafieian-Kopaei, 2013; Ibrahim *et al.*, 2022; Küçükgergin *et al.*, 2010; Küskü-Kiraz *et al.*, 2010; Kwon *et al.*, 2018; Liao *et al.*, 2021; Qiang *et al.*, 2012; Qinna *et al.*, 2012; Tang *et al.*, 2017). A study by Gebhardt (1998) showed that ALE is effective in suppressing hepatic cholesterol synthesis in rats and luteolin is implicated in this activity.

3.3. Effects on the cardiovascular system

Artichoke intake may exert beneficial effects on the cardiovascular system. A previous study by Lupattelli *et al.* (2004) found that artichoke leaf juice has beneficial effects on endothelial function in a sample of 28 individuals with hyperlipidemia, while Roghani-Dehkordi and Kamkhah (2009) demonstrated that artichoke leaf juice is effective in reducing blood pressure in individuals with mild hypertension. Artichoke extracts exert protective effects on the cardiovascular system *in vivo* (Ben Salem *et al.*, 2022a; Bogavac-Stanojevic *et al.*, 2018; Crevar-Sakac *et al.*, 2016; Küçükgergin *et al.*, 2010) and *in vitro* (Juzyszyn *et al.*, 2008; Zapolska-Downar *et al.*, 2002). A previous scientific article reported the health benefits of artichoke bud extract in a rat model of hypertension (Wang *et al.*, 2021). Li and colleagues (2004) found that ALE can improve expression and function of endothelial nitric oxide synthase (eNOS), performing *in vitro* and *ex vivo* experiments and flavones are involved in this activity. ALE can also inhibit the expression of inducible nitric oxide synthase (iNOS) in vascular smooth muscle cells and the phytochemical compounds mainly implicated in this effect are cynarine and cyanidin (Xia *et al.*, 2014).

3.4. Effects on the gastrointestinal system

The oral intake of artichoke can improve gastrointestinal health in humans and animal models. Previous studies demonstrated the beneficial effect of ALE on the gastrointestinal system in individuals with functional (Holtmann *et al.*, 2003) and mild (Marakis *et al.*, 2002) dyspepsia. Other studies showed that ALE is effective in alleviating irritable bowel syndrome (IBS) symptoms in individuals with this condition (Bundy *et al.*, 2004; Walker *et al.*, 2001). Nassar and colleagues (2013) found that an artichoke head extract can exert antiulcerogenic activity in rats. Cynaropicrin is the bioactive compound which may exert antispasmodic effects on the gastrointestinal tract of guinea pigs (Emendörfer *et al.*, 2005) and antigastritis activities in rats (Ishida *et al.*, 2010). Verspohl and colleagues (2008) demonstrated the beneficial effect of ALE on IBS in an experiment performed on the ileum of rats and a previous study found the anti-colitis activity of artichoke pectin in mice (Sabater *et al.*, 2019).

3.5. Antimetabolic and antiobesity activity

The beneficial effects of artichoke consumption on metabolic syndrome and obesity are described in recent research articles. ALE intake may be effective in ameliorating metabolic syndrome biomarkers (Ebrahimi-Mameghani *et al.*, 2018; Rezazadeh *et al.*, 2018a; Rezazadeh *et al.*, 2018b). Ardalani and colleagues (2020) found that ALE can reduce body mass index (BMI) in overweight individuals, while Wauquier and colleagues (2021) demonstrated the protective effect of ALE on obesity and metabolic syndrome, performing an *ex vivo* study. A previous study showed the health benefits of an artichoke extract, studying a cohort of 55 overweight individuals with impaired fasting glycaemia (Rondanelli *et al.,* 2014). Recent research articles demonstrated the antiobesity and antimetabolic syndrome activities of ALE in rodents (Ben Salem *et al.*, 2019; Ben Salem *et al.*, 2022a; Kwon *et al.*, 2018).

