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Review

Taraxacum—A review on its phytochemical and pharmacological profile

Katrin Schütz, Reinhold Carle, Andreas Schieber *

Institute of Food Technology, Section Plant Foodstuff Technology, Hohenheim University, August-von-Hartmann-Strasse 3, D-70599 Stuttgart, Germany

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Abstract

The genus *Taraxacum* is a member of the family Asteraceae, subfamily Cichorioideae, tribe Lactuceae and widely distributed in the warmer temperate zones of the Northern Hemisphere. The perennial weed has been known since ancient times for its curative properties and has been utilized for the treatment of various ailments such as dyspepsia, heartburn, spleen and liver complaints, hepatitis and anorexia. However, its use has mainly been based on empirical findings. This contribution provides a comprehensive review of the pharmacologically relevant compounds of *Taraxacum* characterized so far and of the studies supporting its use as a medicinal plant. Particular attention has been given to diuretic, choleretic, anti-inflammatory, anti-oxidative, anti-carcinogenic, analgesic, anti-hyperglycemic, anti-coagulatory and prebiotic effects. Finally, research needs such as quantification of individual *Taraxacum* constituents and assessment of their pharmacological activities in humans have briefly been outlined.

Keywords: *Taraxacum*; Dandelion; Botany; Pharmacological profile; Phytochemistry

Contents

* Corresponding author. Tel.: +49 711 459 3125; fax: +49 711 459 4110.
E-mail address: schieber@uni-hohenheim.de (A. Schieber).

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1. Introduction

Plants of the genus *Taraxacum* have long been used as medicinal herbs. A first reference to its application is reflected in its name, which is derived from the Greek words "taraxis" for inflammation and "akeomai" for curative. In English speaking countries, dandelion, from the French word "dent-de-lion", referring to the serrated leaves of the plant, is its common name. In French alluding to its diuretic action, the term "pissenlit" (bedwetter) is commonly used.

The first evidence for its therapeutic use was mentioned by Arabian physicians of the 10th and 11th centuries to treat liver and spleen ailments (Kroeber, 1950; Faber, 1958; Sweeney et al., 2005). Since the 16th century, Germany has provided the most extensive records of the application of *Taraxacum* in the western world. The German physician and botanist Leonhard Fuchs (1543) described its use, among others, to medicate gout, diarrhea, blister, spleen and liver complaints. Especially the utilization of dandelion in liver complaints was largely based on the Doctrine of Signatures. Accordingly, yellow flowers are associated with yellow bile ailment (Kroeber, 1950; Faber, 1958). In North American aboriginal medicine, infusions and decoctions of the root and herb were applied to remedy kidney disease, dyspepsia and heartburn (Sweeney et al., 2005). Furthermore, the drug is considered to be a "blood purifier" and is employed as a mild laxative, for treating arthritic and rheumatic complaints as well as eczema and other skin conditions in popular medicine (Bisset et al., 1994). In Germany, aqueous decoction or juice of fresh plant is taken for a spring cure (Weiss and Fintelmann, 2000). Decoction of the whole plant is traditionally used in Mexico to control Diabetes mellitus (Hernandez-Galicia et al., 2002). In Turkish popular medicine, the herb is applied as a laxative, diuretic and potent anti-diabetic medicine (Önal et al., 2005; Ertaş et al., 2005). The Traditional Chinese Medicine knows dandelion, sometimes in combination with other herbs, to treat hepatitis, to enhance immune response to upper respiratory tract infections, bronchitis or pneumonia, and as a compress for its anti-mastopathy activity (Leu et al., 2005; Sweeney et al., 2005).

Apart from being used as a pharmaceutical, dandelion inflorescences, leaves and roots are processed into different food products. Young leaves of cultivated or wild species are consumed fresh as salad, whereas roots are roasted and utilized as a coffee substituted. Additionally, extracts are used as flavor components in various food products, including alcoholic beverages and soft drinks, frozen dairy desserts, candy, baked goods, gelatins and puddings and cheese (Rivera-Núñez, 1991; Leung and Foster, 1996).

Modern herbal monographs on *Taraxacum* have evaluated its empiric use with a positive outcome. According to the British Herbal Medicine Association (1990), the root is useful as a hepatic stimulant, whereas for the leaves a diuretic and choleretic action is described. Therapeutic indications listed in the German Commission E and European Scientific Cooperative for Phytotherapy (ESCOP, 2003) monographs are restoration of the hepatic and biliary function, dyspepsia, loss of appetite and as a supportive measure to treatments where enhanced urinary secretion is desirable, e.g. rheumatism and the prevention of renal gravel (Blumenthal et al., 1998).

Although dandelion is a well-known traditional herbal remedy with a long history, until recently only limited scientific information is available to justify the reputed uses. In fact, medicinal plant therapy is mainly based on the empirical findings during hundreds and thousands of years (Gurib-Fakim, 2006). In the case of dandelion, no data of human or clinical studies are available so far, contrary to artichoke, another well-investigated medicinally used plant of the family Compositae. Moreover, results are sometimes contradictory, and further inaccuracies are the consequence of insufficient description which plant or part of the plant was used and how the extract was obtained.

However, based on the first promising scientific results from the beginning of the last century, more detailed pharmacological investigations of *Taraxacum* have become an issue of increasing interest in the past years. Therefore, in the following an overview of the growing body of literature covering the botany and the occurrence of pharmacologically relevant compounds in dandelion as well as of the studies supporting its use as medicinal plant will be given.

