In Vitro Anticancer Effects of *Taraxacum* Genus Extracts: A Review

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Abstract: Cancer is one of the leading causes of death across the globe, affecting millions of lives. Natural products derived from traditional medicines have been used to treat many illnesses including cancer. *Taraxacum officinale*, commonly known as dandelion, and other similar species have been a growing topic of interest for their potential anticancer effects. A review of the current literature showed that researchers have experimented with crude extracts from different organs of the dandelion plant, notably root, leaf, flower, and whole plant extracts, to show their effect on cancer cell lines. A comparison of these extracts' anticancer potential was conducted. Based on published literature, research has "room to grow" studying extracts from dandelion leaves, seeds, and flowers, in addition to numerous untested species. Several studies have conducted phytochemical analysis and assessed the cytotoxicity of both the crude extract and its individual fractions. Most studies have found that none of the isolated fractions exhibited the same level of potency as the crude extract. To unravel how these distinct components combine to replicate the effects of traditional medicines, a synergistic research approach is required to identify the optimal combination of these fractions or bioactive molecules.

Introduction

Taraxacum officinale, more commonly known as the dandelion, can be traced back to glacial and interglacial times in Europe (Godwin 1956). It is believed that various species of the genus *Taraxacum* colonized the western hemisphere prior to the Gondwana supercontinent split about 180 million years ago (Richards 1973). It has been used in herbal Native American, Mexican (Sansores-España, Pech-Aguilar et al. 2022), Greek, Chinese medicine, and others (Sharifi-Rad, Roberts et al. 2018) for centuries due to its anti-inflammatory and anti-oxidative properties (Yarnell and Abascal 2009). In the United States, dandelions are considered invasive weeds that serve no purpose. Dandelions are found throughout Oklahoma (Palmer 2007, 2022), and are the second earliest blooming plant in central Oklahoma (Osborn 2015). What makes these weeds so special and gives them the potential to aid in treating one of the most prolific diseases seen across the globe?

According to the Integrated Taxonomic Information System (ITIS), as of March 2023, there are 15 species of *Taraxacum* in addition to *Taraxacum officinale* (Brouillet 2023). Medicinal aspects of the genus *Taraxacum* have been a popular topic of academic studies for

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decades. Almost half of the reported biomedical research are from studies on *Taraxacum officinale* alone (Martinez, Poirrier et al. 2015).

Due to the versatility of uses these plants have offered to holistic and herbal medicine cultures, scientists have been attempting to validate these uses for more clinical settings. In particular, the antimicrobial effects of the *Taraxacum* genus have been thoroughly investigated. Researchers found that the plants were effective in inducing growth arrest, or "halo zones" in agar plates of multiple bacteria. Notably, different species of *Taraxacum* plants were found to create halo zones against *Klebsiella pneumoniae* (Shahidi Bonjar, Aghighi et al. 2004), *Staphylococcus aureus* (Demin 2010), and *Bacillus subtilis* (Tahir, Nazir et al. 2017), all of which are incredibly common in the environment and are known to cause many different aliments.

In more recent years, multiple studies have examined the possible anticancer effects of *Taraxacum* plants to fight against more serious illnesses. There has been a spike in researchers running experiments to examine the possible anticancer effects of *Taraxacum officinale* and related *Taraxacum* species. Cancer is the second leading cause of death in the United States. In 2021, approximately 1.9 million new cancer cases were diagnosed, and 608,570 cancer-caused deaths occurred (Siegel, Miller et al. 2022). As the number of cancer diagnoses increases, the number of new forms of cancer therapy increases. However, there continues to be a high rate of death associated with these cancers. The need for new, innovative, less expensive cancer therapies having fewer harsh side effects is ever growing.

While many studies have identified compounds present in *Taraxacum*, there is surprisingly less research on crude extracts or compound mixtures to determine if such combinations will provide similar effects to those reported with traditional medicines (Martinez, Poirrier et al. 2015, Scaria, Sood et al. 2020). The purpose of this review is to focus on dandelion crude extract research reported in the literature, with specific emphasis on *in vitro* cancer cell culture studies. These studies include isolated plant parts or mixtures, or the whole plant. During active growth, dandelions continuously demonstrate leaves and roots; less often, other parts related to reproduction (e.g., flowers, seeds, petals, bracts, seed heads) are present (Vijverberg, Welten et al. 2021) (**Table 1**). Many of the studies reported here do not adequately describe which parts are included in the extracts that were tested, nor which species was extracted, leaving room for interpretation of results.

In this work, we review the current state of knowledge regarding the anticancer effects of *Taraxacum officinale* and related species. Because the dandelion is a complex plant with a diverse biochemical composition, coupled with variations in the parts utilized across different studies, we decided to structure the review into sections by the part of the plant used (whole plant extract, roots, roots, leaves, flowers, and seeds). We then discuss the overall knowledge based on analysis of the data and highlight potential areas for future research.

Methods

We searched databases available online and written in English through the University of Central Oklahoma, including Google Scholar, JSTOR, ProQuest, PubMed, Science Direct, and Web of Science using keywords such as "taraxacum" or "dandelion" with "crude extract", "in vitro" "phytochemistry", "pharmacology" "cancer cell". Each abstract was read to determine if crude extracts of *Taraxacum* were used, and what kind of *in vitro* cells/experiments were conducted. From this evaluation, the papers collected were read in their entirety for further preparation.

Dandelion Whole Plant Extracts

Multiple studies using extracts from the whole dandelion plant (dandelion whole extract, or DWE) have been reported. DWE had a negative effect on triple-negative breast cancer (TNBC) migration, proliferation, and its ability to invade tumor-associated macrophages (TAMs) (Deng, Jiao et al. 2021). When tested

Table 1. Summary of dandelion crude extracts tested in experimental models.