3.6. Anticancer activity

The anticancer activity of artichoke is well reported in the scientific literature. A previous study showed the protective effect of an artichoke extract on pleural mesothelioma in a sample of 18 individuals with asbestos-related benign pleural disease (Muti *et al.*, 2022). ALE exerts antitumor effect against malignant pleural mesothelioma *in vivo* and *in* vitro (Pulito *et al.*, 2015). Liu and colleagues (2019) demonstrated the anticancer activity of cynaropicrin in HeLa cells. This bioactive compound found in artichoke may exert an inhibitory effect on thioredoxin reductase and promote oxidative stress, which lead to apoptosis. Previous studies showed the beneficial effects of this plant in a rat model of hepatocellular carcinoma (Metwally *et al.*, 2011) and the potential anticancer effects of artichoke extracts in human hepatocellular carcinoma (Menghini *et al.*, 2010; Miccadei *et al.*, 2008), uterine leiomyoma (Islam *et al.*, 2021), breast cancer (Mileo *et al.*, 2012; Mileo *et al.*, 2015; Mileo *et al.*, 2020) and colon cancer (Villarini *et al.*, 2021) cells. Cynaropicrin may exert anticancer activity in anaplastic thyroid cancer (Lepore *et al.*, 2019) and lung carcinoma (Ding *et al.*, 2021) cells. Yang and colleagues (2022) showed the antitumor effects of this bioactive compound against neuroblastoma *in vivo* and *in vitro*. A study by Abdel-Moneim *et al.* (2021) found the beneficial effect of artichoke extracts on lung cancer in rats, which is exerted mainly through antioxidant, proapoptotic and antiproliferative activities.

3.7. Probiotic and prebiotic activities

Artichoke may exert probiotic and prebiotic activities, as demonstrated by human and *in vitro* studies. The oral intake of artichoke fortified with a probiotic (i.e., *Lactobacillus paracasei*) can improve constipation in individuals with this condition (Riezzo *et al.*, 2012; Valerio *et al.*, 2010). Previous research studies reported the prebiotic activity of long-chain inulin from artichoke in a sample of 31 healthy individuals (Costabile *et al.*, 2010) and *in vitro* (López-Molina *et al.*, 2005; Zeaiter *et al.*, 2019). Fissore and colleagues (2015) demonstrated that artichoke fibres (i.e., inulin and pectin of low degree of methylation) have prebiotic effects *in vitro*. A study by Van den Abbeele *et al.* (2020) showed that an artichoke extract exerts this activity *in vitro*.

