11 Health benefits of dandelion

Potential health benefits of dandelions include providing antioxidants, lowering blood pressure, regulating blood sugar, and managing weight.

Dandelion is a plant with yellow flowers. Taraxacum officinale is the most common variety of this plant, and it grows in many parts of the world.

Botanists consider dandelions to be herbs. People use different parts of dandelions for medicinal purposes, including the:

leaves
stems
flowers
roots

Dandelions may benefit human health in a number of ways as part of a balanced diet and supplement regimen. However, as with all dietary or supplement changes, people should speak with a doctor before incorporating it into their diet.

This article discusses the possible health benefits of dandelion, how to use it, and its possible side effects.

1. Providing antioxidants

Amor Burakova/Stocksy United

Antioxidants work to neutralize the harmful effects of free radicals. The human body produces free radicals naturally, but they cause harm by accelerating aging or the progression of certain diseases.

Dandelions contain beta-carotene, which is an antioxidant that helps protect cells from damage. ResearchTrusted Source shows that carotenoids such as beta-carotene play a vital role in reducing cell damage.

The flower of the dandelion is also full ofTrusted Source antioxidants such as flavonoids and polyphenols.

Learn about the best antioxidant foods.

2. Reducing cholesterol
Dandelions contain bioactive compounds that may help lower a person's cholesterol.

Research conducted in animals and test tubes has shown that dandelion may be able to help reduce blood lipids. This can include cholesterol and triglycerides.

It may be possible that people can use dandelion to help treat high cholesterol, but more research in humans is still necessary.

Learn about foods that can help lower cholesterol.

3. Regulating blood sugar
There is some evidence to suggest that dandelions contain compounds that may help with regulating blood sugar.

Some studies in animals suggest that dandelion's hypoglycemic properties and ability to lower both insulin resistance and fasting blood glucose levels may help manage type 2 diabetes.

However, further research is required to make any definitive claims.

Learn about ways to lower blood sugar levels.

4. Reducing inflammation
Some studies indicate that dandelion extracts and compounds may help reduce inflammation in the body.

In a 2022 reviewTrusted Source, researchers noted that chemicals present in dandelions may have anti-inflammatory properties.

Another 2022 studyTrusted Source also identified the anti-inflammatory benefits of dandelion in mice and zebrafish larvae.

More research in humans is necessary to further assess whether dandelion can effectively reduce inflammation in the human body.

Learn about anti-inflammatory diets.

5. Lowering blood pressure
There is little research to support the use of dandelion for lowering blood pressure.

However, dandelion leaves are a good sourceTrusted Source of potassium. A diet rich in potassium may helpTrusted Source reduce blood pressure in people with high blood pressure.

Learn about foods that can help lower blood pressure.

6. Aiding weight loss
Some animal research suggests that dandelion could help with weight loss.

Polyphenols, compounds in dandelion leaf and plant extracts, may be usefulTrusted Source in managing obesity.

Strong evidence to support this claim is lacking, however.

Learn about foods to avoid when trying to lose weight.

7. Reducing cancer risk
Some limited research has indicated that dandelion may help reduce the growth of certain types of cancer.

So far, studies have looked at dandelion's impact on cancer growth in test tubes and found that it may help slow the growth of certain cancers.

One 2017 studyTrusted Source examining cancer growth in a test tube determined that dandelion extract may help reduce the growth of liver cancer. Other research has shown similar benefits for:

colon cancer
breast cancer
pancreatic cancer
prostate cancer
However, research in humans is necessary to determine whether consuming dandelion actually protects against cancer.

Learn about cancer-fighting foods.

8. Boosting the immune system
There is some evidence that suggests that dandelions can help boost the immune system.

A 2021 review notes that dandelions have both antiviral and antibacterial properties. For example, one 2020 studyTrusted Source found that dandelions help limit the growth of hepatitis B in cells in test tubes.

However, researchers need to do more studies to determine the impact of dandelions on the immune system.

Learn about the best foods for boosting the immune system.

9. Aiding digestion
Some people use dandelion as a traditional remedy for constipation and other digestion issues.

According to a 2022 reviewTrusted Source, dandelion-derived products may help protect against gastrointestinal disorders. This may be due in part to their anti-inflammatory and antioxidant properties.

However, more studies are necessary as research into the possible benefits of dandelion for digestive health is currently limited.

Learn about foods that can aid digestion.

10. Keeping skin healthy
Some research indicates that dandelion may help protect the skin from sun damage.

Ultraviolet (UV) light causes considerable damage to the skin and contributes to skin aging. A 2015 studyTrusted Source on skin cells in a test tube found that dandelion could reduce the impact of one type of damaging UV light.

Protecting the skin from UV damage can help prevent premature aging. However, researchers need to conduct studies on humans to verify these results.

Learn about foods that can help boost skin health.

11. Promoting liver health
Research shows that dandelion may be able to help prevent and treat some liver diseases. This includes:

acetaminophen-induced liver injury (AILI)
nonalcoholic fatty liver disease (NAFLD)
alcohol-related liver damage
Researchers conducted this research in animals and test tubes, so human studies are necessary to determine if dandelion can actually be used medicinally for these purposes.

Learn about the best foods for protecting the liver.

Supplements and dosage
Dandelion leaves are sometimes present in salads, but they aren't found in all areas. Picking dandelions in a backyard is unsafe due to the potential presence of pesticides or animal excrement.

However, it is possible to obtain dandelion supplements or teas and coffees infused with dandelion root. The Food and Drug Administration (FDA) has recognized dandelion as generally being safe to include in food products.

Data on safe doses of dandelion supplements is limited. Similar to other supplements, its potency and effectiveness can vary widely between manufacturers.

Dandelion supplements can causeTrusted Source allergic reactions in some people. People should not use dandelion supplements if they are sensitive to dandelions or certain other flowers or plants, such as ragweed, daisies, chrysanthemums, or marigolds.

People trying supplements should follow instructions on the bottle for recommended doses and always speak with a doctor before taking them.

Frequently asked questions

Is it OK to eat a dandelion?

Dandelions are generally safe to eat. They may be eaten in soup or salad, or the flowers can be used to make wine. However, it is best to eat them in moderation, as there is currently no informationTrusted Source about the safety of consuming them in large quantities.

Can I eat dandelions from my yard?

It may be safe to eat dandelions growing in a person's yard, but there are some safety rules that should be followed. A person should never harvest and eat plants in a yard that has been sprayed with pesticides or from a yard close to a road that spreads fuel emissions or dust that may cover the plant.

When following safe practices, a person can generally consume the dandelion petals, roots, and leaves.

Are all dandelions the same?

Taraxacum officinale is the most common variety of dandelion, but there are actually hundreds of different micro-species.

Who should avoid taking dandelion?

According to the Northern New England Poison Center, regularly consuming dandelions or taking dandelion supplements may not be suitable for people who are taking certain medications, such as lithium, diuretics, blood sugar-lowering medications, or blood thinners.

It is best to contact a doctor for advice before adding dandelion to the diet.

Summary

Dandelions have many potential health benefits. Some research suggests that they may provide a good source of antioxidants, help reduce cholesterol, regulate blood sugar, boost the immune system, and reduce inflammation.

Dandelion may also lower blood pressure, aid in digestion and weight loss, promote skin and liver health, and reduce the risk of cancer.

However, many of the claims need additional research to prove the effectiveness of dandelions on health in humans.

It is best to contact a doctor before adding dandelions to the diet. The doctor can discuss the possible benefits, risks, and interactions with any medications a person may be taking.

foods

MDPI

Review

Dandelion (*Taraxacum officinale* L.) as a Source of Biologically Active Compounds Supporting the Therapy of Co-Existing Diseases in Metabolic Syndrome

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Abstract: Nowadays, many people are struggling with obesity, type 2 diabetes, and atherosclerosis, which are called the scourge of the 21st century. These illnesses coexist in metabolic syndrome, which is not a separate disease entity because it includes several clinical conditions such as central (abdominal) obesity, elevated blood pressure, and disorders of carbohydrate and fat metabolism. Lifestyle is considered to have an impact on the development of metabolic syndrome. An unbalanced diet, the lack of sufficient physical activity, and genetic factors result in the development of type 2 diabetes and atherosclerosis, which significantly increase the risk of cardiovascular complications. The treatment of metabolic syndrome is aimed primarily at reducing the risk of the development of coexisting diseases, and the appropriate diet is the key factor in the treatment. Plant raw materials containing compounds that regulate lipid and carbohydrate metabolism in the human body are investigated. Dandelion (*Taraxacum officinale* F.H. Wigg.) is a plant, the consumption of which affects the regulation of lipid and sugar metabolism. The growth of this plant is widely spread in Eurasia, both Americas, Africa, New Zealand, and Australia. The use and potential of this plant that is easily accessible in the world in contributing to the treatment of type 2 diabetes and atherosclerosis have been proved by many studies.

Keywords: dandelion; metabolic syndrome; antioxidant activity; hypolipidemic effect; anti-diabetes; antiplatelet activity

Citation: Kania-Dobrowolska, M.; Baraniak, J. Dandelion (*Taraxacum officinale* L.) as a Source of Biologically Active Compounds Supporting the Therapy of Co-Existing Diseases in Metabolic Syndrome. *Foods* **2022**, *11*, 2858. https://doi.org/10.3390/foods11182858

Academic Editors: Annalisa Chiavaroli and Luigi Brunetti

Received: 29 August 2022
Accepted: 13 September 2022
Published: 15 September 2022

1. Introduction

Metabolic syndrome is affecting an increasing number of people in almost all well-developed countries. The number of people, including children and young adults, with type 2 diabetes, obesity, and atherosclerosis is growing every year. These people often do not receive comprehensive treatment, and each diagnosed component disorder of the metabolic syndrome is treated separately. At the same time, there is a growing awareness in society of the importance of proper diet and physical activity in the prevention and treatment of many diseases. People with coexisting diseases classified as metabolic syndrome, according to the definition, in addition to traditional treatment, are increasingly reaching for other methods, such as the use of herbal medicine. Herbs have accompanied man for years in medicine, cosmetology, as well as in the kitchen. There are a number of plant raw materials that affect lipid and carbohydrate metabolism and improve digestion. One such plant is the dandelion. Dandelion is used both as a medicinal agent and as food. The root is a substitute for cereal coffee, the leaves are eaten raw in salads, and syrups are made from the flowers. Dandelion has many chemical compounds that affect lipid metabolism, protect the liver, regulate blood sugar, and affect digestion and, indirectly, obesity. In addition, some compounds in dandelion regulate platelet aggregation and affect blood pressure regulation. It seems that all these properties recommend this plant for use in complementary therapy in the treatment of coexisting diseases in metabolic syndrome.

2. Definition and Etiology of Metabolic Syndrome (MetS)

Metabolic syndrome is the co-occurrence of factors such as central (abdominal) obesity, elevated blood pressure, and disorders of sugar and fat metabolism in the human body, which eventually leads to the development of cardiovascular disease and type 2 diabetes. Lifestyle has an impact on the occurrence of metabolic syndrome. The treatment of metabolic syndrome is primarily aimed at reducing the risk of developing diabetes, hypertension, and cardiovascular disease.