Extract type	Species extracted	Experimental model*	Cell lines	Refs
Whole Plant Extract	*T. officinale*	Breast cancer stem cells	Primary cell culture	(Trinh, Doan-Phuong Dang et al. 2016)
		Breast cancer cells	MCF-7	(Rawa'a, Dhia et al. 2018)
		Normal liver cells	WRL-68	(Rawa'a, Dhia et al. 2018)
		Pediatric cancer cells (18)	RAMOS, MV4-11, etc.	(Menke, Schwermer et al. 2018)
		Normal human fibroblasts	NHDF-C	(Menke, Schwermer et al. 2018)
	T. formosanum	Bronchial epithelial cells	BEAS-2B	(Chien, Chang et al. 2018)
		Lung adenocarcinoma cells (2)	CL1-0 CL1-5	(Chien, Chang et al. 2018)
		Breast cancer cell lines (3)	MDA-MB-231 ZR75-1 MCF-7	(Lin, Chen et al. 2022)
	T. mongolicum	Breast cancer cell lines (3)	MDA-MB-231 ZR75-1 MCF-7	(Lin, Chen et al. 2022)
		Monocytic leukemia cells	U937	(Deng, Jiao et al. 2021)
		Breast cancer cells (2)	MDA-MB-231 MDA-MB-468	(Deng, Jiao et al. 2021)
		Breast cancer cells (2)	MDA-MB-231 MCF-7	(Li, He et al. 2017)
		Embryonic kidney cells	HEK293	(Li, He et al. 2017)
		Breast cancer cells (2)	MDA-MB-231 MDA-MB-468	(Wang, Hao et al. 2022)
		Normal mammary epithelial cells	MCF-10A	(Wang, Hao et al. 2022)
Unknown source	*Taraxacum sp.*	Lung adenocarcinoma cells	A549	(Man, Wu et al. 2022)
Root Extract	*T. officinale*	Breast cancer cells	MCF-7/AZ	(Sigstedt, Hooten et al. 2008)
		Prostate cancer cells	LNCaP C4-2B	(Sigstedt, Hooten et al. 2008)
		Normal colon mucosal epithelial cells	NCM460	(Ding and Wen 2018)
		Prostate cancer cells (2)	DU-145 PC-3	(Nguyen, Mehaidli et al. 2019)
		Colonic epithelial cells	FHC	(Nguyen, Mehaidli et al. 2019)
		Colon cancer cells (2)	HT-29 HCT116	(Ovadje, Ammar et al. 2016)
		Colonic epithelial cells	NCM460	(Ovadje, Ammar et al. 2016)
	Taraxacum sp.	Esophageal SCC (4)	KYSE450 NEC Eca109 EC9706	(Duan, Pan et al. 2021)
		Normal esophageal cells	NE3	(Duan, Pan et al. 2021)

Table 1. Continued.

		Cancer cells (3)	HepG2 MCF7 GCT116	(Rehman, Hamayun et al. 2017)
		Normal cells	HS27	(Rehman, Hamayun et al. 2017)
		Gastric cancer cells (2)	SGC7901 BGC823	(Zhu, Zhao et al. 2017)
		Normal gastric epithelial cells	GES-1	(Zhu, Zhao et al. 2017)
		Melanoma cells (2)	A375, G361	(Chatterjee, Ovadje et al. 2011)
		Normal human fibroblasts	Primary	(Chatterjee, Ovadje et al. 2011)
		T-cell leukemia (2)	Jurkat E6-1 dnFADD Jurkat	(Ovadje, Chatterjee et al. 2011, Ovadje, Hamm et al. 2012)
		Peripheral blood mononuclear cells	Primary	(Ovadje, Chatterjee et al. 2011, Ovadje, Hamm et al. 2012)
		Chronic myelomonocytic leukemia cells (3)	MV-4-11 HL-60 U-937	(Ovadje, Hamm et al. 2012)
		Pancreatic cancer cells (2)	BxPC-3 PANC-1	(Ovadje, Chochkeh et al. 2012)
		Normal human fibroblasts	Primary	(Ovadje, Chochkeh et al. 2012)
Leaf Extract	*T. officinale*	Breast cancer cells	MCF-7/AZ	(Sigstedt, Hooten et al. 2008)
		Prostate cancer cells	LNCaP C4-2B	(Sigstedt, Hooten et al. 2008)
	Taraxacum sp.	Colon cancer cells	HT-29	(Xue, Zhang et al. 2017)
Flower Extract	*T. officinale*	Breast cancer cells	MCF-7/AZ	(Sigstedt, Hooten et al. 2008)
		Prostate cancer cells	LNCaP C4-2B	(Sigstedt, Hooten et al. 2008)
		Colorectal cancer cells	Caco-2	(Hu and Kitts 2003)
Seed Extract	*T. officinale*	Hypopharyngeal cancer cells	FaDu	(Milovanovic, Grzegorczyk et al. 2022)
		Cervical cancer cells	HeLa	(Milovanovic, Grzegorczyk et al. 2022)
		Kidney epithelial cells	Vero	(Milovanovic, Grzegorczyk et al. 2022)
		Normal fibroblasts	CCD-1059Sk	(Milovanovic, Grzegorczyk et al. 2022)
	Taraxacum sp.	Esophageal SCC cells (5)	KYSE450 Eca109 NEC EC9706 TE-13	(Li, Deng et al. 2022)

*Number in parentheses indicates number of cell lines tested.