2. Botany and cultivation

The genus *Taraxacum* is a member of the family Asteraceae, subfamily Cichorioideae, tribe Lactuceae and is found widely distributed in the warmer temperate zones of the Northern Hemisphere, inhabiting fields, roadsides and ruderal sites. According to Hegi (1987), the genus *Taraxacum* WIGG. includes approximately 30–57 varieties with many microspecies, divided into nine sections. In Europe, plants of the species *Taraxacum officinale* WEBER ex WIGG. belonging to the section Borealia are used for medicinal purposes, whereas plants of the species *Taraxacum platycarpum* DAHLST are utilized in Traditional Chinese Medicine (Hiermann, 1992; Leung and Foster, 1996; Ho et al., 1998).

Dandelion is a perennial weed producing a stout taproot, which reaches an average length of 15–30 cm. However, roots 60–100 cm in length are also found. The roots are capable of producing new plants even when the plant is cut at or below the soil surface. The large, light to dark green leaves (5–40 cm long) are clustered in a rosette at the base of the plant and are deeply serrated. The flowering stalks are upstanding, 5–40 cm long and carrying a solitary, terminal inflorescence. On average, each plant is developing 5–10 flowers. The florescence ranges from 7 to 15 mm in diameter and is composed of 140–400 yellow, ligulate florets (Kirchner, 1955; Faber, 1958). The fruits are conical achenes, brown and crowned by a white, hairy pappus, which allows the seeds to be distributed by wind (Hiermann, 1992; Hock, 1994). The drug originates either from wild sources or from cultivated plants. For cultivation, the plants are sowed from April or June in drills, or young dandelion plantlets cultivated under glass are bedded out into manured soil using special machines (Hock, 1994). The main suppliers are Bulgaria, former Yugoslavia, Romania, Hungary and Poland (Bisset et al., 1994).

3. Pharmacologically relevant dandelion constituents

Medicinal plants typically contain several different chemical compounds that may act individually, additively or in synergy to improve health (Gurib-Fakim, 2006). Bitter substances are known for their stimulation of the digestion, while phenolic compounds are accounted for the anti-inflammatory and anti-oxidative activity of plant extracts. Therefore, focus was set on the elucidation of such pharmacologically important compounds in dandelion plants in the past decades.

3.1. Constituents of dandelion roots

The therapeutic actions of *Taraxacum* species have partially been ascribed to their bitter principles, more precisely to some sesquiterpenes typical of members of the Compositae. In extracts of *Taraxacum officinale* WEBER roots, a number of such sesquiterpenes including the eudesmanolides tetrahydroridentin B and taraxacolide-*O*-β-glucopyranoside (Hänsel et al., 1980), the guaianolides 11β,13-dihydrolactucin and ixerin D (Kisiel and Barszcz, 2000), and three germacranolide esters, taraxinic acid β-glucopyranoside, its 11,13-dihydro-derivative and ainslioside were identified (Fig. 1) (Hänsel et al., 1980; Kisiel and Barszcz, 2000). Furthermore, the two germacranolide and guaianolide glycosides sonchuside and vernoflexuoside were isolated from roots of *Taraxacum bicorne* DAHLST and *Taraxacum hondoens* NAK. et KOIDZ. (Michalska and Kisiel, 2001; Kisiel and Michalska, 2005). Two further eudesmanolides glucosylated at the C-1 position, 2β-D-hydroxysantamarine-1-β-D-glucopyranoside and 3β-hydroxy-4α*H*-3-dihydrosantamarine-β-D-glucopyranoside were found in methanolic extracts of subaerial parts of *Taraxacum linearisquameum* SOEST (Zidorn