The first definition of metabolic syndrome was proposed by the World Health Organization (WHO) in 1998 [1]. The components of metabolic syndrome include type 2 diabetes, insulin resistance, abnormal glucose tolerance or abnormal fasting glucose, and at least two of the other criteria: microalbuminuria, reduced HDL (high-density lipoproteins cholesterol) or elevated triglycerides, or European Group for the Study of Insulin Resistance (EGIR); microalbuminuria was not considered as a component of the metabolic syndrome. Insulin resistance/hyperinsulinemia occurring together with a fasting blood glucose above or equal to 110 mg/dL (IFG), or impaired glucose tolerance (IGT), the presence of hypertension; elevated triglycerides and/or reduced HDL levels; and abdominal obesity were considered the main criteria for the diagnosis of MetS. Abdominal obesity was assessed by waist measurement rather than waist/hip ratio (WHR) or body mass index (BMI), as per the WHO definition [2]. Subsequent modifications of the MetS definition reduced the emphasis on the relevance of a specific criterion occurrence and focused on the simultaneous occurrence of at least three of the above-mentioned criteria. The focus was on simplifying the diagnosis of MetS in clinical practice by concentrating on identifying people who have an increased risk of cardiovascular disease and treating lipid and non-lipid risk factors, with particular attention paid to insulin resistance. As a result of this approach, there have been changes introduced in the diagnosis of MetS included in the report National Cholesterol Education Program, Adult Treatment Panel III (NCEP-ATP III). It was found that the MetS diagnosis criteria did not require the determination of insulin resistance, making it simple in clinical practice. Although central obesity was recognized as a risk factor underlying the development of metabolic syndrome, all components of MetS were treated equally [3]. The criteria developed by the International Diabetes Federation (IDF-International Diabetes Federation) focus on the co-occurrence of abdominal obesity (waist circumference) together with at least two factors, such as elevated triglycerides, reduced HDL-cholesterol fraction, elevated blood pressure, elevated fasting glucose, or diagnosed type 2 diabetes. As with the NCEP-ATPIII criteria, the authors concluded that determining insulin resistance, which is not easy to measure, is not a requirement for diagnosing MetS. In the report, the authors noted that abdominal obesity is strongly associated with insulin resistance, and measuring abdominal circumference is easy and quick [4–6]. According to the guidelines of the Polish Forum for the Prevention of Cardiovascular Diseases (PFPChUK), updated in 2015, metabolic syndrome is a clinical condition characterized by the co-occurrence of multiple interrelated metabolic factors that increase the risk of developing atherosclerotic cardiovascular disease and type 2 diabetes [7]. According to Polish studies, metabolic syndrome includes abdominal obesity and impaired glucose tolerance (insulin resistance and/or hyperinsulinemia), dyslipidemia (high triglycerides and/or low HDL fraction cholesterol), as well as hypertension, and the activation of pro-inflammatory and pro-thrombotic processes. The criteria for the diagnosis of metabolic syndrome according to the PFPChUK are as follows: an increased waist circumference equal to or greater than 80 cm in women and equal to or greater than 94 cm in men, a triglyceride level equal to or greater than 150 mg/dL (1.7 mmol/L) or the use of medications to reduce it, a fasting glucose level equal to or greater than 100 mg/dL (5, 6 mmol/L) or the use of hypoglycemic drugs, and reduced HDL cholesterol less than 50 mg/dL (1.3 mmol/L) in women and less than 40 mg/dL (1.0 mmol/L) in men or the use of drugs to increase its concentration, elevated systolic blood pressure equal to or higher than 130 mm Hg and/or diastolic blood pressure equal to or higher than 85 mm Hg or the use of hypotensive drugs in patients with a positive history of hypertension. According to the team's study of the PFPChUK, if

a patient meets at least three of the above criteria, metabolic syndrome can be diagnosed. The reasons for the development of MetS are linked to several complex mechanisms that have yet to be fully elucidated. There is some debate as to whether the individual elements of the MetS form separate pathological states or whether they are subject to a common broader pathogenetic process. In addition to genetic and epigenetic factors, some lifestyle and environmental factors such as overeating and physical inactivity have been identified as major contributors to the development of MetS. Disorders such as atherosclerosis, type 2 diabetes, and obesity are classified as diet-related diseases. A poor diet (consuming too many calories) is believed to increase the risk of visceral adipose tissue accumulation. One hypothesis for the development of MetS considers visceral obesity as an activating factor in insulin resistance, chronic inflammation, and neurohormonal activation [7]. Metabolic syndrome factors are presented in Figure 1.

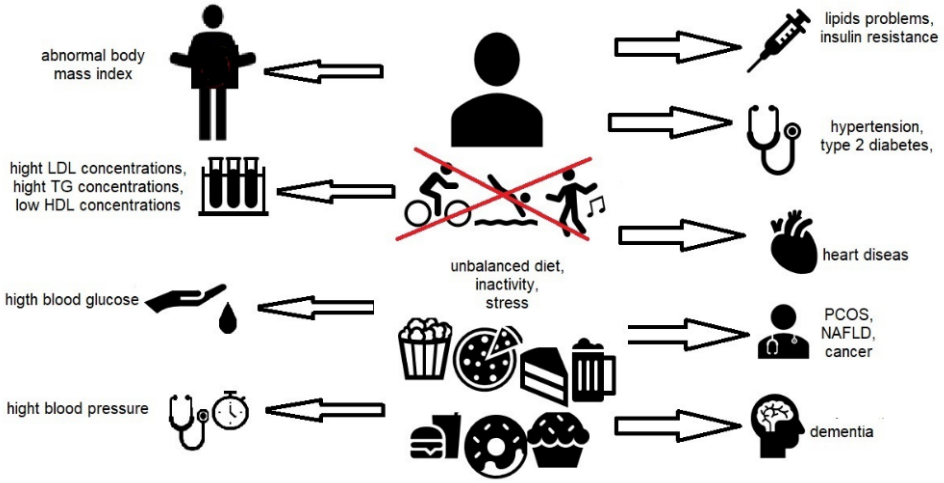


Figure 1. Metabolic syndrome factors/PCOS—polycystic ovary syndrome; NAFLD—non-alcoholic fatty liver disease/.

3. Lifestyle vs. Metabolic Syndrome

Lifestyle demonstrates a huge impact on the development of metabolic syndrome. Its change can significantly reduce the risk of MetS' possible occurrence. The results from the Diabetes Prevention Program Research Group indicated that lifestyle modification by reducing body weight by 7% and increasing physical activity to 150 min per week reduced the incidence of diabetes more effectively than metformin treatment in people without diabetes but with prediabetes [8–12]. Therefore, one of the first steps to be taken in treating metabolic syndrome is to change the lifestyle by reducing the caloric content of the meals, increasing physical activity, and reducing body weight. Health problems and conditions such as diabetes, obesity, and hypertension are treated with approved drugs providing clinically proven effects and safety of use. However, it also appears that many natural plant materials can be helpful in maintaining normal blood glucose and cholesterol levels. Among medicinal plants that may be efficient in the prevention of type 2 diabetes mellitus, the most popular are: galega (*Galega officinalis* L.), common bean (*Phaseolus vulgaris* L.), fenugreek (*Trigonella foenum-graecum* L.), alfalfa (*Medicago sativa* L.), white mulberry (*Morus alba* L.), ginger (*Zingiber officinale* Rosc.), maize (*Zea mays* L) [13]. Among the plants with the ability to affect lipid metabolism are: garlic (*Allium sativum* L.), turmeric (*Curcuma longa* L.), milk thistle (*Silybum marianum* L.), cardoon (*Cynara cardunculus* L.), Panax ginseng (*Panax ginseng* C.A. Meyer). One of these herbal plants with beneficial pharmacological effects on the set of disease factors included in the metabolic syndrome is dandelion (*Taraxacum officinale* F.H. Wigg.).

4. Dandelion—Plant Characteristics

Dandelion (*Taraxacum officinale* L. syn. *Taraxacum vulgare* L.), belonging to the Asteraceae family, is a pharmacopeial, edible plant. It probably originated from Europe; it also gradually spread to Asia, then North America, and later to some South American countries. In many European countries, it is a common weed growing in fallow fields, roadsides, meadows, and lawns. Dandelion is a perennial weed with sturdy taproot, long green leaves organized in a rose-like manner, single yellow flowers, and characteristic cotton-like fruits with many seeds that are scattered by the wind [14]. The pharmacopeial raw materials are the roots of the dandelion (Taraxaci radix), herba, and also flowers. The traditional uses of dandelion that are mentioned in the literature concern its use as a remedy in kidney diseases, diabetes, bacterial infections, diuretic, liver, kidney, and spleen disorders, and as an anti-inflammatory factor [15]. On the other hand, dandelion parts are used as food, mainly as a salad ingredient, young leaves are placed in many dishes, and the inulin-rich roots are used as substitutes for coffee or tea [15]. It has been detected that approximately 100 g of fresh leaves contain 88.5 g of water, 19.1 g of crude protein, 6.03 g of crude fat, 10.8 g of crude fiber, and 0.67 g/100 g dry matter of calcium, 6.51 g/100 g dry matter of potassium, 3.99 g/100 g dry matter of zinc, 12.6 mg/100 g dry matter of tocopherols, 156.6 mg/100 g dry matter of L -ascorbic acid and 93.9 mg/100 g dry matter of carotenoids [16]. Dandelion flower extracts can be used as flavor additives in many food products, such as desserts, candies, baked cakes, puddings, and other similar food products [17]. The main active compounds of dandelion are presented in Figure 2.

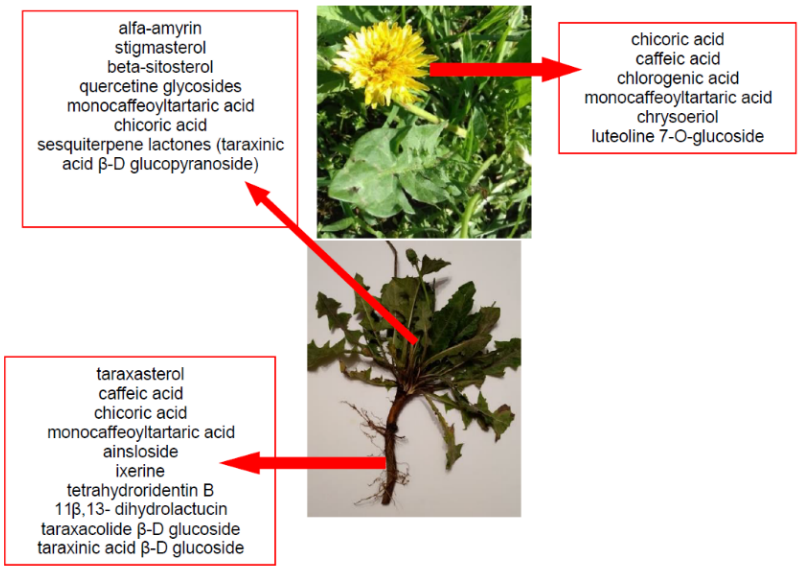


Figure 2. The main active compounds of dandelion.

Dandelion roots contain mainly sesquiterpene lactones and triterpenes and sterols (taraxasterol, taraxerol, cycloartenol, beta-sitosterol, stigmasterol) [18]. Lactones have a bitter taste and are often an ingredient in products that stimulate digestion. The literature evidence suggests that phenolic acids and sesquiterpene lactones are the main components of the dandelion root responsible for its antidiabetic potential [19]. Dandelion leaves and flowers contain polyphenols, mainly hydroxycinnamic acid derivatives (HCAs) and flavonoids (apigenin and luteolin derivatives) [20–22]. They are characterized by strong antioxidant and hypocholesterolemic properties. HCAs induce antiradical and protective effects against oxidative processes [22], while flavonoids inhibit the formation of reactive oxygen species and nitrogen by inhibiting NO synthase and COX-2 protein expression [23,24]. Chicoric acid is effective in preventing the formation and worsening of the atherosclerosis process [24]. Dandelion roots also contain significant amounts of inulin [14,20]. Inulin is a naturally occurring polysaccharide belonging to a class of dietary

fibers known as fructans. This plant is also an important source of vitamins (A, C, E, K, and B) and minerals (for example, iron and silicium), sodium, copper, zinc, magnesium, and manganese) [14,25]. Dandelion leaves are also a rich source of potassium, which may be related to the plant's diuretic activity [26]. Selected phytochemicals of dandelion are presented in Table 1.

Table 1. Selected phytochemicals of dandelion and their effects.