on non-small-cell lung cancer (NSCLC), DWE exhibited antioxidant effects as well as anticancer effects. DWE was unable to decrease cancer cell proliferation in a significant manner, but it was able to decrease the number of colonies formed by the cancer. It was also found that DWE exhibited inhibitory effects on the migration of cancer cells. DWE treatment decreased phosphorylation of ERK1/2 but did not have effects on p38 and JNK1/2 (Chien, Chang et al. 2018). In another study using breast cancer stem cells (BCSC), DWE was shown to inhibit BCSC proliferation by inducing apoptosis. DWE also increased the ROS in cancer stem cells (Trinh, Doan-Phuong Dang et al. 2016). While these studies reported effects only on diseased cells, another study compared DWE effects on cancer vs. non-cancerous cells, using MCF-7 (human breast cancer) cells against WRL-68 (normal human hepatic) cells. The study demonstrated that DWE significantly reduced cell viability of the cancerous cells but not the non-cancerous cells (Rawa'a, Dhia et al. 2018). Another study tested a panel of 18 cancer cell lines against a normal human fibroblast line and found DWE was more potent against the cancer cells than normal cells (Menke, Schwermer et al. 2018).

One study using *T. mongolicum* and *T. formosanum* aqueous extracts tested against 3 breast cancer cell lines showed mixed results on the cell lines; both extracts reduced cell migration and colony formation, but *T. mongolicum* was more cytotoxic to the tested cell lines (Lin, Chen et al. 2022). A similar study found *T. mongolicum* DWE extract inhibited triple-negative breast cancer cell viability and induced apoptosis (Li, He et al. 2017). A follow-up study using a multi-omics approach showed the effects were exerted mainly by seven compounds including luteolin, and through interference with lipid metabolism (including phospholipid and fatty acid metabolism) (Wang, Hao et al. 2022).

A crude extract from an unknown dandelion species and plant part was tested against A549 lung adenocarcinoma cells, where it was shown to be cytotoxic in a dose-dependent manner (Man, Wu et al. 2022). Further investigation into the metabolomic profile showed deficiencies in purine metabolism, but also glycerophospholipid metabolism, which was also reported in (Wang, Hao et al. 2022). These and other noted metabolic changes suggested DWE affected malignant proliferation, membrane stability/structure, and cells' ability to adhere to their extracellular matrix, all providing the stimulus for apoptosis.

While these studies offer substantial evidence supporting the potential therapeutic benefits of DWE, the absence of detailed information regarding specific plant parts included in the DWE description introduces some ambiguity when interpreting or comparing results with other studies. Additionally, the extraction methods varied from cold aqueous, hot aqueous, or ethanol to ethyl acetate processes (Lin, Chen et al. 2022; Deng, Jiao et al. 2021; Chien, Chang et al. 2018). This variability suggests that the substances extracted for testing may differ, potentially yielding diverse results.

Dandelion Root Extracts

One part of the dandelion that is consistently present year-round is the root, and consequently much of the published *in vitro* cancer studies focused on dandelion root extracts (DRE). Root aqueous extracts reduced viability but not cell growth of LNCaP C4-2B prostate cancer cells and MCF-7/AZ breast cancer cells. ERK phosphorylation was unaffected in either of the cell lines. DRE treatment blocked *in vitro* collagen invasion of MCF-7/AZ but not LNCaP C4-2B (Sigstedt, Hooten et al. 2008). Another study showed aqueous DRE was effective against esophageal squamous cell carcinoma (ESCC) cell growth, proliferation, migration, and invasion, but was less effective against normal esophageal cells. DRE inhibited *in vivo* tumorigenesis and induced apoptosis (Duan, Pan et al. 2021).

Another DRE study combined *in vitro* testing with an *in vivo* mouse model. Aqueous DRE increased cell viability and prevented apoptosis of NCM460 colonocytes induced by dextran sodium sulfate (DSS), correlated with reduced ROS production. Using female C57BL/6 mice as a model for humans, DRE inhibited DSS-induced ulcerative colitis and reduced

inflammation and oxidative stress in the colon of the mice (Ding and Wen 2018).