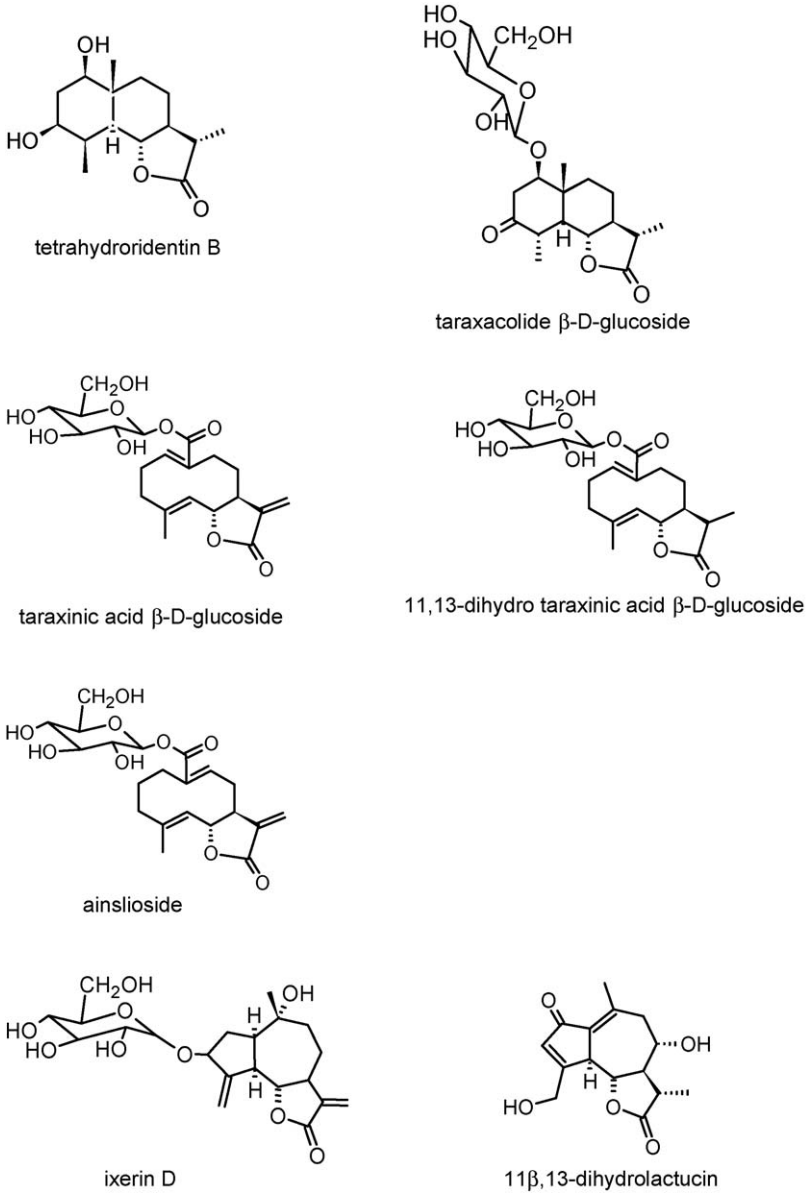

Fig. 1. Chemical structures of characteristic *Taraxacum* sesquiterpene lactones.

et al., 1999). In recent studies, the sesquiterpene lactones deacetylmatricarin and structurally related 2-oxo-guaianolides unusual for this taxon were described in *Taraxacum platycarpum* DAHLST (Ho et al., 1998), *Taraxacum obovatum* (WILLD.) DC (Michalska and Kisiel, 2003), *Taraxacum hondoense* (Kisiel and Michalska, 2005) and *Taraxacum bessarabicum* (Kisiel and Michalska, 2006). Compounds of this type are particularly characteristic of plants like *Chamomilla recutita* (L.) RAUSCHERT (chamomile) and *Achillea millefolium* L. (yarrow) belonging to the tribe Anthemideae of the Asteraceae. Furthermore, matricarin-type guaianolides produced by these varieties may be used individually or in combination for authentication of *Taraxacum* species (Kisiel and Michalska, 2006). In addition to these sesquiterpenes, the isolation of taraxacoside, an acylated γ-butyrolactone glycoside, from roots of *Taraxacum officinale* was reported (Rauwald and Huang, 1985). Other constituents isolated from dandelion roots (*Taraxacum officinale*) include various triterpenes and phytosterols such as taraxasterol, ψ-taraxasterol, their acetates and their 16-hydroxy derivatives arnidol and faradiol, α- and β-amyrin, β-sitosterol, β-sitosterol-β-D-glucopyranoside and stigmasterol (Fig. 2) (Burrows and Simpson, 1938; Hänsel et al., 1980; Akashi et al., 1994).

Furthermore, the presence of several phenolic compounds, e.g. chicoric acid and its isomer, monocaffeoyltartaric, 4-caffeoylquinic, chlorogenic, caffeic, *p*-coumaric, ferulic, *p*-hydroxybenzoic, protocatechuic, vanillic, syringic and *p*-hydroxyphenylacetic acids as well as three coumarins, umbelliferone, esculetin and scopoletin in dandelion roots was demonstrated (Fig. 3) (Clifford et al., 1987; Wolbis et al., 1993; Williams et al., 1996). In roots of *Taraxacum formosanum*, distributed mainly in the littoral areas of north Taichung in Taiwan, two further novel compounds, taraxafolide and (+)-taraxafolide-B, were recently isolated and characterized by spectral analysis (Leu et al., 2005).