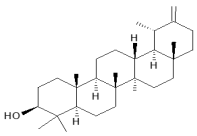
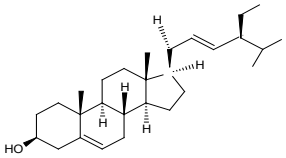
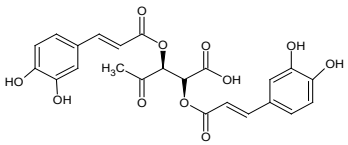
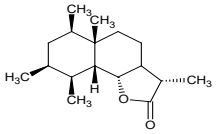
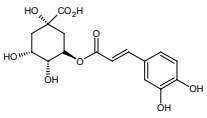
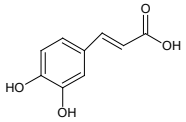
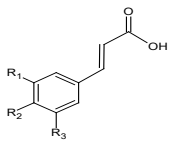
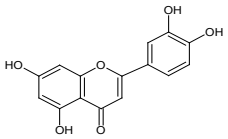
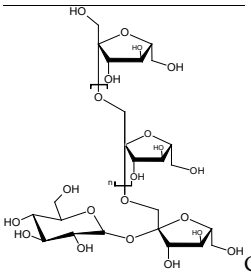
Name of the Phyto-Component and Parts of the Plant	Structure	Actions	References
taraxasterol (phytosterol) root	 $C_{30}H_{50}O$	antihyperglycemic and anti-inflammatory properties	[27]
		anti-inflammatory activity	[28,29]
		decreases protein expression levels of PTBP1 and SIRT1, and may inhibit HBV and be a potential anti-HBV drug,	[30]
stigma sterol (phytosterols) leaf and steam	 $C_{29}H_{48}O$	anti-inflammatory, anti-hyperglycemic, antimicrobial properties	[31]
chicoric acid all parts of the plant	 $C_{22}H_{18}O_{12}$	antidiabetic agent with both insulin-sensitizing and insulin-secreting properties, preventing the formation and/or progression of atherosclerosis, antiradical and protective actions against oxidation processes, meanwhile, flavonoids inhibit the formation of reactive oxygen and/or nitrogen species by suppressing NO synthase and COX-2 protein expression	[32,33]
tetrahydroridentin B sesquiterpen lactone root	 $C_{15}H_{24}O_4$	activated the transcription factor nuclear factor erythroid 2-related factor 2 (Nrf2) in human hepatocytes, induced the Nrf2 target gene heme oxygenase	[34]
chlorogenic acid flower	 $C_{16}H_{18}O_9$	antioxidant properties	[35]
		anti-inflammatory, antibacterial, antiviral, hypoglycemic, lipid-lowering, anticardiovascular, antimutagenic, anticancer, immunomodulatory	[36]
caffeic acid flower and root	 $C_9H_8O_4$	anti-oxidative and immunostimulatory properties	[35]
hydroxycinnamic acids fruit	 R_2-OH p-coumaric acid R_3-OCH_3; R_2-OH ferulic acid R_1-OCH_3; R_2-OH; R_3-OCH_3 sinapic acid	in experiments on plasma and platelets, using several different parameters (lipid peroxidation, protein carbonylation, oxidation of thiols, and platelet adhesion), the highest antioxidant and antiplatelet potential was demonstrated	[37]

Table 1. *Cont.*

Name of the Phyto-Component and Parts of the Plant	Structure	Actions	References
luteolin aboveground plant parts	 $C_{15}H_{10}O_6$	important role in the amelioration of LPS-induced oxidative stress and inflammation.	[38]
inulin root	 $C_{6n}H_{10n+2}O_{5n+1}$	influences the development of normal intestinal microflora	[39]

5. Pharmacological Activity of Dandelion for Potential Use in the Treatment of Metabolic Syndrome (MetS)

5.1. Antidiabetic Effect

According to the data provided in the scientific journals, plant products and plant-derived compounds exhibit antidiabetic effects through mechanisms such as reducing the activity of enzymes (α-amylase with β-galactosidase and α-glucosidase) that break down sugars, including polysaccharides, inhibiting renal glucose reabsorption and flow through potassium channels [19]. Different extracts (methanolic, chloroform, aqueous, petroleum ester) of dandelion root were tested for antidiabetic activity in mice with normal glycemia and alloxan-induced diabetes. In addition, the authors carried out in vitro glucose uptake assays using HepG2 and 2-NDBG. The results from the in vivo study showed that an aqueous extract of Taraxacum officinale root (400 mg/kg) caused a significant decrease in blood glucose levels (62.33%, $p \leq 0.05$), while other extracts ($p > 0.05$) showed a statistically insignificant activity in mice with alloxan-induced diabetes. No effect of the extracts on glycemia was noted in non-diabetic mice. The extracts lowered glucose levels ($p > 0.05$) in the subcutaneous glucose tolerance test. The aqueous extract showed significantly higher glucose uptake (149.6724%, $p \leq 0.05$). A phytochemical examination of the aqueous extract confirmed a higher total phenolic content than flavonoids, and chlorogenic acid, protocatechuic acid, and luteolin-7-glucoside were identified [40]. Dandelion extract also inhibited the formation of advanced glycation end products (AGEs) (IC50 = 69.4 mg/L) more effectively than the drug commonly used in diabetes, named aminoguanidine (IC50 = 138 mg/L) [41]. Dandelion leaf and root extracts and taraxinic acid β-d-glucopyranosyl ester activated nuclear erythroid-associated transcription factor 2 (Nrf2) in human hepatocytes. The leaves of *Taraxacum officinale* induced the Nrf2 target gene Hmox1. Taraxinic acid β-d-glucopyranosyl ester isolated from the leaves was found to increase Nrf2 transactivation in a dose-dependent manner. The results obtained by Esatbeyoglu et al. (2017) [34] suggest that the antioxidative activity of dandelion leaf extract is responsible for the taraxinic acid β-d-glucopyranosyl ester [34]. Other studies have tested the effect of dandelion extract on insulin secretagogue activity. Dry ethanolic extracts of *Taraxacum officinale* at concentrations ranging from 1 to 40 µg/mL were tested in vitro for insulin release from INS-1 cells in the presence of 5.5 mM glucose, with glibenclamide as a control. Insulin secretagogue activity could be observed for dandelion extracts at a concentration of 40 µg/mL [42]. Alpha-glucosidase was also inhibited by aqueous extracts of *Taraxacum officinale* depending on the origin (alpha-glucosidase from baker's yeast, rabbit liver, and rabbit small intestine) [43,44] demonstrated the antihyperglycemic effect of a

herbal preparation containing 9.7% Taraxaci radix (*Taraxacum officinale* F.H. Wigg.) in an experiment on mice with alloxan-induced non-obesity diabetes (NOD). It was noted that the extract statistically significantly reduced glucose and fructosamine levels. [44]. A follow-up study revealed the effect of the dandelion extract on the catalytic activity of glutathione S-transferases (GSTs) and the formation of malondialdehyde (MDA) in the liver of mice as an indicator of oxidative stress in early diabetes. After a 7-day administration of the dandelion extract (at a dose of 20 mg/kg body weight) to NOD diabetic mice, a significant increase in catalytic GST concentration and a statistically insignificant decrease in MDA concentration were observed [44]. Similar results were obtained by Cho et al. 2002 [45] after administering an aqueous extract of dandelion leaves to rats with streptozotocin-induced diabetes. They observed a decrease in MDA levels in the rats' liver and a significant reduction in serum glucose levels [45].

α-Glucosidase is an enzyme responsible for breaking down complex carbohydrates: di-, oligo-, and polysaccharides into simple sugars, including glucose. By inhibiting the decomposition of the alpha bonds of carbohydrates, inhibitors of α-glucosidase reduce the absorption of glucose into the blood from the gastrointestinal tract, resulting in lower postprandial glycemia. It was found that the dandelion extracts showed the ability to inhibit alpha-glucosidase [46]. In vitro studies conducted by Mir et al. (2015) [47] on methanolic and aqueous extracts of dandelion leaves, roots, and flowers confirmed their potential to inhibit α-amylase and α-glucosidase activity. It was noted that aqueous extracts inhibited enzymes more strongly than methanolic extracts, with leaf extracts showing the highest activity, followed by root extracts and the weakest activity from dandelion flowers [47]. Li and his team, based on the obtained experimental results, concluded that the aqueous extract of dandelion root, with a composition of polysaccharides (63.92 ± 1.82 mg/g), total flavonoids (2.57 ± 0.06 mg/g), total phenolic compounds (8.93 ± 0.34 mg/g), and saponins (0.54 ± 0.05 mg/g) statistically showed a significant ability to inhibit α-glucosidase and α-amylase activities [48]. Synergism was also observed between the effects of dandelion root extract and Astragalus (*Astragalus* L.) extract. In addition, it was found that mixing the extracts from these plants could alleviate insulin resistance in IR-HepG2 cells.

Choi and his team in 2018 [49] isolated from *Taraxacum officinale*, in addition to the 22 previously known compounds listed below (no. 1–22), three new butyrolactones (1–3) and three butanates (4–6), or taraxioside A-F (Figure 3) (1) 1,2,5-tri-O-p-hydroxyphenylacetyl-L-chiro-inositol, (2) chrysoeriol, (3) 5,7,30-hydroxy-40,50-dimethoxy flavone, (4) methyl 3,4-dihydroxycinnamate, (5) 5,7,40-hydroxy-30,50-dimethoxy flavone, (6) luteolin, (7) 3-glycerindole, (8) calquiqueignan D, (9) calquiquelignan E, (10) tricin 40-O-[threo-b-guaiacyl-(700-Omethyl)-glyceryl] ether, (11) tricin 40-O-[erythro-b-guaiacyl-(700-O-methyl)-glyceryl] ether, (12) loliolide, (13) epiloliolide, (14) annuionone, (15) 11b,13-dihydrotaraxinic acid b-O-glucopyranoside, (16) 3,4-dihydroxy-5,7-megastigmadien-9-one, (17) komaroveside A, (18) 6S,9R-roseoside, (19) 6S,9S-roseoside, (20) adenosine, (21) aesculetin-7-O-b-D-glucopyranoside, and (22) syringin. Their chemical structures were determined by interpreting the spectroscopic data and comparing them with data from the literature. The authors evaluated all isolates for their α-glucosidase inhibitory activity. New compounds I through VI (IC50 145.3–181.3 μM) showed inhibitory activity similar to acarbose (IC50 179.9 μM). Compounds 1 and 6 were the strongest inhibitors, with IC50 values of 61.2 and 39.8 μM, respectively. Compounds II and 6 showed mixed-type inhibition, while compound 1 and acarbose showed competitive inhibition [49].

Perumal et al. 2022 [50] studied the antidiabetic potential of a combination of dandelion and *Momordica charantia* extracts. They determined antidiabetic properties in vitro; the inhibition of α-amylase, α-glucosidase, and dipeptidyl peptidase-4 (DPP-4), and glucose-uptake in L6 muscle cells.