A series of studies with DRE compared cancer cell effects against non-cancerous cells, to provide further support for future clinical studies. One study compared DRE effects on gastric cancer versus normal gastric epithelial cells (Zhu, Zhao et al. 2017). DRE inhibited cancerous but not normal gastric cells, in part by targeting a long-noncoding RNA, CCAT1. Another study showed DRE (aqueous extract)-treated A375 melanoma cells exhibited a decrease in cell viability, while having no viability reduction in normal human fibroblasts. DRE treatment induced caspase-8 dependent apoptosis in the melanoma cells, correlated with increased mitochondrial ROS production. Other apoptotic markers were observed, including dissipation of the mitochondria membrane potential. Higher DRE doses were necessary to decrease viability in another melanoma cell line (G361) compared to the A375 cell line (Chatterjee, Ovadje et al. 2011). Another study compared aqueous DRE with ethanolic extract of lemongrass, using both *in vitro* and xenograft *in vivo* testing. DRE induced caspase-dependent apoptosis in two prostate cancer cell lines, but not normal colonic epithelial cells. Using immunocompromised CD1 nu/nu mice as an *in vivo* model, DRE was able to reduce tumor weight and volume (Nguyen, Mehaidli et al. 2019). When aqueous DRE was tested against human leukemia (Jurkat) cells, the higher the concentration of DRE used to treat the cells, the higher the amount of apoptosis was exhibited by the cells. DRE was able to reduce the cell viability of the leukemia cells by 60%. This apoptosis was shown to be caused by the activation of caspase 8, which then activated caspase 3, resulting in apoptosis. To ensure that the DRE was not damaging non-cancerous cells, peripheral blood mononuclear cells were treated with DRE and there were no significant damage and changes reported after treatment (Ovadje, Chatterjee et al. 2011). Another human leukemia cell line derived from chronic myelomonocytic leukemia (CMML) demonstrated 60% viability decrease. The remaining viable 40% were treated with a second round of aqueous DRE, which induced apoptosis through the extrinsic pathway, damaged the mitochondrial membrane, and induced autophagy. Normal peripheral blood monocytes under the same treatment regimen were unaffected (Ovadje, Hamm et al. 2012). In a similar fashion, aqueous DRE was tested on pancreatic cancer cells (BxPC-3 and PANC-1) versus non-cancerous pancreatic cells. DRE was shown to induce apoptosis in the BxPC-3 cells at 48 hours and PANC-1 cells at 24 hours. Multiple low-concentration doses were more effective inducing apoptosis than one large concentration dose. As with the Jurkat and CMML results, apoptosis occurred through the extrinsic pathway and autophagy was induced. These treatments were nontoxic to normal human fibroblasts (Ovadje, Chochkeh et al. 2012). More recently, aqueous DRE was tested against colon cancer cells (HT-29 and HCT166) and decreased cell viability in both cell lines by 50% yet did not decrease the cell viability of non-cancerous colon epithelial cells (NCM460). When a migration scratch assay was performed, DRE was successful in inhibiting cell migration of HT-29 and HCT166 cell lines while failing to inhibit the NCM460 cell line. DRE increased ROS in the cancerous HT-29 cells but not the non-cancerous colorectal cells. Multiple pathways of apoptosis were induced in the colorectal cancer cells. (Ovadje, Ammar et al. 2016). Because many of the DRE studies compared cancerous to non-cancerous cells, this *in vitro* evidence suggests that future studies *in vivo* are warranted.

Collectively, DRE has been tested on more cell types than other plant parts. The results indicate that DRE selectively inhibits cancerous cells, compared to normal cells. Similar to DWE, various preparation methods were used, and unnamed species extracted, making it challenging for future studies to reproduce reported results. The intricate mechanisms behind cell-type selectivity and potential off-target effects remain to be determined. Nevertheless, these findings suggest a promising avenue for future *in vitro*, *in vivo*, and clinical studies to determine the therapeutic potential of DRE**.**

Dandelion Leaf Extracts

Numerous studies have investigated the antioxidant potential of dandelion leaf extract (DLE) to protect against ROS damage in various cell and animal models; however, the published data on DLE effects on cancer cells is limited. Aqueous DLE was able to decrease the viability of MCF-7/AZ breast cancer cells and LNCaP C4-2B prostate cancer cells by 50%; cell growth of the breast cancer cell line was reduced by 40%. The DLE treatment resulted in a decrease of ERK activity, but not a decrease in the levels of ERK in the breast cancer cell line. DLE treatment did not influence the prostate cancer's cell growth. Finally, it was discovered that DLE was unable to inhibit the *in vitro* collagen matrix invasion of MCF-7/AZ cells. DLE was able to block the invasion of LNCaP C4-2B cells (Sigstedt, Hooten et al. 2008).

Another study compared the amount of phenolics and flavonoids in extracts taken from the root, flower, stem, and leaves of the dandelion (Xue, Zhang et al. 2017). 50% ethanolic DLE contained a higher phenolic content than all the other extracts while extracts from the leaves and the flowers were found to have the highest flavonoid content than the other extracts. This study also compared the antioxidant activity between dandelion root, flower, stem, and leaf extracts. The high phenolic content of DLE was correlated with higher antioxidant activity over the other extracts. Further DLE experiments concluded that DLE had a suppressive effect on the ROS production of the HT-29 cells (human colonic epithelial cells). Finally, anti-inflammatory activity testing was performed using HT-29 cells. DLE inhibited activation of p65 (an NF-kappa B signaling molecule) and inhibited inflammatory signaling molecules (Xue, Zhang et al. 2017).

Dandelion Flower Extracts

Few studies have been conducted using *Taraxacum officinale* flowers. In one study, flower extracts were tested for anticancer effects on human colon colorectal adenocarcinoma (Caco-2) cells, using ethyl acetate (EAF) and a water fraction (WF). The DFEs were subjected to antioxidant testing and it was observed that DFE suppressed the formation of conjugated dienes and led to prolonged lag phase durations and lower rates of propagation. It was found that a high ROS concentration of EAF DFE prevented the formation of conjugated dienes and the negative charge of hLDL. The WF DFE showed no antioxidant activity. Both EAF and WF DFEs were cytotoxic to Caco-2 cells at a concentration of 0.1 mg/mL. HPLC profile showed the presence compounds including luteolin and luteolin-7 glucoside, which were shown to be more cytotoxic than EAF and WF (Hu and Kitts 2003).

Aqueous DFE, among other extracts, was tested against MCF-7/AZ breast cancer cells and LNCaP C4-2B prostate cancer cells to observe the anticancer effects against these cell lines. The viability of the breast cancer cells was unaffected by DFE treatment. However, prostate cell viability decreased significantly in the presence of DFE. Researchers ran assays to see if DFE could inhibit ERK, and therefore stop cell growth, in both cancer cell lines. It was concluded that DFE treatment did not affect ERK and cell growth in either of the cell lines. Both cancer lines were able to invade an *in vitro* collagen invasion assay. Through additional assays it was shown that DFE treatment could not block this invasion in MCF-7/AZ cells nor in the LNCaP C4-2B cells (Sigstedt, Hooten et al. 2008)