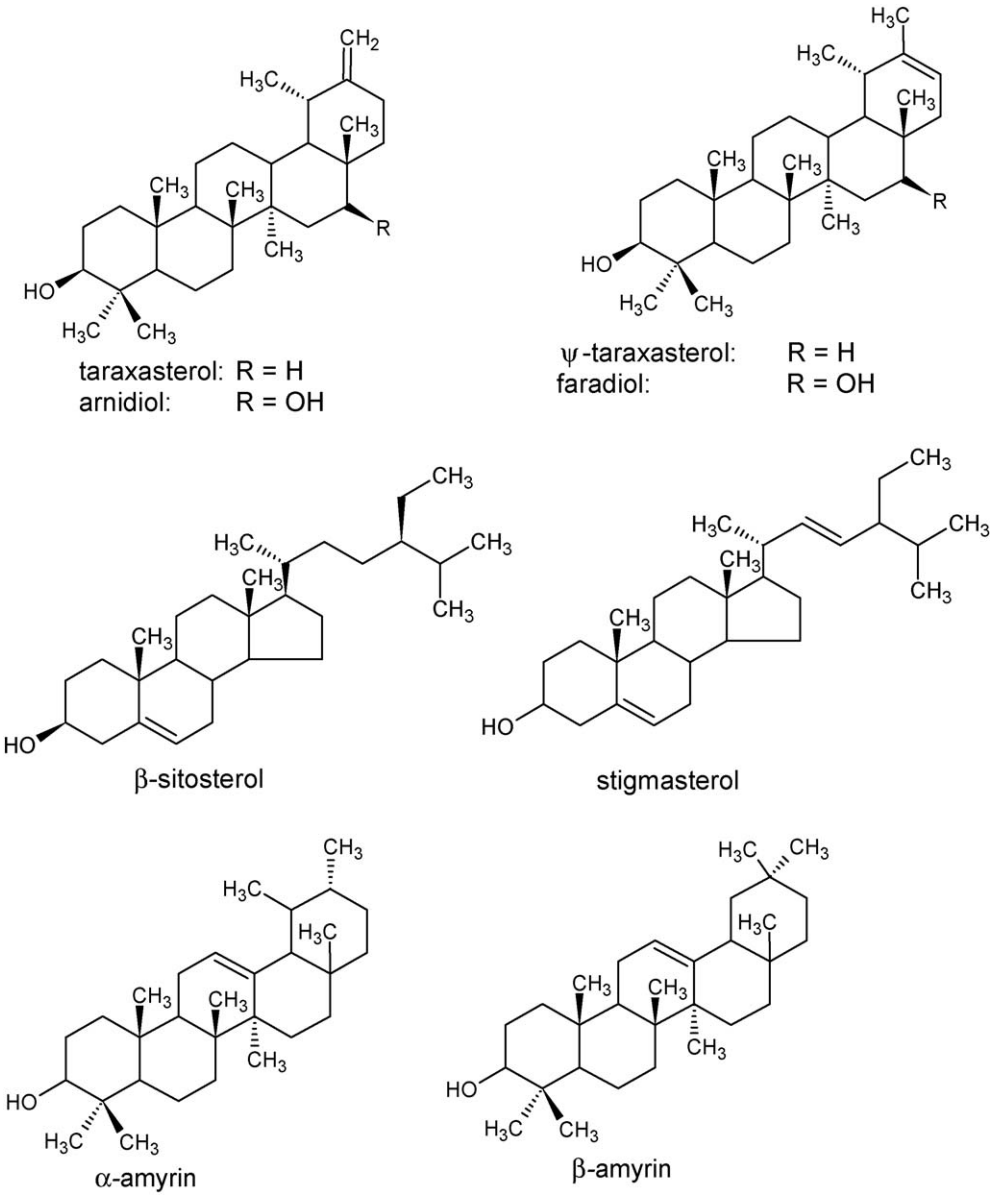

Fig. 2. Chemical structures of some typical triterpenes and phytosterols from *Taraxacum*.

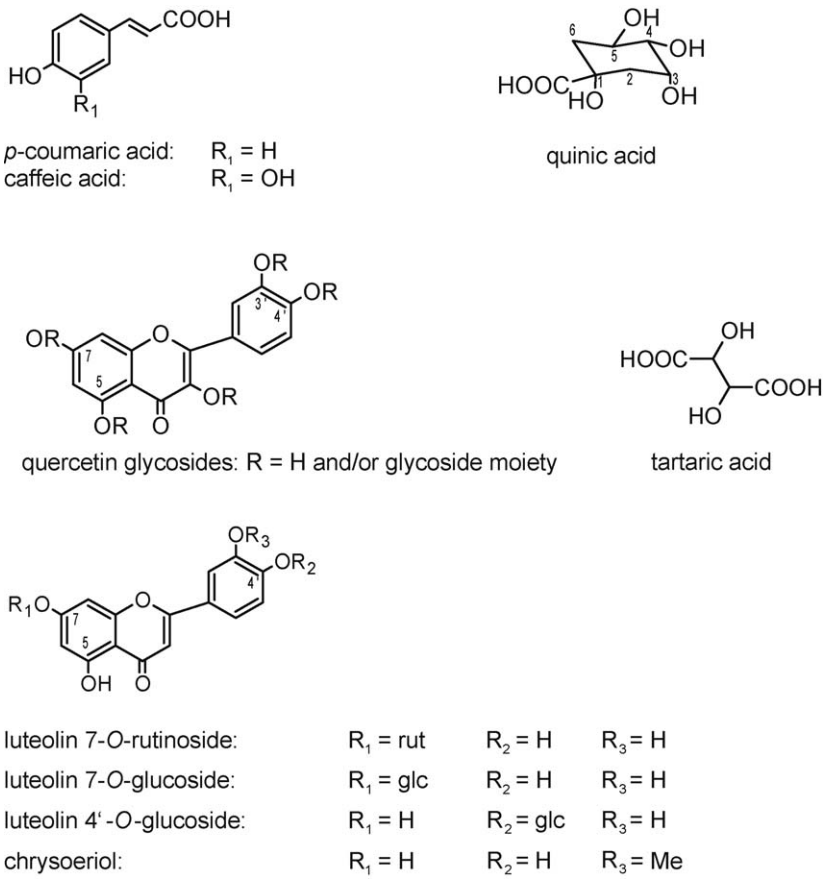

Fig. 3. General structures and substitution patterns of phenolic acids and flavonoids detected in dandelion.