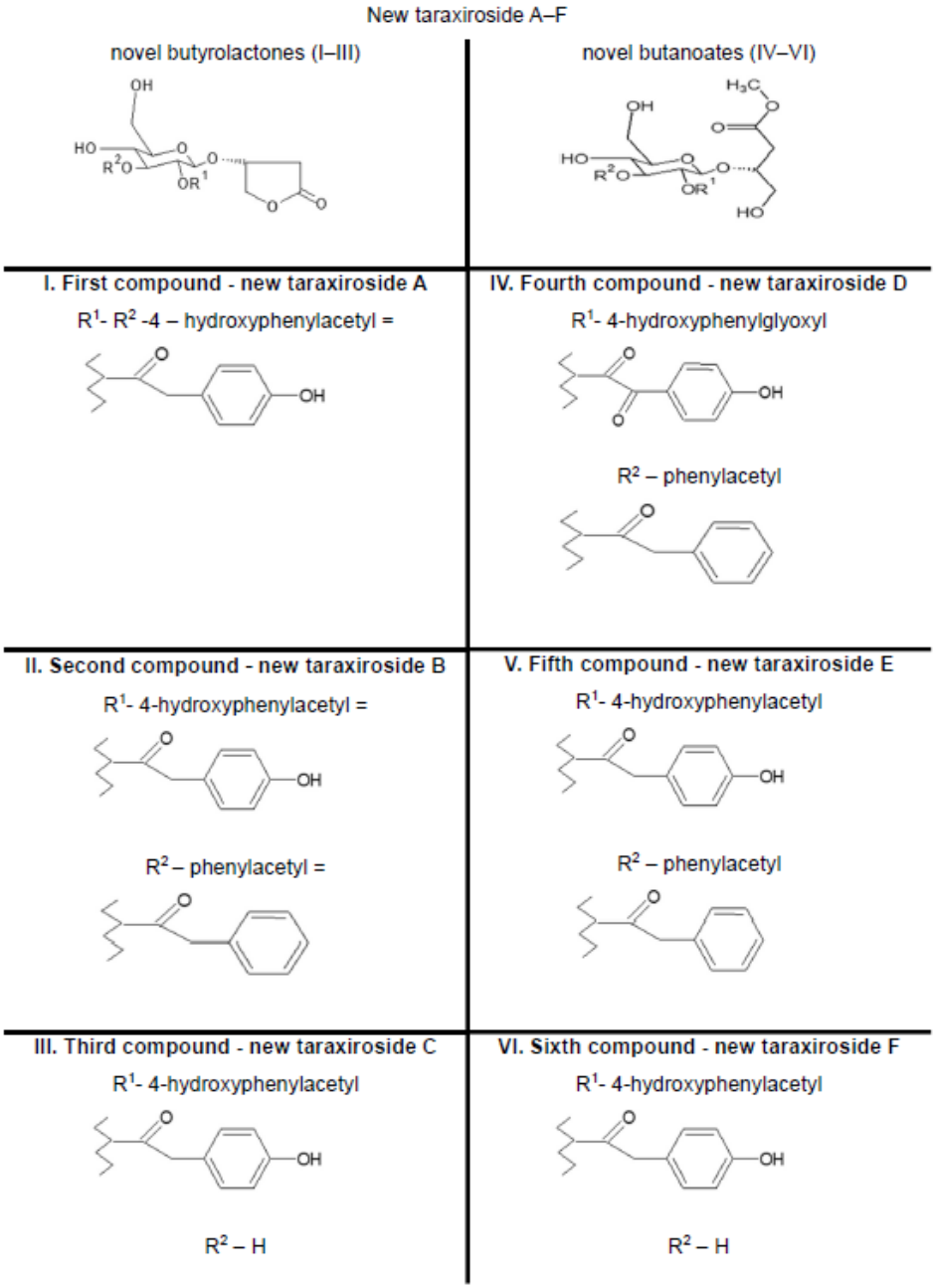


Figure 3. New compounds isolated from *Taraxacum officinale* Choi et al. 2018 [49].

The authors of the study concluded that the antidiabetic efficacy of the combination of the tested herbs was better than the aforementioned herbs used alone. A glucose tolerance test in a study involving rats with streptozotocin–nicotinamide (STZ-NA)-induced diabetes proved that the combination of herbs tested lowered blood glucose levels comparable to the effects of glibenclamide and metformin. The combination of herb extracts showed better antidiabetic properties; it increased the activity of DPP-4, α-amylase, and α-glucosidase [50]. Therefore, the authors suggest that combinations of herbs have a better phytotherapeutic potential for treating type 2 diabetes. In another study conducted by Cho et al. 2002 [45] on a rat model of streptozocin-induced diabetes, the administration of 2.4 g of dandelion aqueous extract/kg of diet reduced postprandial blood glucose levels [45]. In another study conducted in 2012 by Nnamdi and his team [51], the effects of dandelion leaves and roots on streptozotocin (STZ)-induced diabetes in rats were tested. The results provided evidence of a hypoglycemic effect after twice-daily administration of an aqueous or alcoholic extract of *Taraxacum officinale* leaves and roots in amounts of

300 and 500 mg extract/kg b.w. [51]. It was found that the ethanol extract can increase carbohydrate metabolism. It was also suggested that the ethanol extract is more effective than the aqueous extract and that the roots are more therapeutically effective than the leaves in the treatment of diabetes. The experimental results also showed that the effects of the *Taraxacum officinale* extracts were dose-dependent. However, the authors did not analyze the composition of the extracts, so it is not possible to conclude which components of the dandelion are responsible for such activity [51]. In vivo studies in rat models of non-alcoholic steatohepatitis (NAFLD) treated with dandelion extracts showed significant reductions in hepatic lipid accumulation, liver tissue and body weight, and serum cholesterol levels. After the administration of dandelion leaf extracts, insulin resistance was found to be reduced through activation of the AMPK (5′ adenosine monophosphate-activated protein kinase) pathway. Dandelion products, due to the presence of polyphenols and flavonoids in their composition, can regulate the expression of several genes whose dysfunctions contribute to lipid deposition, oxidative stress, and insulin resistance [52]. With the increasing evidence that non-alcoholic fatty liver disease increases the risk of developing type 2 diabetes, it is assumed that non-alcoholic fatty liver disease and non-alcoholic steatohepatitis are specific clinical manifestations of type 2 diabetes through the coexisting process of lipid deposition, chronic inflammation, and liver fibrosis [53]. Other studies have confirmed that polyphenols in dandelion leaf and stem extracts are useful in the treatment of type 2 diabetes and obesity. An ethanolic extract of dandelion was proved to inhibit the formation of advanced glycation end products at IC50 = 69.4 mg/L compared to the antiglycation drug-aminoguanidine (IC50 = 138 mg/L) [54]. Dandelion components also show activity in regulating the pathways responsible for insulin release, most likely by inhibiting certain enzymes involved directly and indirectly in carbohydrate breakdown in the Krebs cycle and glycolytic cycle. The mechanism of insulin release in β cells is a complex process. The ethanolic extract of dandelion at a concentration of 40 μg/mL significantly increased insulin secretion in in vitro studies on the rat INS-1 cell line [42]. In a study performed by Tousch et al. (2008) [32], it was noted that chlorogenic acid CGA is an inhibitor of glucose-6-phosphatase (G6P) in the rat liver and may contribute to intensifying glucose transport, thereby increasing ATP production and stimulating insulin secretion [32]. It is thought that CGA may also regulate β-cell function [55]. An in vivo experiment showed that CGA significantly increases hepatic mRNA expression by interacting with peroxisome proliferator-activated receptor alpha (PPAR-α). Thus, it is investigated that CGA may contribute, through the activation of peroxisome proliferator-activated receptor alpha (PPAR-α) and the stimulation of glucagon-like peptide GLP-1 production, to restore β-cell function, and thus aid in the treatment of type 2 diabetes [56].

5.2. Impact on Lipid Profile

To determine the possible use of dandelion preparations as a natural anti-obesity agent, Zhang et al. (2008) [57] examined its inhibitory activity against pancreatic lipase in vitro and in vivo. The inhibitory activity of a 95% ethanol extract of *T. officinale* and Orlistat was measured using 4-methylumbelliferyl oleate (4-MU oleate) as a substrate at concentrations of 250, 125, 100, 25, 12.5, and 4 μg/mL. To determine pancreatic lipase inhibitory activity in vivo, mice (n = 16) were orally administered corn oil emulsion (5 mL/kg) alone or with 95% ethanolic extract of *T. officinale* (400 mg/kg). The plasma triglyceride levels were measured at 0, 90, 180, and 240 min after administration. It was found that the 95% ethanol extract of *T. officinale* and Orlistat inhibited porcine pancreatic lipase activity by 86.3% and 95.7% at a concentration of 250 μg/mL. The *T. officinale* extract showed a dose-dependent inhibition of IC(50) = 78.2 μg/mL. In addition, it was discovered that a single oral dose of the extract inhibited the increase in plasma triglycerides at 90 and 180 min ($p < 0.05$) [57]. Other in vitro studies have confirmed that flavonoids related to quercetin and luteolin from dandelion inhibit porcine pancreatic lipase [58]. Mice (C57BL/6) that were fed dandelion leaf extract and a high-fat diet had lower serum triglycerides and total cholesterol compared to the control group [59]. Similar findings were reported for rabbits

fed a high-cholesterol diet (1% cholesterol) with dandelion root or leaves for four weeks. In these animals, it was also observed that the level of serum triglycerides was significantly lower compared to the control group [60]. Similar issues were the subject of another research paper. The investigation proved that dandelion extracts had an inhibitory effect on adipocyte differentiation and lipogenesis activity in 3T3-L1 pre-adipocytes. The HPLC analysis of the three plant extracts obtained from leaves and roots, which were used in this study, as well as a commercial root powder, showed the presence of caffeic acid and chlorogenic acid as the main phenolic component. It was found that there was no cytotoxicity effect in the concentrations of the extracts used in the experiments—MTT test. The authors inferred that dandelion extracts could affect adipogenesis and lipid metabolism [61]. Other researchers have searched for other biologically active compounds from a number of plants that would show properties that reduce triglyceride accumulation and increase lipolysis and induce investigated apoptosis. The work demonstrated that 18–22% v/v aqueous-ethanol extract of dandelion root effectively induced the apoptosis of human primary visceral pre-adipocytes during their differentiation while enhancing lipolysis [62]. An interesting study was conducted to reveal how the addition of dandelion extract at a rate of 0.8% to the carp's daily feed ration would affect the hydrochemical parameters (pH, dissolved oxygen, and electrical conductivity). It was found that carp fed a diet supplemented with dandelion extract did not show improved fish production characteristics compared to those found for carp from the control group. Instead, carp from the experimental groups had higher survival rates, final weights, average individual weight gain, and specific growth rates (SGR), but the differences were not statistically significant. Feed supplementation with dandelion extract significantly reduced plasma cholesterol (by 4.76%) and triglycerides (by 61.2%), which may be an interesting finding for breeders ($p \leq 0.05$) [63].

5.3. Impact on Blood Pressure

Oxidative stress is one of the factors co-responsible for the development of hypertension. In subsequent in vitro and in vivo studies, it was verified whether dandelion leaf and root extracts have sufficient antioxidant potential that is able to influence the reduction in hypertension-inducing factors. In this study, the malondialdehyde (MDA) levels were determined in lipid peroxidation assays and in rats with hypertension stimulated by free radical production. Oxidative stress was induced by N ω-nitro- L-arginine methyl ester. Aremu et al. (2019) [64] noted that the extract increased antioxidant activity and reduced lipid peroxidation in the heart, liver, kidney, and brain of the tested rats. The authors suggest that the phenolic compounds present in the extracts may also regulate nitric oxide synthase (NOS) levels and activity by affecting kinase signaling pathways and intracellular Ca^{2+} associated with NOS phosphorylation and NO production. In addition, phenolic compounds can also affect the inhibition of endothelin-1 (vasoconstrictor) and endothelial NADPH oxidase, but more research is required to confirm these theses [64].

