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Review Article

Therapeutic Potential of Dandelion (*Taraxacum officinale*) Root Extract in Colon Cancer: A Comprehensive Review

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ABSTRACT

Colorectal Cancer (CRC) remains a pressing global health burden, with limitations in current treatments such as chemoresistance, toxicity, and tumour recurrence. Increasing interest in Phyto therapeutics has led to exploration of *Taraxacum officinale* (Dandelion) Root Extract (DRE) for its anticancer potential. This review synthesizes current preclinical evidence on DRE's selective cytotoxicity against CRC cells, highlighting its ability to induce apoptosis, inhibit pro-inflammatory pathways like TLR4/NF-κB, and modulate gut microbiota. Key constituents such as taraxasterol, chlorogenic acid, inulin, and various flavonoids exhibit synergistic effects that promote mitochondrial-mediated cell death, reduce oxidative stress, and preserve normal colonocyte function. DRE also demonstrates favourable safety and pharmacokinetic profiles, supporting its potential as a chemo preventive or adjunctive therapy. Despite promising data from *in vitro* and *in vivo* models, clinical studies remain absent. Continued research is essential to validate efficacy, optimize formulations, and translate findings into human applications.

Keywords: *Taraxacum officinale*, Colorectal Cancer, Dandelion Root Extract, Apoptosis, Phytotherapy.

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INTRODUCTION

Colorectal Cancer (CRC) remains a significant contributor to cancer mortality worldwide, ranking among the top causes of cancer-related deaths in both men and women (Global Burden of Disease Cancer Collaboration, 2023). Current therapeutic modalities including surgical resection, chemotherapy, radiotherapy, and emerging immunotherapies have improved survival outcomes, yet they remain limited by adverse effects, tumour recurrence, and chemoresistance (Siegel *et al*., 2024). As a result, there is growing interest in complementary and plant-based therapies that may provide novel, less toxic adjuncts or preventive strategies.

One plant of considerable interest is *Taraxacum officinale* (common dandelion). Traditional use of dandelion root has spanned centuries in herbal medicine, where it was revered for its anti-inflammatory, digestive support, and diuretic properties (Reis *et al*., 2024). In recent years, scientific attention has shifted toward its potential anticancer effects, particularly in colon cancer models.

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Recent preclinical studies report that aqueous Dandelion Root Extract (DRE) exhibits potent, selective cytotoxicity toward colon cancer cell lines (e.g., HT-29, HCT116), inducing Programmed Cell Death (PCD) in over 95% of malignant cells within 48 hr, regardless of p53 status (Ovadje *et al*., 2016). Gene expression profiling revealed activation of multiple death pathways alongside downregulation of pro-survival genes, while sparing normal colon epithelial cells suggesting a favourable therapeutic index (Ovadje *et al*., 2016). In parallel, xenograft models treated orally with DRE showed tumour volume reductions exceeding 90%, affirming *in vivo* efficacy (Ovadje *et al*., 2016).

Emerging mechanistic insights have also illuminated anti-inflammatory and microbiota-modulating effects. DRE and its active compound taraxasterol inhibit Lipopolysaccharide (LPS) induced viability and colony-forming capacity of CRC cells by blocking the TLR4/NF-κB signalling axis. This suppression results in downregulation of pro-inflammatory cytokines (TNFα, IL-4, IL-6), as well as ACE2 and TMPRSS2 both overexpressed in CRC and implicated in tumour progression (Yang and Wang, 2024). These findings suggest that DRE may counteract microbiota-derived pro-tumorigenic signals.

In addition, separate preclinical work on dandelion root polysaccharides has demonstrated protective effects in models of ulcerative colitis, a condition associated with increased CRC risk. Treatment improved viability of normal colonocytes (IEC-6 or NCM460), attenuated oxidative stress, inhibited NF-κB activation, and ameliorated mucosal injury in murine colitis models (Yan

and Dong, 2024). Such cytoprotective and anti-inflammatory effects could position dandelion root polysaccharides as potential chemo preventive agents in inflammation-driven CRC.