Apart from the secondary metabolites mentioned above, the roots of dandelion are a rich source of inulin, the characteristic storage carbohydrate of the Compositae. Inulin biosynthesis is catalyzed by two enzymes. The first enzyme, Suc:Suc 1-fructosyl transferase (1-SST), produces the trisaccharide kestose and glucose, whereas the second, fructan:fructan 1-fructosyl transferase (1-FFT), elongates the fructose chain by catalyzing the transfer of a fructose residue from one fructan molecule to another. Since the activity of 1-SST considerably varies during the growing season and the 1-FFT activity is rather constant, variations in the inulin profile are detectable. Usually, the activity of 1-SST is very high in young roots, accompanied by low sucrose and high glucose contents. As a consequence, low molecular fructans are predominant. Throughout the growing season, the activity steadily decreases, becoming very low during winter. Simultaneously, the concentration of higher polymerized fructan and sucrose increases, while glucose levels drop (Van den Ende et al., 2000; Wilson et al., 2001). Inulin contents of roots range from 2% in spring to 40% in autumn (Bisset et al., 1994). The fructans represent a polydisperse mixture of oligomers and polymers, where the fructose units are linked by β-2,1 bonds. A glucose molecule normally resides at the end of each fructose chain and is linked by an α-1,2 bond as in sucrose. Additionally, fructan chains without a glucose residue were detected in smaller amounts (Fig. 4) (Ernst et al., 1996).

3.2. Constituents of aerial parts

As in roots, the bitter taste of dandelion leaves has been ascribed to the two sesquiterpenes taraxinic acid β-D-glucopyranoside and 11,13-dihydrotaraxinic-acid β-D-glucopyranoside as well as *p*-hydroxyphenylacetic acid and β-sitosterol (Kuusi et al., 1985). Compared to roots, dandelion leaves are characterized by higher polyphenol contents. Thus, in tea made from leaves 16 mg/g were found, whereas only 1.2 mg/g total

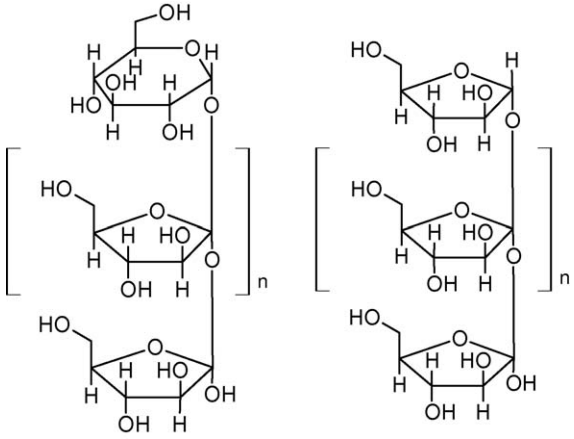

Fig. 4. General structures of fructans from *Taraxacum*.

cinnamic acids were determined in teas obtained from the roots (Williams et al., 1996). The most abundant phenolic compounds in leaves and flowers are hydroxycinnamic acid derivatives, in particular caffeic acid esters such as chlorogenic, dicaffeoyltartaric (chicoric acid) and monocaffeoyltartaric acids (Williams et al., 1996; Budzianowski, 1997). Various flavonoid glycosides such as luteolin 7-*O*-glucoside, luteolin 7-*O*-rutinoside, isorhamnetin 3-*O*-glucoside, quercetin 7-*O*-glucoside and apigenin 7-*O*-glucoside were identified in dandelion leaves and in a combined leaf and flower extract (Wolbis and Krolikowska, 1985; Wolbis et al., 1993; Williams et al., 1996; Kristó et al., 2002). In a very recent study, the occurrence of numerous di- and triglycosylated flavonoids in a dandelion root and herb extract was described (Fig. 3) (Schütz et al., 2005). Furthermore, the coumarins cichoriin and aesculin were identified in a leaf extract (Williams et al., 1996; Budzianowski, 1997). Five β-carboline alkaloids, taraxacine-A and taraxacine-B among them, as well as the phenyl-propanoid taraxafolin, were isolated from the aerial parts of *Taraxacum formosanum* and characterized by spectral analysis (Leu et al., 2003). In addition, the high content of potassium in leaves (4.89% dry matter) and stem (7.73% dry matter) is remarkable (Hook et al., 1993; Wilman and Riley, 1993; Wilman and Derrick, 1994).

4. Pharmacological profile

Throughout the ages, several health-promoting benefits, including diuretic, laxative, cholagogue, anti-rheumatic, anti-inflammatory, choleretic, anti-carcinogenic and hypoglycemic activities, have been attributed to the use of dandelion extracts or the plant itself. In the following, the scientific investigations supporting the pharmacological properties ascribed to *Taraxacum* are reviewed.

4.1. Diuretic activity

An aqueous extract of dandelion roots (*Taraxaci radix*) or dandelion herb (*Taraxaci folium*) was administered through a gastric tube to male rats at a dose of 50 mL/kg body weight. The results showed that the diuretic action of extracts obtained from dandelion herb was consistently stronger than that from the root extracts, reaching the highest diuretic and saluretic indices corresponding to 8 g dried herb/kg body weight. Comparable diuretic and saluretic indices were reached with furosemide at 80 mg/kg body weight. After daily administration of the fluid extract, rats and mice exhibited a weight loss of ca. 30% parallel with the diuresis. Furthermore, the high potassium content of the leaf compensated for the potassium eliminated in the urine. Thus, *Taraxacum* is devoid of furosemide side effects due to potassium loss such as hepatic coma and circulatory collapse (Rácz-Kotilla et al., 1974). Purified fractions isolated from dandelion roots collected in autumn were examined using saline-loaded mice. A petrol ether fraction and two methanol fractions in concentration of 50 mL/kg body weight slightly increased the final urine volume (Hook et al., 1993). In contrast, Tita et al. (1993) could not confirm a diuretic or natriuretic activity following per os or intraperitoneal application of an ethanolic extract of *Taraxacum officinale* during 2 h of observation using the method described by Lipschitz et al. (1944). In a study on the prevention of stone kidney formation no significant differences were found in diuresis in female Wistar rats receiving an aqueous dandelion (*Taraxacum officinale*) root extract compared to the control group (Grases et al., 1994).