5.4. Effects on Blood Coagulation

The inhibitory effect on platelet aggregation in humans by ethanolic extracts of dandelion root (*Taraxacum officinale* F.H. Wigg.) was examined. The extracts showed dose-dependent inhibition of platelet aggregation, where the maximum inhibition was 85% at a concentration equivalent to 0.04 g dried root/mL human platelet-rich plasma (PRP). The effect was obtained regardless of whether platelet aggregation was induced by arachidonic acid or collagen. The extracts were fractionated into two groups of compounds with masses above (Mr > 10,000) and below (Mr < 10,000). The fraction containing low-molecular-weight polysaccharides (Mr< 10,000) resulted in 91% inhibition, while the other fraction enriched in triterpenes and steroids (Mr > 10,000) showed 80% inhibition of platelet aggregation. Both at a concentration equivalent to 0.04 g raw material/mL PRP [65]. In another in vitro study, Lis and the team (2018) [66] determined the antiplatelet and antioxidant properties of four standardized phenolic fractions of dandelion. The following fractions were ana-

lyzed: two leaf fractions of 50% and 85% methanol and two petal fractions of 50% and 85% methanol. The hemostatic activity in the plasma was determined: activated partial thromboplastin time (APTT), prothrombin time (PT), and thrombin time (TT). It was found that none of the dandelion fractions tested caused damage to human platelets over the entire range tested. The results of the study show that dandelion, especially its aboveground parts containing hydroxycinnamic acid, which has antioxidant and antithrombotic effects of the hemostatic system; that is, they may be promising preparations in the prevention of cardiovascular diseases, especially those related to changes in hemostasis and oxidative stress [66]. Studies concerning the antioxidant potential of dandelion preparations have confirmed that a diet rich in dandelion preparations can be helpful in treating diseases related to oxidative stress and hemostatic disorders. Although a great number of chemical compounds present in dandelion, such as hydroxycinnamic acid and sesquiterpene lactones, were previously detected, new compounds are still being discovered and analyzed. Recently, inositol 4-hydroxyphenylacetate (PIE) esters have been characterized. In work performed by Jedrejek et al. 2019 [67], five fractions of dandelion extract were analyzed, where each was characterized by different contents of active compounds. Detailed LC-MS and chemical tests of the dandelion fractions identified about 100 phytochemical compounds, including new ones. In all concentration ranges tested (0.5–50 μg/mL), the dandelion root preparations did not cause platelet hemolysis. The results indicate that dandelion roots constitute a safe and readily available source of different classes of natural compounds with antioxidant, anticoagulant, and antiplatelet effects [67].

The aim of another in vitro study was to evaluate the activity of dandelion extracts, which were standardized for chicoric acid content. Four phenolic fractions extracted from leaves (fractions A and B) and flower petals (fractions C and D) were characterized by different concentrations of chicoric acid. The biomarkers of oxidative stress, coagulation, and platelet activation parameters were determined. The results suggest that chicoric acid has antioxidant and anti-adhesive potential. The authors noted that the fraction richest in chicoric acid (leaf fraction A) possesses anti-adhesive and anti-aggregation properties stronger than chicoric acid alone. These findings strongly suggest the possibility of a synergistic effect between the compounds in fraction A and also the presence of compounds such as phenolic acid derivatives and flavonoids, which may exhibit stronger properties than chicoric acid [68]. Relying on previous in vitro studies, another research group decided to test the effects of the same extracts in in vivo studies, conducting tests on rats. The animals were given a diet enriched in phenolic fractions obtained from dandelion leaves and petals (694 mg/kg diet/day) for 4 weeks. The phenolic fractions obtained from the dandelion leaves and petals contained, respectively, 4.10 $\pm$ 0.05 and 1.41 $\pm$ 0.07 mg of l-chicoric acid in the daily dose. It was found that supplementation with the petal fraction increased plasma thiols. The leaf fraction reduced the level of protein carbonylation and affected the lipid profile—triglycerides, total cholesterol, lipoprotein pooling index, and the plasma atherogenicity index were reduced. The authors concluded that the phenolic fractions from *T. officinale* rich in hydroxycinnamic acids should be considered as potential components of functional foods with beneficial effects on human health [33].

The phytochemical analysis of dandelion fruits is also an issue worthy of interest. It should be noted that the root, leaf, and flowers are relatively well studied. Research on dandelion fruits is rarely undertaken. However, fruits are also used in medicine and food. Lis et al. 2020 [37] obtained a methanolic extract of dandelion fruit (E1). Analysis of an extract revealed the presence of hydroxycinnamic acid (HCA) derivatives and flavone derivatives. Several new metabolites were also detected, such as biflavones and some flavonolignans. Multistage fractionation of the methanolic extract of dandelion fruit was carried out. Two fractions were prepared: phenolic acid extract (E2) and flavonoid extract (E3). The E3 extract was divided into four flavonoid fractions: A (luteolin fraction; 880 mg GAE/g), B (philonotisflavone fraction; 516 mg GAE/g), C (flavonolignans fraction; 384 mg GAE/g), and D (flavone aglycones fraction; 632 mg GAE/g). The highest antiradical activity of DPPH was exhibited by fractions A > B > Trolox, medium Trolox > E3 > E2 > E1, and the

lowest by C and D. No cytotoxic effect on platelets was noted for any of the dandelion preparations tested. Several different parameters, as well as lipid peroxidation, protein carbonylation, thiol oxidation, and platelet adhesion, were analyzed. The hydroxycinnamic acid extract (E2), flavonoid extract (E3), and luteolin fraction (A) showed the highest antioxidant and antiplatelet potential [37].

The antiplatelet potential of four fractions obtained from different parts of the dandelion (fractions A and B from roots; fraction C from leaves; fraction D from petals) on platelet activation and thrombus formation in whole blood were analyzed as well as the effect of the tested fractions on the platelet proteome were also evaluated. The authors found that fraction C from dandelion leaves reduced thrombus formation and platelet activation after collagen stimulation. None of the fractions tested caused changes in the platelet proteome. The preparations obtained from different parts of the dandelion can have a beneficial effect in the prevention and treatment of cardiovascular diseases caused by hyperactivation of platelets [69].

5.5. Dandelion vs. Obesity

To determine the possible use of the dandelion preparations as a natural anti-obesity agent, Zhang et al. 2008 [57] measured its inhibitory activity against pancreatic lipase in vitro and in vivo. The inhibitory activity of a 95% ethanol extract of *T. officinale* and Orlistat was measured using 4-methylumbelliferyl oleate (4-MU oleate) as substrate at concentrations of 250, 125, 100, 25, 12.5, and 4 μg/mL. To determine the pancreatic lipase inhibitory activity in vivo, mice (n = 16) were orally administered corn oil emulsion (5 mL/kg) alone or with 95% ethanolic extract of T. officinale (400 mg/kg). The plasma triglyceride levels were measured at 0, 90, 180, and 240 min after administration. It was found that 95% ethanol extract of *T. officinale* and Orlistat inhibited porcine pancreatic lipase activity by 86.3% and 95.7% at a concentration of 250 μg/mL. *T. officinale* extract showed a dose-dependent inhibition of IC(50) = 78.2 μg/mL. In addition, it was noted that a single oral dose of the extract inhibited the increase in plasma triglycerides at 90 and 180 min ($p < 0.05$) [57]. The mice were administered dandelion extract, which showed anti-obesity potential through a dose-dependent inhibitory effect on pancreatic lipase activity and an increase in plasma triglyceride levels. The results indicate that *T. officinale* may be an alternative to Orlistat, a drug which often causes adverse effects [57]. In another study, the anti-obesity effects of the dandelion ethanol extract were examined. The ethanolic extract of *Taraxacum officinale* was administered orally at a dose (150 and 300 mg/kg), and Orlistat was used as a reference drug. The experimental rats were fed a high-fat diet. The high-fat diet caused significant increases in body weight, fat mass, serum glucose concentration, as well as cholesterol and triglycerides levels. The authors noted that *Taraxacum officinale* extract significantly reduced body weight, lipid parameters, organ weights, and fat pad mass. The value of the study, however, is diminished by the fact that the content of phytoactive compounds in the extract was not determined. Unfortunately, it is not possible to determine which compounds are responsible for such effects [70]. The possibility of using dandelion extracts to compose formulations and functional foods affecting obesity reduction was also investigated. In the Aabideen et al. 2020 [71] experiment, various aqueous-ethanol extracts were tested for their antioxidant potential. Next, 60% of the extracts with the strongest antioxidant activity were subjected to in vivo testing. BALB/c mice weight gain, fecal fat content, and food intake were compared after an administration of an 8-week fat-rich diet. An increase in the body weight of 44.94% of mice on the high-fat diet (HFD), compared to the NDG control group of 22.21% after eight weeks was observed. After eight weeks on the HFD diet, the obese mice were divided into groups to evaluate the effects of plant extracts on obesity parameters. Treatment with plant extracts and comparative Orlistat was continued for another eight weeks. Mice given the plant extract at 300 mg/kg b.w. reduced their weight to 32.22 ± 1.86 g, and those consuming the drug Orlistat reduced their weight to 30.09 ± 1.61 g compared to the untreated group (HFD) (52.66 ± 2.03 g). The Orlistat-treated mice had a fecal fat content of 11.65%, the 300 mg/kg b.w. extract

group had a fecal fat content of 9.92% compared to the HFD mice at 5.67%. Food intake in mice in the HFD + 300 extract groups was 3.65 g/mouse/day, and HFD + Orlistat was 3.8 g/mouse/day compared to mice on the HFD diet of 4.12 g/mouse/day. The findings suggest that dandelion preparations may be an alternative to the use of the drug Orlistat [71]. A study conducted by Majewski and his team detected that the consumption of aqueous dandelion flower syrup (278.2 g/kg diet for four weeks) had beneficial effects on rat blood lipid regulation, which was manifested by increasing HDL fraction, increasing plasma superoxide radical (SOD) scavenging, and decreasing lipid peroxidation. In addition, the liver damage marker ALP content was lowered. The aqueous syrup of dandelion flowers contained hydroxycinnamic acids and flavonoids. Studies have discovered that syrup from *T. officinale* floral water at a dose of 278.2 g/kg of diet affects antioxidant levels and reduces smooth muscle contraction in the blood vessel wall. The authors concluded that phenolic compounds in flower syrup exhibit health-promoting properties. Its antioxidant activity is responsible for these properties [72].

The preparations (extracts, syrups, etc.) obtained from different parts of the dandelion (root, leaves, and flowers) show health-promoting effects. They have the ability to regulate glucose levels and lipid profile, affect digestive enzymes, and indirectly reduce obesity. However, this has been observed mainly in in vitro studies or in animal models. It was stated that there is a need for in-depth studies on this issue with healthy volunteers and people with various cardiovascular diseases, obesity, or type 2 diabetes who would be given dandelion preparations.

6. Reports on the Toxic Effects of Dandelion and its Preparation

Dandelion has been consumed as food and used as herbal medicine for centuries, and the side effects of its consumption are rather rare. Dandelion root and dandelion extracts have "generally recognized as safe" status approved by the FDA for use in dietary supplements. Fresh *Taraxacum officinale* leaves and other parts are consumed as food in many countries.

Many studies on animals have been conducted regarding the potential toxicity of this plant. Toxicological studies have been conducted, and LD_{50} at *per os* administration to mice was determined to be greater than 20 g/kg body weight [73]. In subchronic toxicity studies (4 months), no toxic effect was noted in rats fed with dandelion leaves (33% in the diet) [74]. No acute toxicity was observed in rabbits after the oral administration of dehydrated dandelion plant at a dose of 3–6 g/kg body weight. The LD_{50} (intraperitoneal injection) of the liquid extract of the herb and root for mice was 28.8 g/kg and 36.6 g/kg, respectively. It was only discovered that taraxacum acid esters could cause contact dermatitis [75]. In vitro studies have noted that dandelion infusions can inhibit cytochrome 3A4 (IC50 = 140.6 µg/mL), which may lead to interactions with the metabolism of, for example, immunosuppressive drugs [76]. In studies with rats, it was shown that doses up to 1000 mg/kg b.w. did not cause mortality when administered by the oral route, as did doses of 1600, 2900, and 5000 mg/kg b.w. [64].