Dandelion Seed Extracts

Dandelion seeds and fruits are similar; the fruit functions akin to a seed coat and is difficult to separate from the seed (Dr. Jenna Messick, UCO, personal communication). While some dandelion fruit extract (DFE) antioxidant studies have been published, no published cancer reports using dandelion fruit extracts were identified. Two publications about the medicinal properties of dandelion seed extract (DSE) were recently published. DSE was able to reduce the survival and proliferation rates of esophageal squamous cell carcinoma (ESCC) cells. Additionally, DSE induced apoptosis and suppressed migration, invasion, and angiogenesis (Li, Deng et al. 2022). A second study tested DSE against hypopharyngeal cancer (FaDu), cervical

adenocarcinoma (HeLa), and colon cancer (RKO) cells versus normal kidney cells and skin fibroblasts. When all cell types were tested for cytotoxicity, the extract showed selectivity for the hypopharyngeal and colon cancer cells compared to the normal cells, while HeLa cells were resistant to the DSE (Milovanovic, Grzegorczyk et al. 2022).

Dandelion extract effects when combined with other plant extracts

An additional publication described research using extracts that contain a mixture of mushrooms and plants, including dandelion. Specifically, the mixture included *Coix* seed, *Lentinula edodes* (shiitake mushroom), *Asparagus officinalis L., Houttuynia cordata* (chameleon plant), Dandelion, and *Grifola frondosa* (hen of the wood mushroom) (Chen, Yue et al. 2021).

Discussion

Dandelion has a long history of use as a medical herb. It has been shown to have antioxidant and anti-inflammatory benefits. Many of the above publications are from recent years, especially those that work with dandelion seed extract. This research is still in its infancy and needs to be expanded upon in future experiments. Since there are so few publications on this topic pertaining to each part of the dandelion, more experiments will need to be conducted with each extract before the research can move towards clinical use.

Because research teams used different types of cancer cells for their experiments it is difficult to make direct comparisons between the different types of extracts. However, there are clear trends that these extracts do, in fact, exhibit anticancer effects. Many of the researchers ran similar assays, including proliferation, viability, and migration assays. There is evidence that membrane stability is compromised through lipid metabolism effects. In nearly every case, no matter which extract was used and no matter what cancer cell lines were used, the cancer cells were inhibited by the extract treatment. This indicates a trend that dandelion extracts are showing signs of having anticancer properties that should have limited cytotoxicity to the non-cancerous cell environment.

In more recent years, researchers have begun fractionating dandelion extracts to find their biocomponents, in hopes of isolating purified anticancer chemicals. These publications evaluated the total flavonoids of an extract (He, Han et al. 2011, Kang, Miao et al. 2021), dandelion polysaccharides (Ren, Yang et al. 2021), and specific components, such as inulin fructan (Zhang, Song et al. 2021), taraxasterol (Ovadje, Ammar et al. 2016), and luteolin (Tsai, Tsai et al. 2021). The phytochemical analysis of dandelion roots, leaves, and flowers has been published extensively. Common components found in all three include caffeic acid, chlorogenic acid (Hu and Kitts 2003, González-Castejón, Visioli et al. 2012, Xue, Zhang et al. 2017), syringic acid, ferulic acid, and chicoric acid (González-Castejón, Visioli et al. 2012, Xue, Zhang et al. 2017) **(Table 2)**. While there is one publication detailing the phytochemical components of dandelion fruit (Lis, Jedrejek et al. 2020) there are no recent publications showing the phytochemical components of dandelion seeds.

Cancer is not the only aliment that dandelion extracts have been shown to combat. A China-based research group from the South-Central University for Nationalities used an ethyl acetate extract of dandelion and observed its anti-asthma effects (Sarı and Keçeci 2019). The Chinese Academy of Sciences published work showing the anti-influenza potential of dandelion (Zhao, Liu et al. 2020). A Canadian team showed that dandelion extracts could be used to protect human cells from UV radiation (Yang and Li 2015). In 2022, researchers from King Saud University used DSE to treat mice with hypercholesterolemia and determine the effect (El-Nagar, Al-Dahmash et al. 2022).

Much work has been done to characterize dandelion extracts, their chemicals, and effects *in vitro* and *in vivo*. However, many of these studies do not identify the species tested. Reported methods of extraction differ, leaving

Table 2. Phytochemical components of extracted dandelion plant parts. Data are from references (Hu and Kitts 2003, González-Castejón, Visioli et al. 2012, Xue, Zhang et al. 2017).

Biocomponent	DWE	DRE	DLE	DFE
10,15-octadecadienoic acid	x			
11,13-dihydro-taraxinic acid β-glucopyranoside		x	x	
11β,13-dihydrolactucin		x		
4-caffeoylquinic acid	x	x		
4-coumaric acid			x	x
4-hydroxybenzoic acid	x			
9,10,11-trihydroxy-(12Z)-octadecanienoic acid	x			
9,10,11-trihydroxy-9,11-octadecadienoic acid	x			
Acylated γ-butyrolactone glycoside		x		
Aesculin			x	
Ainslioside		x		
Apigenin 7-*O*-glucoside			x	
Apigenin				x
Arnidiol		x	x	
Caffeic acid	x	x	x	x
Caffeoyl hexoside	x			
Caffeoyl-D-glucose	x			
Caftaric acid	x			
Chicoric acid	x	x	x	x
Chlorogenic acid	x	x	x	x
Chrysoeriol			x	
Cichoriin			x	
Cis-caftaric acid	x			
Esculetin	x	x		
Faradiol		x		
Ferulic acid	x	x	x	x
Gallic acid			x	
Hesperidin	x			
Hydroxy-10,12,15-Octadecatrienoic acid	x			
Hydroxycinnamic acid derivative	x			
Isorhamnetin	x			x
Ixerin D		x		
Lupeol		x		
Luteolin	x			x
Luteolin 7-diglucoside			x	
Luteolin 7-glucoside	x		x	x
Luteolin hexoside	x			
Luteolin-7-O-rutinoside	x		x	
Monocaffeoyltartaric acid		x	x	
Picrasinoside F.	x			
Protocatechuic acid		x		
Quercetin	x		x	x

Table 2. Continued.