4.2. Choleretic activity

As for the diuretic and saluretic activity, the only reports on investigations into the choleretic efficacy available in the literature date back to the 1930s and late 1950s. Büssemaker (1936) reported an approximately 40% increase in bile secretion after intraduodenal application of an alcoholic extract of the whole plant to rats. Böhm (1959) also demonstrated a distinct increase in bile production in rats after intraduodenal administration of an alcoholic *Taraxacum officinale* leaf extract. In contrast, an aqueous leaf extract was ineffective in the same test model. Pirtkien et al. (1960) achieved a 12% increase in choleretic activity in Wistar rats using a dandelion extract, which however, was not characterized further.

4.3. Anti-inflammatory activity

Tita et al. (1993) observed a partial inhibition of rat paw oedema induced by carrageenan and following intraperitoneal treatment with 100 mg/kg dm. A dried 80% ethanolic extract of *Taraxacum officinale* root administered orally at 100 mg/kg body weight 1 h before oedema elicitation inhibited carrageenan-induced rat paw oedema by 25%, whereas a 45% inhibition was observed after application of indomethacin at 5 mg/kg (Mascolo et al., 1987). The methanolic extract of flowers from *Taraxacum officinale* and *Taraxacum platycarpum* showed inhibition rates of 95 and 87%, respectively, of tetradecanoylphorbol-13-acetate (TPA)-induced ear oedema in mice. In an earlier study, the triterpene uvaol isolated from dried flowers of *Taraxacum platycarpum* inhibited the TPA-induced inflammation almost equivalent to that of indomethacin with 0.1 mg/ear being the 50% inhibitory dose (Yasukawa et al., 1996). Extracts of *Taraxacum officinale* leaf and roots exhibited slightly lower inhibition rates of 69 and 51%, respectively, in the same assay (Yasukawa et al., 1998). Kim et al. (2000) studied the effect of a *Taraxacum officinale* leaf extract on the production of tumor necrosis factor alpha (TNF-α) from primary cultures of rat astrocytes stimulated with substance *P* and lipopolysaccharide. The extract administered at concentrations of 100 and 1000 μg/mL significantly supressed TNF-α production by inhibiting interleukin-1 production. Therefore, the authors suggested an anti-inflammatory activity of dandelion leaf extract in the central nervous system. In a very recent study, Seo et al. (2005) investigated the protective effect of an aqueous leaf extract (*Taraxacum officinale*) against cholecystokinin octapeptide-induced acute pancreatitis through significantly decrease of the pancreatic weight/body weight ratio. Additionally, the secretion of interleukin-6 and TNF-α dropped, while the pancreatic level of heat shock proteins HSP60 and HSP72 increased in animals treated with dandelion leaf extract. In another investigation, the aqueous methanol

extract of the root of *Taraxacum officinale* was partitioned successively with hexane, ethyl acetate and butanol. Significant inhibitory activity toward the formation of leukotriene B_4 from human neutrophils, activated with calcium ionophore, was found for the butanol fraction (86% inhibition at 3 μg/mL), while the ethyl acetate and water fractions displayed only weak inhibitory activity (32 and 21% at 3 μg/mL, respectively) (Kashiwada et al., 2001).

4.4. Anti-oxidative activity

Hagymási et al. (2000a) studied the effects of dandelion extracts (*Taraxacum officinale*) on liver microsomes of Wistar rats. Liver microsomes are highly sensitive to lipid peroxidation when incubated in the presence of NADPH and ADP-Fe^{2+}. Both leaf and root extracts diminished enzymatically induced lipid peroxidation and reduced cytochrome *c* with and without NADPH in a concentration-dependent manner indicating anti-oxidant activity. In a following study, the same authors proved hydrogen-donating ability, reducing power property and radical scavenging capacity of lyophilized aqueous dandelion leaf and root extracts. Due to the higher polyphenol content, the leaf extract was a more effective hydrogen donor, reducing agent and hydrogen peroxide scavenger compared to the root extract (Hagymási et al., 2000b). The anti-oxidant/pro-oxidant action of various *Taraxacum officinale* WEBER extracts of flower, leaf, stem and root, either alone or in combination with CCl_4 or fullerenol, was assessed by measuring liposomal lipid peroxidation induced by Fe^{2+} and ascorbic acid. Anti-oxidant effects were observed for all dandelion extracts investigated with the exception of the ethyl acetate flower extract in combination with CCl_4, the chloroform and aqueous stem extract, either alone or in combination with CCl_4, and the aqueous root extract, either alone or in combination with CCl_4. Fullerenol exhibited an anti-oxidant effect in combination with all the extracts accompanied by a decreased lipid peroxidation (Popovic et al., 2001). In a more recent study, dandelion (*Taraxacum officinale*) flower extracts, in particular the ethyl acetate fraction, scavenged reactive oxygen species (ROS) and prevented DNA from ROS-induced damage in vitro. The suppression of oxidative stress was attributed to luteolin and luteolin 7-*O*-glucoside (Hu and Kitts, 2003). In another study, the most efficient inhibition of hydroxyl radical production could be achieved with ethyl acetate and water extracts of dandelion flowers and aqueous dandelion stem extract. Pronounced inhibitory effects were also obtained using chloroform and ethyl acetate extracts of leaf and ether, or *n*-butanol extracts of roots (Kaurinovic et al., 2003). Besides ROS, an overproduction of reactive nitrogen species (RNS) may also result in tissues damage and vascular leakage common to inflammatory bowel disease, septicaemia and rheumatoid arthritis (Darley-Usmar et al., 1995).