Dandelion intake is generally considered safe and well-tolerated in adults if taken in moderation, but some side effects exist, such as diarrhea, upset stomach, or irritated skin. According to Yarnell et al. 2009 [74], it seems that due to its bitter content, dandelion should be consumed with caution by people with diagnosed acute gastroenteritis or reflux esophagitis [74], acute inflammation, or obstruction of the gastrointestinal tract. Allergies to dandelion may also occur. No information on dandelion toxicity or serious adverse effects in humans has been encountered in the scientific literature [77].

7. Final Remarks

Dandelion is an interesting herbal plant that can be successfully used in the food, pharmaceutical, and cosmetic industries. It manifests multidirectional pharmacological activity that is widely documented in the scientific literature. This paper presents the properties of dandelion, which can be successfully used in the treatment and prevention

of metabolic syndrome. A review of available in vivo and in vitro studies indicates that dandelion extracts can prevent diabetic complications, improve lipid metabolism, as well as exhibit inhibitory activity on sugar-degrading enzymes. The aforementioned activity, according to the definition describing metabolic syndrome, is part of the current recommendations for its treatment, the primary aim of which is to prevent the development of diabetes, hypertension, and other cardiovascular diseases. The multidirectional effects of the dandelion and its preparations are presented graphically in Figure 4.

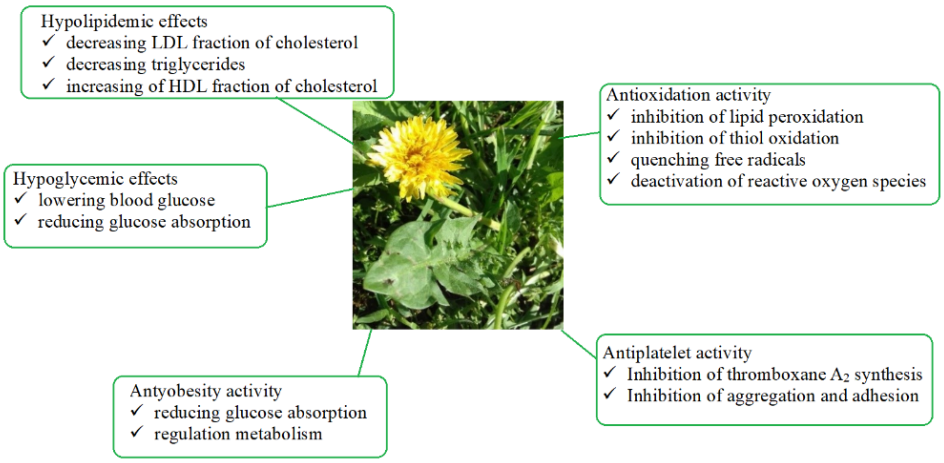


Figure 4. Multidirectional effects of dandelion and its preparations.

Many questions still remain to be clarified. Therefore, new in-depth scientific research on all biological activities of *Taraxacum officinale* in relation to human health is essential for a thorough understanding of the mechanisms of action of the preparations from this plant.

Author Contributions: All of the authors contributed significantly to the research; M.K.-D.—conceptualization and original draft preparation; J.B.—writing, review and editing. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Data Availability Statement: Not applicable.

Acknowledgments: The study was supported by Institute of Natural Fibres and Medicinal Plants National Research Institute (Poland) founds.

Conflicts of Interest: The authors declare no conflict of interest.

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Review

New Perspectives on the Effect of Dandelion, Its Food Products and Other Preparations on the Cardiovascular System and Its Diseases

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Abstract: Cardiovascular diseases (CVDs) have been the leading cause of death for over 20 years. The main causative factors are believed to be high cholesterol, obesity, smoking, diabetes, and a lack of physical activity. One of the most commonly used treatments is a combination of anticoagulant and antithrombotic therapy; however, it often causes unwanted side effects. The European Society of Cardiology, therefore, recommends a prophylactic strategy, including a varied diet rich in fruits, vegetables, and medicinal plants; all of which are sources of natural compounds with antiplatelet, anticoagulant, or antioxidant activities, such as phenolic compounds. One such plant with multidirectional health-promoting effects and a rich source of secondary metabolites, including phenolic compounds, is dandelion (*Taraxacum officinale*). The present mini-review presents the current state of knowledge concerning the effects of dandelion consumption on the cardiovascular system and CVDs based on various in vitro and in vivo trials; it discusses the value of dandelion as a food product, as well as extracts and pure compounds, such as chicoric acid, which can be obtained from the various plant organs. The paper also sheds new light on the mechanisms involved in this activity and describes the cardioprotective potential of dandelion products and preparations.

Keywords: cardiovascular disease; dandelion; food product; safety

Citation: Olas, B. New Perspectives on the Effect of Dandelion, Its Food Products and Other Preparations on the Cardiovascular System and Its Diseases. *Nutrients* **2022**, *14*, 1350. https://doi.org/10.3390/nu14071350

Academic Editor: Sonia de Pascual-Teresa

Received: 16 February 2022
Accepted: 22 March 2022
Published: 24 March 2022

1. Introduction

According to World Health Organization (WHO) reports, cardiovascular diseases (CVDs) have been the leading cause of death globally over the past 20 years. Despite the rapid development of innovative treatments and diagnostic techniques, it is estimated that around 20 million people worldwide are currently dying from CVDs [1]. The most common forms of CVD are atherosclerosis, arterial hypertension, myocardial infarction, stroke, and heart failure, with the main causative factors being high cholesterol, obesity, smoking, diabetes, and lack of physical activity. These symptoms are also typically accompanied by alterations in hemostasis.

Hemostasis is maintained primarily by a complex interaction between blood platelets, the endothelium, and various coagulation and fibrinolysis factors [2,3]. These processes play an important role by regulating the fluidity of circulating blood and by facilitating clot formation following damage to the endothelial wall [4]. However, hemostasis can be modulated by the effect of oxidative stress, resulting in the development of pathological processes that lead to the formation of atherosclerosis in acute coronary syndrome and cerebral ischemic events [5–7].

One of the most common treatment strategies employed for CVDs is based on a combination of anticoagulant and antithrombotic therapy, including such drugs as aspirin, clopidogrel (tienopyrin), rivaroxban warfarin, dabigatran, and apixaban. These drugs act through a range of mechanisms [8,9]; for example, aspirin prevents the production of thromboxane A_2 (TXA_2) by inhibiting the activity of cyclooxygenase in blood platelets, while clopidogrel blocks P2Y12 receptors on blood platelets. Unfortunately, the use of such

medication often causes unwanted side effects in many patients, such as hemorrhagic and ischemic complications [8,10,11].

The European Society of Cardiology recommends the consumption of a varied diet rich in fruits, vegetables, or medicinal plants, which are sources of natural compounds with antiplatelet, anticoagulant, or antioxidant activity. Dandelion (*Taraxacum officinale*) is also a good source of secondary metabolites, such as phenolic compounds. The chemical content of dandelion has been detailed in a recent review, together with its varied antibacterial, anti-inflammatory, cytotoxic, and diuretic properties [12–16]. However, no paper has yet reviewed the prophylactic and therapeutic potential of dandelion and its bioactive components against CVDs, and their effects on the cardiovascular system in general.

To address this gap, the present paper is intended as a mini-review of current literature examining the effects of dandelion on the cardiovascular system and its diseases in various in vitro and in vivo studies; it also describes the properties of its food products and preparations, as well as its extracts, complex fractions, and pure compounds, such as chicoric acid, obtained from the roots, leaves, fruits, and flowers. This paper also sheds new light on the mechanisms involved in their action and describes the cardioprotective potential (including antiplatelet and anticoagulant action) of these products and preparations from different plant organs. This review is based on papers identified in electronic databases: PubMed, Scopus, ScienceDirect, and Web of Knowledge. The last search was run on December 30 2021. The following terms were used: "dandelion;" "Taraxacum officinale;" "dandelion and cardiovascular disease;" "dandelion and hemostasis;" and "dandelion and oxidative stress."

2. General Description of Dandelion and Its Products

The dandelion, Taraxacum officinale, also known as the common denichine or the drinifer, is a percentine of the Asteraceae family, a subfamily of the Cichorioideae. The Latin name of the plant derives from the Greek words taraxic, meaning ignition, and akeomia, i.e., treatment [17]. Although the dandelion is believed to originate in Europe, it is found throughout the entire northern hemisphere, including northern Europe, the temperate zone of North America, as well as Asia [15,17,18]. It can grow from sea level to alpine elevations and tolerates every soil type [12–16].

Dandelion is a rich source of phenolic acids (chicoric acid, chlorogenic acid), flavonoids (luteolin derivatives, quercetin), and terpenes (sesquiterpene lactones). It is also a strong source of vitamins (A, C, E, K, and B) and minerals (calcium, sodium, magnesium, iron, copper, silicon, zinc, manganese) [17,19]. More details about the chemical composition and nutritional value of dandelion plant organs are given by Grauso et al. [14], Lis and Olas [15], and Garcia-Oliveira et al. [16].

Although dandelion is mainly known for its medicinal properties, it has for many years been successfully used worldwide in the food industry as an entirely non-toxic and edible plant; indeed, the U.S. Food and Drug Administration has placed dandelion on the list of safe products for people with rare allergies [20,21]. However, the dose should not exceed 4 g or 12 g per day for the aerial parts of the plant or 1 g or 3 g per day for the root. The roots, leaves, and flowers may be eaten raw or cooked [14].

Due to their high nutrient content, dandelion leaves are often included as a salad ingredient, and the inulin-rich roots are used as substitutes for coffee or tea. In Asian countries, fried dandelion leaves are popular in combination with brown rice. Young leaves can also be prepared in the form of soup. In Turkey, fresh dandelion leaves are used as a spice and added to many dishes, and the ground dried leaves can also be used as a seasoning [22]. Dandelion leaves are also believed to have a positive effect on the cardiovascular system due to their high potassium content (397 mg potassium/100 g) [19,23]; indeed, increased potassium intake with food (about 3500 mg/day for an adult) has been found to lower blood pressure [23].

While both the flowers and roots can be used for winemaking, the two parts require different production processes [24]. In addition, the flowers, leaves, and roots can be

consumed as herbal teas, while the flowers can also be made into syrup. In Canada and the UK, whole dandelions [25] are added to beer, while in Belgium, the flowers can be used as additives to a beer-based drink called saison, known for its strong fruity aftertaste. In addition, flower extracts can be used as flavor additives in a range of foods such as desserts, candies, baked cakes, jellies, and puddings [19]. The flower buds can be added to pancakes and omelets, and in some European countries, they are preserved in vinegar and served similar to capers [25]. Dandelion marmalades and liquors are commonplace in Italy [21]. In Great Britain, dandelion wine, made from petals and sugar and often lemon juice, is also popular as a carbonated drink.

Dandelion extracts can be purchased in capsule form as dietary supplements, especially in North America [15,26,27]. In addition, dandelion is a valuable species for supplying bees with nectar [18].

In addition to its flavor qualities, dandelion is traditionally used in infusions and decoctions as aperitif, tonic, and stimulant; however, studies suggest only a minor effect [17]. It has also been used for many centuries as a remedy for kidney, liver, and gallbladder disorders [27–34]. The beneficial effects of dandelion are dependent on the chemical compounds contained in the plant. These include sesquiterpene lactones, which have been found to have anti-inflammatory and antibacterial effects, as well as triterpenes or phytosterols, which possess anti-atherosclerotic properties. In addition, dandelions have high levels of phenolic compounds, including phenolic acids, with antioxidant properties and coumarins with anticancer, anti-inflammatory, antibacterial, and antithrombotic effects. The roots are also rich in inulin, which has a probiotic, hypoglycemic, and immune-boosting effect [14,15,17,19].

3. The Effect of Dandelion and Its Products on Cardiovascular System

3.1. In Vivo Studies

In vivo studies suggest that dandelion organs, especially the leaves and roots, may play an important role in the prophylaxis and treatment of CVDs [35–44].