Quercetin-7-O-glucoside			x	
Rutin			x	
Scopoletin		x		
Stigmasterol		x		
Syringic acid	x	x	x	x
Taraxacolide-O-β-glucopyranoside		x		
Taraxacoside		x		
Taraxasterol		x		
Taraxinic acid β-glucopyranoside		x	x	
Tetrahydroridentin B		x		
Trans-cinnamic acid			x	x
Umbelliferone		x		
Vanillic acid	x	x	x	
α-amyrin		x		
β-amyrin		x	x	
β-sitosterol		x	x	
β-sitosterol-β-D-glucopyranoside		x		
ρ-coumaric acid	x	x		
ρ-hydroxybenzoic acid		x	x	
ρ-hydroxyphenylacetic acid		x		

it difficult to compare one study to another. Studies often use different cell types for testing, making comparisons difficult. More clinical studies are needed (Li, Chen et al. 2022), but current knowledge should be fine-tuned before proceeding (Sharifi-Rad, Roberts et al. 2018), in order to compare results to traditional medicine (Martinez, Poirrier et al. 2015, Scaria, Sood et al. 2020). Only a few of the known dandelion species have been tested; untested species may have anticancer potential (Li, Chen et al. 2022). Future work with big data set analysis of phytochemical mixtures combined with observed health benefits and/or "symptomics" should begin to tease out specific benefits of dandelion constituents for future therapies.

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References

Brouillet, L. (2023). "Taraxacum F.H. Wigg." Retrieved 5/30, 2023, from https://www.itis.gov/servlet/SingleRpt/SingleRpt?search_topic=TSN&search_value=36199#null.

Chatterjee, S. J., P. Ovadje, M. Mousa, C. Hamm and S. Pandey (2011). "The efficacy of dandelion root extract in inducing apoptosis in drug-resistant human melanoma cells." Evid Based Complement Alternat Med **2011**: 129045.

Chen, X., W. Yue, L. Tian, N. Li, Y. Chen, L. Zhang and J. Chen (2021). "A plant-based medicinal food inhibits the growth of human gastric carcinoma by reversing epithelial–mesenchymal transition via the canonical Wnt/β-catenin signaling pathway." BMC Complementary Medicine and Therapies **21**(1): 137.

Chien, J. T., R.-H. Chang, C.-H. Hsieh, C.-Y. Hsu and C.-C. Wang (2018). "Antioxidant property of Taraxacum formosanum Kitam and its antitumor activity in non-small-cell lung cancer cells." Phytomedicine **49**: 1-10.

Demin, G. (2010). "Analysis of nutritional components of Taraxacum mongolicum and its antibacterial activity." Pharmacognosy Journal **2**(12): 502-505.

Deng, X.-X., Y.-N. Jiao, H.-F. Hao, D. Xue, C.-C. Bai and S.-Y. Han (2021). "Taraxacum mongolicum extract inhibited malignant phenotype of triple-negative breast cancer cells in tumor-associated macrophages microenvironment through suppressing IL-10 / STAT3 / PD-L1 signaling pathways." Journal of Ethnopharmacology **274**: 113978.

Ding, A. and X. Wen (2018). "Dandelion root extract protects NCM460 colonic cells and relieves experimental mouse colitis." J Nat Med **72**(4): 857-866.

Duan, X., L. Pan, Y. Deng, Y. Liu, X. Han, H. Fu, Y. Li, M. Li and T. Wang (2021). "Dandelion root extract affects ESCC progression via regulating multiple signal pathways." Food Funct **12**(19): 9486-9502.

El-Nagar, D. M., B. A. Al-Dahmash, S. Alkahtani, A. A. Kalu and A. Rady (2022). "Dandelion (Taraxacum officinale) seeds extract attenuates hypercholesterolemia in swiss albino mice." Journal of King Saud University - Science **34**(7): 102198.

Godwin, H (1956). The history of the British flora. Cambridge University, Cambridge, UK. 384 pp.

González-Castejón, M., F. Visioli and A. Rodriguez-Casado (2012). "Diverse biological activities of dandelion." Nutrition Reviews **70**(9): 534-547.

He, W., H. Han, W. Wang and B. Gao (2011). "Anti-influenza virus effect of aqueous extracts from dandelion." Virol J **8**: 538.

Hu, C. and D. D. Kitts (2003). "Antioxidant, Prooxidant, and Cytotoxic Activities of Solvent-Fractionated Dandelion (Taraxacum officinale) Flower Extracts in Vitro." Journal of Agricultural and Food Chemistry **51**(1): 301-310.

Kang, L., M.-s. Miao, Y.-g. Song, X.-y. Fang, J. Zhang, Y.-n. Zhang and J.-x. Miao (2021). "Total flavonoids of Taraxacum mongolicum inhibit non-small cell lung cancer by regulating immune function." Journal of Ethnopharmacology **281**: 114514.

Li, X. H., X. R. He, Y. Y. Zhou, H. Y. Zhao, W. X. Zheng, S. T. Jiang, Q. Zhou, P. P. P. Li and S. Y. Han (2017). "Taraxacum mongolicum extract induced endoplasmic reticulum stress associated-apoptosis in triple-negative breast cancer cells." J Ethnopharmacol **206**: 55-64.