Hu and Kitts (2004) demonstrated that luteolin and luteolin 7-*O*-glucoside in dandelion flower extracts administered at concentrations lower than 20 μM significantly ($p < 0.05$) suppressed the protein expression of inducible nitric oxide synthase (iNOS) and cyclooxygenase-2 (COX-2) in bacterial lipopolysaccharide-activated mouse macrophage RAW264.7 cells. These inducible enzymes are responsible for the production of nitric oxide and prostaglandin E_2 (PGE_2). In contrast, chlorogenic and caffeic acids present in the extract at concentrations as high as 100 μM had no effect on the suppression of nitric oxide production. The marked anti-oxidative activity of a dandelion flower crude extract was confirmed in various chemical model systems (Hu and Kitts, 2005).

4.5. Anti-carcinogenic activity

An aqueous root extract of *Taraxacum japonicum* inhibited both the initiation and promotion in two-stage carcinogenesis of mouse skin tumors induced by different types of initiators (Takasaki et al., 1999a). Based on these findings, 11 triterpenoids isolated from *Taraxacum japonicum* were investigated in a preliminary in vitro screening. In the following in vivo two-stage test, taraxasterol and taraxerol exhibited strong inhibitory effects in the carcinogenesis of mouse skin tumors. Furthermore, oral administration of taraxasterol showed remarkable inhibitory effects on spontaneous mammary carcinogenesis applied at a concentration of 2.5 mg in 100 mL drinking water (Takasaki et al., 1999b).

Koo et al. (2004) investigated the effects of dried aqueous dandelion (*Taraxacum officinale*) herb extracts on the cytotoxicity and production of cytokines in human hepatoma cell lines (Hep G2). The dandelion extract caused a time-dependent and partially dose-dependent reduction of cell viability by 26%. Furthermore, in cells treated with 0.2 mg/mL extract for 48 h, maximum secretion of TNF-α (186 ± 2.0 pg/mL) and IL-1α (66 ± 1.7 pg/mL) was observed. The increased amounts of TNF-α and IL-1α contributed to dandelion extract-induced apoptosis, which was almost completely neutralized by addition of anti-TNF-α and IL-1α antibodies. These results suggest that the extract induced cytotoxicity through TNF-α and IL-1α secretion in Hep G2 cells. As a consequence of the induced secretion of TNF-α, increased nitric oxide production from recombinant interferon-γ primed mouse peritoneal macrophages was observed (Kim et al., 1998, 1999). Nitric oxide has received increasing attention as a potent macrophage-derived effector molecule against tumors (Stuehr and Nathan, 1989).

Taraxinic acid, the compound resulting from hydrolysis of the sesquiterpene lactone glycoside taraxacinic acid-1-*O*-β-D-glucopyranoside, isolated from *Taraxacum coreanum* NAKAI was investigated for its activity against cancer cells and showed significant cytotoxicity against human leukemia-derived HL-60 cells, with IC_{50} at concentrations of 34.5–135.9 μM. Its glycoside showed no effect at levels up to 200 μM. Moreover, cell growth was inhibited in a concentration- and time-dependent manner (15–30 μM taraxinic acid). Apart from its anti-proliferative activity, taraxinic acid induced the differentiation of human leukemia cells to monocyte/macrophage lineage in various test systems (Choi et al., 2002). In contrast, no effects on cellular growth of human gastric cancer cell lines AGS were detected using lyophilized ethanolic extracts of *Taraxacum mongolicum* (Ko et al., 2004).

4.6. Analgesic activity

In the hot plate test according to Woolfe and Macdonald (1944), 100 mg/kg body weight of a dry ethanolic dandelion (*Taraxacum officinale* WEBER) extract administered intraperitoneally to mice enhanced reaction time about 38% after 180 min. The same dose reduced the writhing response to phenylquinone in mice about 24%, while after oral treatment with 1 g/kg body weight a reduction of about 44% was observed (Hendershot and Forsaith, 1959; Tita et al., 1993).

4.7. Anti-allergic activity

Desacetylmatricarin, a guaianolide sesquiterpene isolated from *Taraxacum platycarpum* DAHLST, was investigated for its anti-allergic activity by measuring the release of β-hexosaminidase from rat basophilic leukemia (RBL-2H3) cells, which occurs concomitantly with the release of histamin when mast cells are immunologically activated. Desacetylmatricarin exerted a significant inhibition of the β-hexosaminidase release from RBL-2H3 cells in a dose-dependent manner. Its IC_{50} value of 7.5 μM is considerably lower than that of disodium cromoglycate (IC_{50} value is estimated over 100 μM) (Ho et al., 1998).