3.1.1. Antioxidant and Hypolipidemic Properties

Choi et al. [36] studied the effect of dandelion treatment on antioxidative enzyme and lipid profiles in rabbits consuming a high-cholesterol diet. Briefly, the rabbits were administered 1% dandelion leaf extract, containing 8% phenolic compounds, and 1% dandelion root extract, with 9% phenolic compounds; their cholesterol and total lipid levels were measured after administration. It was found that the dandelion treatment (250 g/day for one month) appeared to have antioxidant properties and resulted in improvements in aortal thickness. However, these results were not consistent with the beneficial effect on blood lipids in the context of a high-fat diet.

Another study by Majewski et al. [37] examined the effect of four-week supplementation with phenolic fractions from dandelion petals and leaves (enriched with L-chicoric acid) on Wistar rats. The rats were fed dandelion leaf or petal fractions daily, with 4.10 ± 0.05 and 1.41 ± 0.07 mg L-chicoric acid, respectively. Both dandelion fractions were found to have antioxidant properties, and the leaf fraction appeared to modify the lipid profile of the rats, resulting in decreased total cholesterol and triglyceride. The authors attribute this positive spectrum of activities to the chicoric acid present in the samples [37].

The oxidative stress plays a key role in the development of hypertension. Aremu et al. [38] observed that 21-day treatment with 500 mg/kg/day dandelion leaf extract (70% ethanol-water (v/v) extract, with 4 GA eq/mg extract total phenolic content) had antioxidant properties, which conferred significant antioxidant protection against hypertension in rats stimulated by free radical production: in this case, oxidative stress was induced by *N* ω-nitro- L-arginine methyl ester. The extract was found to elevate total antioxidant capacity and decrease lipid peroxidation, a marker of oxidative stress, in the heart, liver, kidney, and brain, among others. The authors also suggested that the phenolic compounds present in the tested extract regulate the level and activity of nitric oxide synthase (NOS)

by interacting with kinase signaling pathways and the intracellular Ca^{2+} associated with NOS phosphorylation and NO production. In addition, these phenolic compounds might inhibit endothelin-1 (a vasoconstrictor) and endothelial NADPH oxidase. It was found that doses up to 1000 mg/kg BW did not cause mortality when administrated via the oral route, nor doses of 1600, 2900, and 5000 mg/kg BW.

3.1.2. Anti-Obesity Effect

Dandelion extract (150 and 300 mg/kg, 10 weeks) was found to have anti-obesity effects in mouse and rat models [39,40], manifested as a decrease in body weight among animals consuming a high-fat diet [40]; however, the chemical content of the extract and its total phenolic content were not specified in the study. Similarly, 60% ethanolic dandelion leaf extract, with a total phenolic content of about 123 mg gallic acid equivalent (GA) per g was also found to have anti-obesity properties [41]; treatment was found to improve the lipid profile and aspartate aminotransferase (AST) and alanine aminotransferase (ALT) concentrations in obese mice. The animals received this plant extract at 300 mg/kg body weight (BW)/day for eight weeks. In addition, docking analysis based on the computation of molecular-binding energies suggests that some of the phenolic compounds present in the extract, including kaempferol, luteolin, and myricetin, may inhibit pancreatic lipase activity.

Majewski et al. [42] indicated that consumption of dandelion flower syrup (27.82% for four weeks) did not appear to influence body weight when consumed with a normal-fat diet. However, the tested syrup was found to positively regulate antioxidant status and prostanoid content in an obese rat model. The primary phenolic components of this syrup were flavonoids (about 22 μg luteolin eq/mL) and hydroxycinnamic acids (about 468 μg L-chicoric acid eq/mL) [42].

It was also found that treatment with *T. coreanum* Nakai regulated lipid metabolism via the liver kinase B1–AMP-activated protein kinase signaling pathway, and promoted β-oxidation by a peroxisome proliferator-activated receptor [43]. As such, this plant may have a beneficial effect on obesity. In this experiment, male C57BL mice received 100 or 200 mg/kg of dandelion leaf extract or root extract orally for five weeks.

3.1.3. Other Biological Activities

Modareri et al. [44] studied the effect of a 20-day course of hydro-alcoholic injections of dandelion extract (50–200 mg/kg body weight) on the levels of various blood cells, including blood platelets, in mice. However, no information was given about the plant organ used for the extract or its chemical content.

Although dandelion preparations have been found to demonstrate multifunctional action on the cardiovascular system and CVDs (Table 1 and Figure 1), they have only been observed in animal models. There is a need for more observations on healthy people or people with various CVDs who have been supplemented by dandelion preparations.

Table 1. Effect of dandelion preparations on the cardiovascular system and its diseases (in vivo and in vitro studies).

Dandelion Preparation	Dose	Subject	Effect	Reference
In vivo studies				
Flowers				
Water syrup	27.82% for 4 weeks	Obese rats	Antioxidant effect	[42]
Leaves				
1% extract	250 g/day for 1 month	Rabbits	Antioxidant effect and hypolipidemic properties	[36]
95% ethanol extract	400 mg/kg	Mice	Anti-obesity effect	[39]
Ethanolic extract	150 and 300 mg/kg for 10 weeks	Rats	Anti-obesity effect	[40]
60% ethanolic extract	300 mg/kg body weight (BW)/day for 8 weeks	Obese mouse	Anti-obesity effect	[41]
Phenolic fraction	694 mg/kg of diet for 4 weeks	Wistar rats	Antioxidant effect	[37]
70% ethanol-water (*v*/*v*) extract	500 mg/kg/day for 21 days	Hypertensive rats	Antioxidant effect	[38]
Petals				
Phenolic fraction	694 mg/kg of diet for 4 weeks	Wistar rats	Antioxidant effect	[37]
Roots				
1% extract	250 g/day for 1 month	Rabbits	Antioxidant effect and hypolipidemic properties	[36]
In vitro studies				
Fruits				
Flavonoid preparations: extracts and fractions	10 and 50 μg/mL	Human plasma and blood platelets	Antioxidant and antiplatelet effects	[45]
Leaves				
Phenolic fraction	1–50 μg/mL	Human plasma and blood platelets	Antioxidant and anticoagulant effects	[46,47]
Petals				
Phenolic fraction	1–50 μg/mL	Human plasma and blood platelets	Antioxidant and anticoagulant effects	[46–48]
Roots				
Preparations	0.5–50 μg/mL	Human plasma and blood platelets	Antioxidant, antiplatelet, and anticoagulant effects	[47–49]

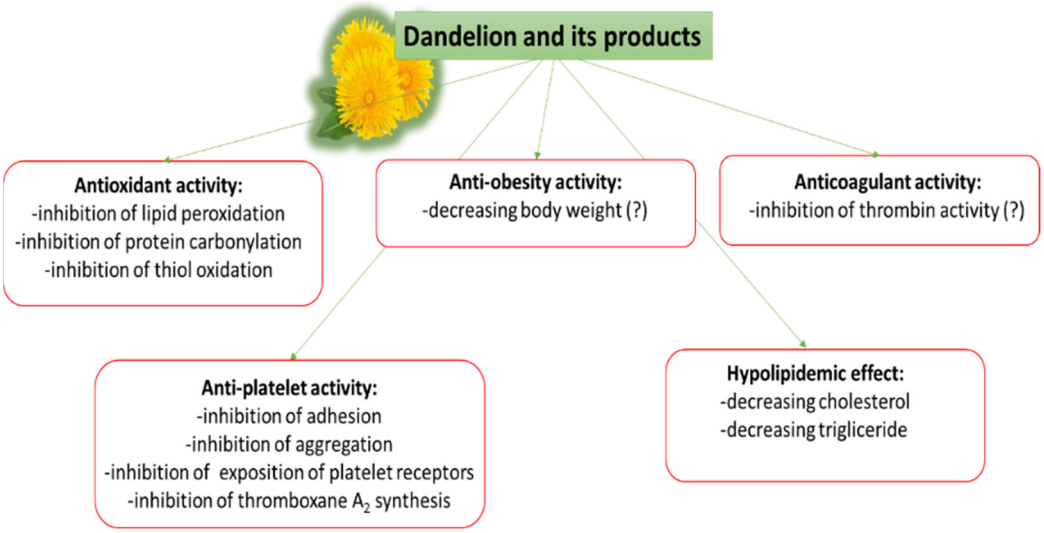

Figure 1. Multifunctional action of dandelion and its products on CVDs.

3.2. In Vitro Study

Some papers indicate that preparations obtained from dandelion organs may have an effect on hemostasis, including blood platelet activation and coagulation processes in in vitro studies [45–50]. For example, an analysis of the effects on coagulation activity of human plasma found that 85% dandelion leaf fraction and 50% and 85% dandelion petal fractions significantly increased thrombin time in the range of 0.5–50 µg/mL. In addition, these fractions significantly increased plasma thrombin time when pre-incubated with thrombin at the highest concentration (50 µg/mL) [47,49]. In contrast, no anticoagulant effect was reported for dandelion fruit preparations incubated with human plasma in in vitro studies [45].

Lis et al. [45] studied the effects of three extracts from dandelion fruits on blood platelet activation; a methanolic extract of dandelion fruits (E1) and two extracts enriched with polyphenols (188 mg gallic acid equivalents/g); one with cinnamic acids (extract E2; 448 mg GA eq/g) and another with flavonoids (extract E3; 377 mg GA eq/g). The study also examined the activity of an additional four fractions isolated from extract E3: fraction A (luteolin fraction; 880 mg GA eq/g), fraction B (philonotisflavone fraction; 516 mg GA eq/g), fraction C (flavonolignan fraction; 384 mg GA eq/g), and fraction D (flavone aglycone fraction; 632 mg GA eq/g). The authors noted that extracts E2 and E3 and fractions A, B, and C significantly inhibited ADP-activated platelet adhesion to fibrinogen, while flavonoid fractions A to C inhibited thrombin-activated platelet adhesion at both tested doses (10 and 50 µg/mL). Other findings suggest that this inhibition may be related to low GPIIb/IIIa receptor exposition. In addition, extract E3 and the four fractions (A–D; 50 µg/mL) significantly inhibited the arachidonate metabolism in thrombin-activated platelets, with the luteolin-rich fraction A (10 and 50 µg/mL) inhibiting this process by approximately 60%. Similarly, the flavonoids present in dandelion fruits may also affect blood platelet activation by influencing the arachidonic acid metabolism [45]. Extracts E2, E3, and fraction A (50 µg/mL) were found to demonstrate anticoagulant potential against whole blood; however, this may be conditioned by the presence of caffeic acid derivatives (mainly chicoric acid), flavonoid derivatives, and luteolin. The effect of different dandelion preparations on blood clot formation was measured in a real-time hydrodynamic blood flow model using Total Thrombus-formation Analysis System (T-TAS); platelet thrombus formation was visualized on a collagen-coated chip.

Other studies have examined the effect of chicoric acid, the main component of the dandelion leaf and petal fractions, on blood platelet activation [48]. At two tested concentrations (10 and 50 µg/mL), chicoric acid inhibited thrombin-stimulated platelet adhesion to collagen by approximately 20%, and inhibited arachidonic acid metabolism. It was also

found that the tested fractions from dandelion leaves and petals reduced the adhesion of resting platelets and thrombin-stimulated platelets to collagen. Moreover, chicoric acid (50 μg/mL) inhibited the adhesion of thrombin-activated platelets to fibrinogen by about 20%, and ADP-activated platelets by about 40%.

In addition, the dandelion leaf and petal fractions also demonstrated anti-adhesive and anti-aggregatory effects [48] with the leaf fraction demonstrating stronger antiplatelet activity than chicoric acid alone, which may be due to the synergetic effect of the phenolic compounds within the fraction. In addition, the leaf fraction contains various phenolic acid and flavonoid derivatives, including luteolin, which may have a stronger effect than the single compound alone [48]. Elsewhere, treatment with dandelion leaf fraction was found to reduce P-selectin exposition and the presence of active GPIIb/IIIa on collagen-stimulated platelets and inhibit thrombus formation in human whole blood [50]. These parameters were measured by T-TAS and flow cytometry.