Li, Y., Y. Chen and D. Sun-Waterhouse (2022). "The potential of dandelion in the fight against gastrointestinal diseases: A review." J Ethnopharmacol **293**: 115272.

Li, Y., Y. Deng, X. Zhang, H. Fu, X. Han, W. Guo, W. Zhao, X. Zhao, C. Yu, H. Li, K. Lei and T. Wang (2022). "Dandelion Seed Extract Affects Tumor Progression and Enhances the Sensitivity of Cisplatin in Esophageal Squamous Cell Carcinoma." Frontiers in Pharmacology **13**.

Lin, C. J., J. T. Chen, L. J. Yeh, R. C. Yang, S. M. Huang and T. W. Chen (2022). "Characteristics of the Cytotoxicity of Taraxacum mongolicum and Taraxacum formosanum in Human Breast Cancer Cells." Int J Mol Sci **23**(19).

Lis, B., D. Jedrejek, J. Rywaniak, A. Soluch, A. Stochmal and B. Olas (2020). "Flavonoid Preparations from Taraxacum officinale L. Fruits—A Phytochemical, Antioxidant and Hemostasis Studies." Molecules **25**(22): 5402.

Man, J., L. Wu, P. Han, Y. Hao, J. Li, Z. Gao, J. Wang, W. Yang and Y. Tian (2022). "Revealing the metabolic mechanism of dandelion extract against A549 cells using UPLC-QTOF MS." Biomed Chromatogr **36**(3): e5272.

Martinez, M., P. Poirrier, R. Chamy, D. Prüfer, C. Schulze-Gronover, L. Jorquera and G. Ruiz (2015). "Taraxacum officinale and related species—An ethnopharmacological review and its potential as a commercial medicinal plant." Journal of Ethnopharmacology **169**: 244-262.

Menke, K., M. Schwermer, J. Felenda, C. Beckmann, F. Stintzing, A. Schramm and T. J. Zuzak (2018). "Taraxacum officinale extract shows antitumor effects on pediatric cancer cells and enhance mistletoe therapy." Complement Ther Med **40**: 158-164.

Milovanovic, S., A. Grzegorczyk, Ł. Świątek, A. Dębczak, K. Tyskiewicz and M. Konkol (2022). "Dandelion seeds as a new and valuable source of bioactive extracts obtained using the supercritical fluid extraction technique." Sustainable Chemistry and Pharmacy **29**: 100796.

Nguyen, C., A. Mehaidli, K. Baskaran, S. Grewal, A. Pupulin, I. Ruvinov, B. Scaria, K. Parashar, C. Vegh and S. Pandey (2019). "Dandelion Root and Lemongrass Extracts Induce Apoptosis, Enhance Chemotherapeutic Efficacy, and Reduce Tumour Xenograft Growth In Vivo in Prostate Cancer." Evid Based Complement Alternat Med **2019**: 2951428.

Osborn, B. (2015). "First Flowering Dates for Central Oklahoma." Oklahoma Native Plant Record **15**(1).

Ovadje, P., S. Ammar, J. A. Guerrero, J. T. Arnason and S. Pandey (2016). "Dandelion root extract affects colorectal cancer proliferation and survival through the activation of multiple death signalling pathways." Oncotarget **7**(45): 73080-73100.

Ovadje, P., S. Chatterjee, C. Griffin, C. Tran, C. Hamm and S. Pandey (2011). "Selective induction of apoptosis through activation of caspase-8 in human leukemia cells (Jurkat) by dandelion root extract." Journal of Ethnopharmacology **133**(1): 86-91.

Ovadje, P., M. Chochkeh, P. Akbari-Asl, C. Hamm and S. Pandey (2012). "Selective induction of apoptosis and autophagy through treatment with dandelion root extract in human pancreatic cancer cells." Pancreas **41**(7): 1039-1047.

Ovadje, P., C. Hamm and S. Pandey (2012). "Efficient Induction of Extrinsic Cell Death by Dandelion Root Extract in Human Chronic Myelomonocytic Leukemia (CMML) Cells." PLOS ONE **7**(2): e30604.

Palmer, M. W. (2007). "The Vascular Flora of the Tallgrass Prairie Preserve, Osage County, Oklahoma." Castanea **72**(4): 235-246.

Rawa'a, A. M., S. H. Dhia and K. I. Nabeel (2018). "Cytotoxic Activity of Taraxacum officinale Ethanolic Plant Extract against Human Breast Cancer (MCF-7) Cells and Human Hepatic (WRL-68) Cells." Iraqi Journal of Cancer and Medical Genetics المجلة العراقية للسرطان والوراثة الطبية 11(1): 16-21.

Rehman, G., M. Hamayun, A. Iqbal, S. A. Khan, H. Khan, A. Shehzad, A. L. Khan, A. Hussain, H. Y. Kim, J. Ahmad, A. Ahmad, A. Ali and I. J. Lee (2017). "Effect of Methanolic Extract of Dandelion Roots on Cancer Cell Lines and AMP-Activated Protein Kinase Pathway." Front Pharmacol **8**: 875.

Ren, F., Y. Yang, K. Wu, T. Zhao, Y. Shi, M. Song and J. Li (2021). "The Effects of Dandelion Polysaccharides on Iron Metabolism by Regulating Hepcidin via JAK/STAT Signaling Pathway." Oxid Med Cell Longev **2021**: 7184760.

Richards, A. J (1973). "The origin of Taraxacum agamospecies". Bot J Linn Soc **66**: 189-211.

Sansores-España, D., A. G. Pech-Aguilar, K. G. Cua-Pech, I. Medina-Vera, M. Guevara-Cruz, A. L. Gutiérrez-Solis, J. G. Reyes-García and A. Avila-Nava (2022). "Plants Used in Mexican Traditional Medicine for the Management of Urolithiasis: A Review of Preclinical Evidence, Bioactive Compounds, and Molecular Mechanisms." Molecules **27**(6).