3.8. Antioxidant activity

Artichoke is a source of bioactive compounds and its antioxidant activity has been demonstrated in many research studies involving humans, animal models and *in vitro*. ALE intake exerts antioxidant activity in individuals with metabolic syndrome, lowering oxidized-LDL (ox-LDL) levels (Rezazadeh *et al.*, 2018a). Skarpanska-Stejnborn and colleagues (2008) showed the antioxidant effect of ALE in a sample of 22 rowers during the training. The antioxidant activity of cynaropicrin from artichoke was demonstrated in HeLa cells (Liu *et al.*, 2019) and human keratinocytes (Takei *et al.*, 2015). Sesquiterpene lactones (Matsumoto *et al.*, 2021) or cynarine and cyanidin (Xia *et al.*, 2014) from artichoke can inhibit the expression of iNOS *in vitro*. Many previous studies showed that artichoke extracts exert this activity in rodent models of different health conditions (Abdel-Moneim *et al.*, 2021; Ahmadi *et al.*, 2019; Ben Salem *et al.*, 2017b; Ben Salem *et al.*, 2019; Ben Salem *et al.*, 2022a; Ben Salem *et al.*, 2022b; Bogavac-Stanojevic *et al.*, 2018; Celepli *et al.*, 2022a; Celepli *et al.*, 2022b; Cicek *et al.*, 2022; Colak *et al.*, 2016; Crevar-Sakac *et al.*, 2016; Deng *et al.*, 2022; El-Boshy *et al.*, 2017; El Morsy and Kamel, 2015; Elsayed Elgarawany *et al.*, 2020; Gurel *et al.*, 2007; Heidarian and Rafieian-Kopaei, 2013; Ibrahim *et al.*, 2022; Khattab *et al.*, 2016; Küçükgergin *et al.*, 2010; Küskü-Kiraz *et al.*, 2010; Liao *et al.*, 2021; Magielse *et al.*, 2014; Mehmetçik *et al.*, 2008; Metwally *et al.*, 2011; Mohammed *et al.*, 2020; Nasef *et al.*, 2022; Nassar *et al.*, 2013; Tang *et al.*, 2017; Wang *et al.*, 2021). Lee and colleagues (2021b) found the protective role of ALE against oxidative stress, performing experiments in NAFLD mice and HepG2 cells. Other studies showed the beneficial effect of artichoke extracts with high phenolic contents on oxidative stress (Biel *et al.*, 2020; Brown and Rice-Evans, 1998; D'Antuono *et al.*, 2018; Speroni *et al.*, 2003). Pérez-García and colleagues (2000) demonstrated the antioxidant effect of ALE *in vitro*. This artichoke extract is effective in blocking reactive oxygen species (ROS) generation in human leukocytes and the phytochemicals mainly involved are luteolin, caffeic acid, cynarine and chlorogenic acid. Previous studies showed that artichoke extracts exert antioxidant activity *in vitro* (Carpentieri *et al.*, 2022; Gebhardt, 1997; Gebhardt and Fausel, 1997; Juzyszyn *et al.*, 2008; Menghini *et al.*, 2010; Miccadei *et al.*, 2008; Zapolska-Downar *et al.*, 2002). Sarawek and colleagues (2008) found that luteolin from artichoke is effective in inhibiting xanthine oxidase (XO) *in vitro*. Two previous studies showed the antioxidant effects of this plant extracts, performing *in vivo* and *in vitro* experiments (Ben Salem *et al.*, 2017a; Jiménez-Escrig *et al.*, 2003). Artichoke seeds (Durazzo *et al.*, 2013), rhizome (Lee *et al.*, 2021a), buds (Lin *et al.*, 2022) and pollen (Kostić *et al.*, 2021) exert antioxidant activity and phenolics are mainly involved in this beneficial effect.

3.9. Antidiabetic effects

The consumption of artichoke may have antidiabetic effects, as demonstrated by research studies on humans and animal models. Rondanelli and colleagues (2014) found the beneficial effect of an artichoke extract on glucose metabolism in a sample of 55 overweight individuals with impaired fasting glycaemia. Artichoke extracts are effective in improving insulin resistance in individuals with metabolic syndrome (Ebrahimi-Mameghani *et al.*, 2018) and rodents (Deng *et al.*, 2022; Kwon *et al.*, 2018; Ibrahim *et al.*, 2022). Ben Salem and colleagues (2017b) found the antihyperglycaemic activity of ALE in diabetic rats. The hypoglycaemic activity of an artichoke flower head extract was demonstrated in obese and normal rats (Fantini *et al.*, 2011). Few studies have been conducted on humans and further studies using large sample sizes are required to confirm these results. Experiments *in vitro* should clarify the molecular mechanisms involved in these activities.

3.10. Antiarthritic effects

Two previous studies found the antiarthritic activity of artichoke. Wauquier and colleagues (2021) showed that ALE has a beneficial effect on osteoarthritis, performing an *ex vivo* experiment using human articular chondrocytes. Another study demonstrated the beneficial effect of cynaropicrin on the metabolism of cartilage *in vitro* (Masutani *et al.*, 2016). These two scientific articles represent a preliminary evidence that artichoke exerts antiarthritic activity and other studies are required to confirm these results.

3.11. Renoprotective activity

The renoprotective effect of artichoke intake has been demonstrated in studies involving animal models. Artichoke bud (Wang *et al.*, 2021), leaf (Ben Salem *et al.*, 2022b; El-Boshy *et al.*, 2017), receptacle and stem (Sümer *et al.*, 2020) extracts may have a protective effect on renal function in rats. Khattab and colleagues (2016) found that ALE exerts a beneficial effect on kidney function in a rat model of gentamicin nephrotoxicity.

3.12. Neuroprotective effects

ALE exerts a neuroprotective effect in rodent models and this effect may be mediated by the antioxidant activity of artichoke (Cicek *et al.*, 2022; Ibrahim *et al.*, 2022). Future studies are needed to confirm these results.