Lis et al. [51] studied the effect of dandelion root extract and its various ingredients on the biological functions of human blood platelets. The experiment used five fractions (A–E) differing in chemical composition: fractions A and B contained 95% and 86% sesquiterpene lactones, fraction C contained mainly hydroxyphenylacetic acid derivatives (about 80% of all compounds), and the dominant constituents of fractions D and E were hydroxycinnamic acids. All tested dandelion root fractions (A–E) significantly inhibited the adhesion of resting blood platelets to collagen. Fraction C (50 μg/mL) and fractions D and E (10 and 50 μg/mL) demonstrated the strongest inhibition of thrombin-stimulated platelet adhesion to collagen, while fraction D (10 and 50 μg/mL) and fractions B, C, and E (50 μg/mL) significantly inhibited thrombin-induced platelet adhesion to fibrinogen. The greatest inhibitory effect on ADP-stimulated platelet adhesion to fibrinogen was observed for fraction E (10 and 50 μg/mL).

Lis et al. [51] reported that fractions A, B, and C from dandelion roots (50 μg/mL) inhibited ADP-stimulated (10 μM) blood platelet aggregation, a risk factor for CVDs, by approximately 20% compared to controls. However, none of the tested root fractions significantly influenced platelet aggregation stimulated by 2 μg/mL collagen [51], nor 1 U/mL thrombin [49].

These results may suggest that the tested dandelion root preparations may exert their anti-aggregation activity by interacting with ADP receptors on the blood platelet membrane [51]. However, the fractions did not influence the exposition of active GPIIb/IIIa on ADP-activated (10 and 20 μM) blood platelets in whole blood [50]. Furthermore, none of these fractions appeared to affect the Platelet Reactivity Index (PRI) [50], a parameter known to correspond with vasodilator-stimulated phosphoprotein (VASP) phosphorylation level.

Lis et al. [51] also found that dandelion root fractions A–E (10 and 50 μg/mL) did not appear to have any significant effect on arachidonic acid metabolism, resulting in the formation of thromboxane A_2. However, the authors noted that the best antiplatelet activity was demonstrated by fraction C, characterized by high levels of hydroxyphenylacetic derivatives of inositol and chlorogenic acids. In addition, as the other phenolic components, including the hydroxycinnamic acid derivatives in fractions D and E, were not found to display such high activity, the authors suggested that sugar alcohol (inositol) may be responsible for the observed antiplatelet properties [51]. Moreover, fractions D and E demonstrated a stronger anticoagulant effect than other fractions (A, B, and C) [49]; it was hypothesized that the anticoagulant properties of these fractions, as well as the underlying mechanism, were associated with the modulation of thrombin activity.

It is important to note that none of the tested dandelion extracts or fractions, nor the chicoric acid isolated from various dandelion organs (0.5 to 50 μg/mL) caused blood platelet lysis, i.e., lactate dehydrogenase leakage, into the extracellular environment [45,47–49,51].

The antioxidant performance of various dandelion preparations was assayed based on lipid peroxidation level, defined as thiobarbituric acid reacting substances (TBARS), and protein oxidation level, based on thiol and carbonyl group level, using plasma and blood

platelets: two important elements of hemostasis. Some results have shown that dandelion leaf, petal, and fruit preparations have antioxidative potential [45,47]. For example, lipid peroxidation in human blood platelets treated with H_2O_2/Fe^{2+} was inhibited by exposure to a 50% dandelion leaf fraction and a 50% dandelion petal fraction (both 50 μg/mL) [47]; in addition, after 30 min of incubation with a 50% leaf fraction (1 and 50 μg/mL), the platelet proteins demonstrated elevated thiol group numbers compared to controls. However, the tested fractions did not demonstrate significant changes in protein carbonylation in blood platelets [47]. Jedrejek et al. [46] indicated that phenolic fractions from petals have better antioxidant activity than those from leaves in human plasma; they propose that this may be due to the fact that the petals are better sources of flavonoids than the leaves.

Lis et al. [45] reported that three of the tested extracts (E1–E3) and two of the luteolin-rich fractions of dandelion fruits (fraction A) and flavone aglycones (fraction D) inhibited H_2O_2/Fe^{2+}-stimulated lipid peroxidation in human plasma when administered at 50 μg/mL; however, no such antioxidant effects were observed for dandelion fruit preparations containing philonotisflavones (fraction B) or flavonolignans (fraction C). In addition, extracts E2 and E3 and fractions B, C, and D inhibited the oxidation of plasma thiol groups following H_2O_2/Fe^{2+} treatment. All the tested dandelion fruit preparations (50 μg/mL) inhibited the carbonylation of proteins in human plasma treated with H_2O_2/Fe^{2+} [45].

Chicoric acid, the main component of dandelion fruit extracts and dandelion leaf and petal fractions, was also found to demonstrate antioxidant activity in human plasma and human blood platelets [48].

In addition, dandelion root fractions A–E were found to reduce the level of human plasma lipid peroxidation caused by H_2O_2/Fe^{2+}, which generated hydroxyl radicals. This molecule has an unpaired electron in its outer orbit, and hence is a highly-reactive particle that can irreversibly damage biomolecules by forming chemical bonds with them. While all fractions (A–E) were found to demonstrate antioxidant effects at 5 μg/mL, both the C fraction (rich in hydroxyphenylacetic derivatives of inositol and chlorogenic acids) and the E fractions (rich in hydroxycinnamic tartaric acid derivatives) were also active at lower concentrations (1 μg/mL). In contrast, while the strongest effect of all tested fractions was reported at a concentration of 50 μg/mL, the best results were obtained for fractions C and for fractions A and E, these being a reduction of more than 30% compared to the positive control plasma treated with H_2O_2/Fe^{2+} alone [49].

Jedrejek et al. [49] also noted that all test fractions from dandelion roots (A–E) had a protective effect on thiol groups in human plasma proteins under oxidative stress; however, the best activity at concentrations of 0.5–50 μg/mL was demonstrated by fraction A, which was rich in amino acid derivatives of sesquiterpene lactones. In contrast, fraction B (containing sesquiterpene lactones and hydroxyphenylacetic inositol derivatives) displayed a protective effect at concentrations of 10 and 50 μg/mL, and fraction D (containing chlorogenic acid) at doses of 0.5, 1, 10, and 50 μg/mL. While all tested dandelion root fractions inhibited H_2O_2/Fe^{2+}-induced plasma protein carbonylation, this change was not always statistically significant [49].

Dandelion root fractions A–E also significantly inhibited H_2O_2/Fe^{2+}-induced lipid peroxidation in human blood platelets. More precisely, 70% inhibition was observed for all five fractions (A–E) at a concentration of 50 μg/mL; however, only A and E demonstrated a protective effect on protein thiol groups at the lowest test concentration (10 μg/mL). Fraction C inhibited protein carbonylation at two tested concentrations (10 and 50 μg/mL), while fraction A was only active at the highest dose (50 μg/mL) and fraction D at the lower concentration (10 μg/mL) [51]. In addition, only fraction A (10 μg/mL) had a significant effect on reducing the level of superoxide anion ($O_2^{\bullet -}$) in resting blood platelets [51].

Kontgiorgis et al. [52] studied the optimum preparation conditions of *T. officinale* beverage with respect to its antioxidant properties. They used dried, commercial dandelion and prepared beverages boiling for 1, 3, and 5 min. Samples prepared under 3 min boiling had the best antioxidant activity, for example, they inhibited lipid peroxidation of linoleic acid.

4. Conclusions

Conventional antiplatelet or anticoagulant drug therapy is often associated with side effects, and in such cases, the use of natural compounds may be a safer alternative. Recent studies have evaluated the potential of various plants to modulate hemostasis with the aim of using them as potential candidates for the prophylaxis and treatment of CVDs. The present study gathers a number of in vitro and in vivo studies that examine the effect of dandelion and its products on various elements of hemostasis, including blood platelets. Studies have found that the active components of dandelions are able to modulate hemostatic processes, including the signal pathways associated with blood platelets, in varied and sometimes opposing ways. Some of the hemostatic mechanisms exerted by dandelion and its products, and their effects on CVDs, are given in Figures 1 and 2. Three key routes by which dandelions and their products may act are: (1) the inhibition of reactive oxygen species (ROS) production; (2) inhibition of the arachidonic acid metabolism; (3) reduction in the exposition of receptors on the platelet surface.

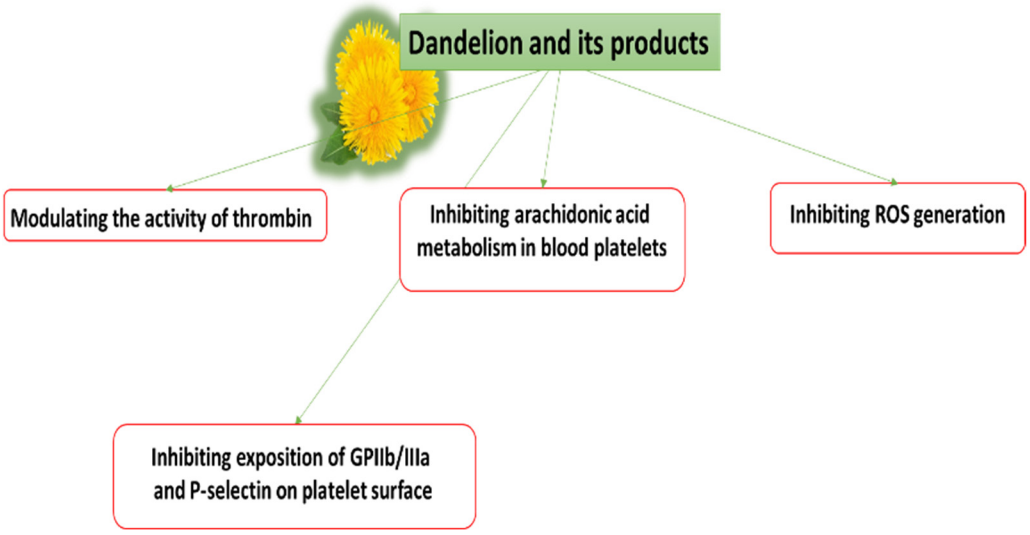

Figure 2. Proposed mechanisms of action of dandelion and its products on hemostasis.

Although the effects of dandelion and its products on hemostasis have been evaluated in different in vitro and in vivo studies (Table 1), the evidence base is insufficient to unequivocally confirm whether dandelion and its products have beneficial effects on hemostasis and CVDs, especially in humans. In addition, their effects on human hemostasis have only been evaluated in vitro, and the precise prophylactic and treatment doses are currently unknown. Both the immediate ingested context and the broader dietary context affect the potential of constituents of a food, beverage, capsule, or tablet to be digested, absorbed, and metabolized; the effect of the whole may differ substantially from the sum of the effects of the individual constituents of dandelion and its products. Therefore, more randomized clinical trials with larger groups are needed, especially including both healthy people and those with risk factors for CVD, including obesity, high cholesterol, smoking, diabetes, and a sedentary lifestyle.

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Not applicable.

Conflicts of Interest: The author declares no conflict of interest.

Abbreviations

AST	aspartate aminotransferase
ALT	alanine aminotransferase
CVDs	cardiovascular diseases
GA	gallic acid
NO	nitric oxide
NOS	nitric oxide synthase
O_2	superoxide anion
OH	hydroxyl radical
PRI	Platelet Reactivity Index
T-TAS	Total Thrombus-formation Analysis System
TXA_2	thromboxane A_2
WHO	World Health Organization
VASP	vasodilator-stimulated phosphoprotein

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