Sarı, A. and Z. Keçeci (2019). "Phytochemical Investigations on Chemical Constituents of Taraxacum bessarabicum (Hornem.) Hand. -Mazz. subsp. bessarabicum (Hornem.) Hand. -Mazz." Iran J Pharm Res **18**(1): 400-405.

Scaria, B., S. Sood, C. Raad, J. Khanafer, R. Jayachandiran, A. Pupulin, S. Grewal, M. Okoko, M. Arora, L. Miles and S. Pandey (2020). "Natural Health Products (NHP's) and Natural Compounds as Therapeutic Agents

for the Treatment of Cancer; Mechanisms of Anticancer Activity of Natural Compounds and Overall Trends." Int J Mol Sci **21**(22).

Shahidi Bonjar, G., S. Aghighi and A. Karimi Nik (2004). "Antibacterial and antifungal survey in plants used in indigenous herbal-medicine of south east regions of Iran." Journal of Biological Sciences **4**(3): 405-412.

Sharifi-Rad, M., T. H. Roberts, K. R. Matthews, C. F. Bezerra, M. F. B. Morais-Braga, H. D. M. Coutinho, F. Sharopov, B. Salehi, Z. Yousaf, M. Sharifi-Rad, M. Del Mar Contreras, E. M. Varoni, D. R. Verma, M. Iriti and J. Sharifi-Rad (2018). "Ethnobotany of the genus Taraxacum-Phytochemicals and antimicrobial activity." Phytother Res **32**(11): 2131-2145.

Siegel, R. L., K. D. Miller, H. E. Fuchs and A. Jemal (2022). "Cancer statistics, 2022." CA: A Cancer Journal for Clinicians **72**(1): 7-33.

Sigstedt, S. C., C. J. Hooten, M. C. Callewaert, A. R. Jenkins, A. E. Romero, M. J. Pullin, A. Kornienko, T. K. Lowrey, S. V. Slambrouck and W. F. Steelant (2008). "Evaluation of aqueous extracts of Taraxacum officinale on growth and invasion of breast and prostate cancer cells." Int J Oncol **32**(5): 1085-1090.

Stork, H. E. (1920). "Studies in the genus Taraxacum." Bulletin of the Torrey Botanical Club **47**(5): 199-210.

Tahir, K., S. Nazir, A. Ahmad, B. Li, A. U. Khan, Z. U. Khan, F. U. Khan, Q. U. Khan, A. Khan and A. U. Rahman (2017). "Facile and green synthesis of phytochemicals capped platinum nanoparticles and in vitro their superior antibacterial activity." J Photochem Photobiol B **166**: 246-251.

Trinh, N. V., N. Doan-Phuong Dang, D. Hong Tran and P. Van Pham (2016). "Taraxacum officinale dandelion extracts efficiently inhibited the breast cancer stem cell proliferation." Biomedical Research and Therapy **3**(7): 34.

Tsai, K. J., H. Y. Tsai, C. C. Tsai, T. Y. Chen, T. H. Hsieh, C. L. Chen, L. Mbuyisa, Y. B. Huang and M. W. Lin (2021). "Luteolin Inhibits Breast Cancer Stemness and Enhances Chemosensitivity through the Nrf2-Mediated Pathway." Molecules **26**(21).

Vijverberg, K., M. Welten, M. Kraaij, B. J. van Heuven, E. Smets and B. Gravendeel (2021). "Sepal Identity of the Pappus and Floral Organ Development in the Common Dandelion (Taraxacum officinale; Asteraceae)." Plants **10**(8): 1682.

Wang, S., H. F. Hao, Y. N. Jiao, J. L. Fu, Z. W. Guo, Y. Guo, Y. Yuan, P. P. Li and S. Y. Han (2022). "Dandelion extract inhibits triple-negative breast cancer cell proliferation by interfering with glycerophospholipids and unsaturated fatty acids metabolism." Front Pharmacol **13**: 942996.

Xue, Y., S. Zhang, M. Du and M.-J. Zhu (2017). "Dandelion extract suppresses reactive oxidative species and inflammasome in intestinal epithelial cells." Journal of Functional Foods **29**: 10-18.

Yang, Y. and S. Li (2015). "Dandelion Extracts Protect Human Skin Fibroblasts from UVB Damage and Cellular Senescence." Oxid Med Cell Longev **2015**: 619560.

Yarnell, E. and K. Abascal (2009). "Dandelion (Taraxacum officinale and T. mongolicum)." Integrative Medicine **8**(2): 35-38.

Zhang, S., Z. Song, L. Shi, L. Zhou, J. Zhang, J. Cui, Y. Li, D.-Q. Jin, Y. Ohizumi, J. Xu and Y. Guo (2021). "A dandelion polysaccharide and its selenium nanoparticles: Structure features and evaluation of anti-tumor activity in zebrafish models." Carbohydrate Polymers **270**: 118365.

Zhao, P., J. Liu, Q. Ming, D. Tian, J. He, Z. Yang, J. Shen, Q. H. Liu and X. Yang (2020). "Dandelion extract relaxes mouse airway smooth muscle by blocking VDLCC and NSCC channels." Cell Biosci **10**: 125.

Zhu, H., H. Zhao, L. Zhang, J. Xu, C. Zhu, H. Zhao and G. Lv (2017). "Dandelion root extract suppressed gastric cancer cells proliferation and migration through targeting lncRNA-CCAT1." Biomedicine & Pharmacotherapy **93**: 1010-1017.

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