3.13. Effects on the reproductive system

Previous studies found that ALE may ameliorate gonadal health in rat models through antioxidant effects (Gurel *et al.*, 2007; Mohammed *et al.*, 2020). The results show the potential beneficial effects of ALE on the reproductive system, but other studies are required to confirm these results and describe in detail the molecular mechanisms underlying these effects.

3.14. Effects on the immune system

The oral intake of artichoke may have positive effects on the immune system in animal models. A previous study by El-Boshy *et al.* (2017) found that ALE is effective in improving the levels of immunostimulatory cytokines in a rat model of cadmium toxicity. Hueza and colleagues (2019) showed that an artichoke extract exerts immunomodulatory activity in rats. These two studies provide the first evidence of the effects of artichoke on the immune system. Other studies are needed to confirm the results and explain the molecular mechanisms.

3.15. Antiphotoaging effects

Cynaropicrin has antiphotoaging effect *in vivo* and *in vitro* by regulating the nuclear factor kappa B (NF-kB) signalling pathway (Tanaka *et al.*, 2013). Takei and colleagues (2015) showed that this bioactive compound from artichoke may prevent ultraviolet B (UVB)-induced photoaging in human keratinocytes through antioxidant effects. These results should be confirmed by future studies.

3.16. Antifungal effects

Only one research study showed the antifungal activity of different artichoke extracts *in vitro* and found that ALE is the most effective. The authors analysed the effect against *Candida albicans*, *Candida lusitaniae*, *Saccharomyces cerevisiae*, *Saccharomyces carlsbergensis*, *Aspergillus niger*, *Penicillium oxalicum*, *Mucor mucedo* and *Cladosporium cucumerinum* (Zhu *et al.*, 2005). Further studies should corroborate these results.

3.17. Prevention of periodontal diseases

Cynaropicrin from artichoke may exert a preventive effect on periodontal diseases *in vitro* by modulating the NF-kB signalling pathway (Hayata *et al.*, 2019). Only one study found this activity and these results should be confirmed.

This review has some limitations. We reported only scientific articles published in PubMed indexed journals, personal criteria were utilised for conducting the literature search and many studies are characterized by small sample sizes or require replication of results.

4. Conclusions

In this study, we show the health-promoting properties of artichoke after performing a literature search. The most common beneficial effects of this plant are those on the liver and lipid profile and antioxidant activity. Other health benefits include improved gastrointestinal and cardiovascular health and anticancer, antimetabolic and antiobesity, prebiotic and probiotic, antidiabetic and renoprotective effects. Only few studies found the beneficial effects of artichoke on the immune system, the reproductive system, the nervous system, arthritis, photoaging, periodontal diseases and fungal infections. Phenolics are the bioactive compounds mainly involved in these properties and ALE is the extract most commonly utilised for these purposes. Many experiments have been conducted on animal models or *in vitro* and reasearch studies involving humans would be helpful to clarify the beneficial effects of artichoke on human health. The health benefits of artichoke are well documented in the scientific literature. Further studies should confirm the results of the articles reported in this review and the molecular mechanisms involved in the health-promoting properties of this plant.

Abbreviations

ALD: alcoholic liver disease

ALE: artichoke leaf extract

BMI: body mass index

eNOS: endothelial nitric oxide synthase

HDL-C: high-density lipoprotein cholesterol

IBS: irritable bowel syndrome

iNOS: inducible nitric oxide synthase

LDL-C: low-density lipoprotein cholesterol

NAFLD: non-alcoholic fatty liver disease

NASH: non-alcoholic steatohepatitis

NF-kB: nuclear factor kappa B

ox-LDL: oxidized-LDL

ROS: reactive oxygen species

UVB: ultraviolet B

XO: xanthine oxidase

Declarations

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Conflict of interest

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Availability of data and material

Data and material available on request from the authors.

Code availability

Not applicable

Authors' contributions

ADN, FG, FP and PZ conceptualised and designed the study. ADN conducted the literature search and drafted the article. All co-authors discussed the findings, critically revised the article and approved the final version of the manuscript.

Ethics approval and consent to participate

Not applicable

Consent for publication

Not applicable

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