4.8. Anti-hyperglycemic activity

Dried ethanolic extracts of *Taraxacum officinale* administered at concentrations between 1 and 40 μg/mL were tested in vitro for insulin release from INS-1 cells in the presence of 5.5 mM glucose using glibenclamide as a control. Insulin secretagogue activity could be observed for dandelion extracts at a concentration of 40 μg/mL (Hussain et al., 2004). Depending on its origin, α-glucosidase was also inhibited by aqueous extracts of *Taraxacum officinale*. The IC_{50} values were 2.3, 3.5 and 1.83 mg plant/mL extract for α-glucosidase from baker's yeast, rabbit liver and rabbit small intestine, respectively (Önal et al., 2005). Petlevski et al. (2001) demonstrated an anti-hyperglycemic effect of a herbal preparation containing 9.7% *Taraxaci radix* (*Taraxacum officinale* WEBER). For its production, the dry plant material was extracted with 60% ethanol. After 28 days the macerate was filtered, ethanol was evaporated, and the residual aqueous extract was lyophilized. Administered to alloxan-induced non-obese diabetic (NOD) mice in concentration of 20 mg/kg body mass the dried ethanol extract significantly decreased the glucose and fructosamine levels. In a continuative study the effects of the plant extract on the catalytic concentrations of glutathione *S*-transferases (GSTs) and malondialdehyde (MDA) in the liver of diabetic NOD mice were investigated as possible indicators of oxidative stress in early diabetes. After a 7-day treatment with the plant extract at a dose of 20 mg/kg body weight, a significant increase in the catalytic concentration of GSTs and a non-significant decrease in MDA concentration was observed, which could be explained by the anti-hyperglycemic effect of the extract (Petlevski et al., 2003). A decrease in hepatic MDA concentration in streptozotocin-induced diabetic rats as well as a significantly decrease in the serum glucose concentration was also observed by Cho et al. (2002) after administration of an aqueous dandelion leaf extract.

4.9. Anti-coagulatory/anti-thrombotic activity

Diabetes mellitus is associated with vessel disease due to enhanced formation of thrombi and ischemia. Ethanolic extracts of dandelion (*Taraxacum officinale* WEBER) root were investigated for their inhibitory effects on human platelet aggregation. The extracts caused a dose-dependent inhibition of ADP-induced aggregation, with a maximal inhibition of 85% observed at a concentration corresponding to 0.04 g dried root/mL of human platelet-rich plasma (PRP). Arachidonic- and collagen-induced platelet aggregation was not affected. The ethanolic extracts were fractionated into higher ($Mr > 10{,}000$) and lower ($Mr < 10{,}000$) molecular weight compounds. A fraction containing low-molecular polysaccharides caused a 91% inhibition, while a second fraction enriched in triterpenes and steroids showed an 80% inhibition of platelet aggregation, both at a concentration equivalent to 0.04 g crude material/mL PRP (Neef et al., 1996). A protein with anti-coagulant activity from *Taraxacum platycarpum* was later purified and characterized by Yun et al. (2002). At concentrations of 70, 255 and 873 nM, respectively, the protein doubled the thrombin time, prothrombin time and activated partial thromboplastin time. In addition, the anti-coagulant activated murine macrophages to induce cyclooxygenase-2, nitric oxide synthase and to secrete TNF-α.

4.10. Prebiotic activity

Aqueous root extracts of *Taraxacum officinale* WEBER were tested for their growth-stimulating activity of 14 different strains of bifidobacteria. The growth of six strains (*B. adolescentis* 1 and 2, *B. bifidum* 1, *B. catenulatum*, *B. longum* 2) was significantly enhanced in the medium containing dandelion root extract, while only two strains developed slightly less intensive in this medium compared to the control. The remaining six strains exhibited equivalent growth in both media. Determination of carbohydrates before and after incubation in all bifidobacterial cultures revealed 1–48% utilization of dandelion oligofructans (Trojanová et al., 2004).

5. Toxicity

In several investigations, the toxicity of dandelion was found to be low, due to absence of any significant toxins or alkaloids. A fluid herb and root extract showed intraperitoneal LD_{50} of 28.8 and 36.6 g/kg body weight, respectively, in mice (Rácz-Kotilla et al., 1974). Ethanolic extracts were also demonstrated to exert very low toxicity when administered to rats and mice up to doses of 10 g/kg (per os) and 4 g/kg (intraperitoneal) of dried drug per kilogram body weight (Tita et al., 1993). Rabbits treated orally with dried whole dandelion plants at 3–6 g/kg body weight showed no visible signs of acute toxicity (Akhtar et al., 1985).

Furthermore, due to the presence of the sesquiterpene lactone taraxinic acid β-glucopyranosyl ester dandelion can cause aller-

gic contact dermatitis (Hausen, 1982; Lovell and Rowan, 1991; Jovanovic et al., 2004; Lundh et al., 2006).

6. Conclusions

Empiric traditional application in humans of dandelion, in particular to treat digestive disorders, is supported by pharmacological investigations. Several studies have demonstrated further health-promoting properties of either dandelion extracts or individual compounds extracted from dandelion leaves or roots, e.g. anti-inflammatory, anti-carcinogenic and anti-oxidative activities. These diverse effects have mainly been attributed to the presence of various polyphenolics and sesquiterpenes. Although a number of compounds were characterized in dandelion plants, studies on the concentration of individual constituents are rather limited and merit further attention. Moreover, the diverse pharmacological activities of dandelion or individual compounds isolated thereof have only been assayed in in vitro or in in vivo tests using laboratory animals, and the results obtained may not necessarily be portable to the situation in humans. Some results, e.g. concerning possible diuretic activity, are even contradictory and require a through reinvestigation. Another problem is the often insufficient description of the species and the plant part used or how the extract applied was obtained. However, according to the WHO, 80% of the world population continues to rely mainly on traditional medicines for their health care (Gurib-Fakim, 2006). In view of this fact and the multitude of promising findings described previously, further research would not only be a scientific challenge but also an interesting economic perspective.

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