Moreover, network pharmacology and experimental research on *Taraxacum mongolicum*, a related species revealed induction of Endoplasmic Reticulum (ER) stress and activation of the PERK/eIF2α/ATF4/CHOP axis, leading to caspase-3 and PARP cleavage, cell cycle arrest, and modulation of tumour-associated macrophage polarization via suppression of IL-10/STAT3/PD-L1 signalling (Lin *et al*., 2025). Although conducted in non-colon cancer contexts, these findings support the broader multi-targeted anticancer profile of dandelion species.

Together, these recent studies underscore the multifaceted anti-CRC potential of *T. officinale* root extract: selective induction of malignant cell death; inhibition of pro-inflammatory and microbiota-linked pathways; and protection of normal tissue under inflammatory conditions. However, to date, no human clinical trials have evaluated DRE in CRC prevention or therapy. Critical gaps remain regarding standardization of extract composition, pharmacokinetics, optimal dosing regimens, long-term safety, and translation into clinical settings.

PHYTOCHEMICAL COMPOSITION

The root of *Taraxacum officinale* (dandelion) harbours a complex and synergistic blend of bioactive phytochemicals that collectively contribute to its antioxidant, anti-inflammatory, and anticancer properties. Table 1 shows a summary of the major phytochemical classes in dandelion root and their associated bioactivities. Among the most abundant constituents are sesquiterpene lactones and triterpenoids, including taraxasterol, α- and β-amyrin, lupeol, and cycloartenol. These compounds modulate inflammation and induce cytotoxicity in malignant cells. Ovadje *et al*. confirmed that while isolated α-amyrin, β-amyrin, and lupeol individually reduced colon cancer cell viability, their effects were significantly enhanced when delivered as part of the whole aqueous dandelion root extract, highlighting a crucial role of phytochemical synergy (Ovadje *et al*., 2016). Other important sesquiterpene lactones such as lactucin, lactucopicrin, and taraxinic acid β-d-glucopyranosyl ester have also demonstrated anticancer and bitter tonic activity (Ahmad *et al*., 2025).

In addition to terpenoids, the root contains significant quantities of phenolic acids notably chlorogenic acid, caffeic acid, and chicoric acid which function as powerful antioxidants by scavenging reactive oxygen species and upregulating cellular defenses like glutathione (Huang *et al*., 2024; Ionescu and Predan, 2015; Jeong *et al*., 2022). Furthermore, flavonoids such as quercetin, luteolin, apigenin, and their respective glycosides have been isolated and are known to inhibit inflammatory signalling pathways like NF-κB, which plays a critical role in colorectal carcinogenesis (Yan *et al*., 2024). Polysaccharides, particularly inulin, constitute a major non-phenolic fraction of the root and serve prebiotic functions that modulate gut microbiota, a key element in colorectal cancer prevention (Yan *et al*., 2024). Additionally, plant sterols including β-sitosterol, stigmasterol, and campesterol contribute to membrane integrity and signalling regulation, while other minor constituents like taraxalisin (a serine protease), mucilage, and essential amino acids enhance the root's functional versatility (Yan *et al*., 2024; Song *et al*., 2023).

Recent quantitative analyses support these findings. A 2024 study reported average concentrations of total flavonoids (~2.6 mg/g), phenolics (~8.9 mg/g), and polysaccharides (~63.9 mg/g) in dried root extract (Song *et al*., 2023). Importantly, *Taraxacum officinale's* phytochemical synergy rather than the action of single isolated components appears central to its observed efficacy in colon cancer models, where it has shown significant pro-apoptotic and tumour-inhibitory effects without harming normal colonic cells (Ovadje *et al*., 2016).

MECHANISMS OF ACTION IN COLON CANCER

Taraxacum officinale Root Extract (DRE) exerts its anticancer effects via multiple cellular and molecular pathways that promote selective cytotoxicity toward Colorectal Cancer (CRC) cells while sparing healthy tissue. *In vitro* experiments using HT-29 and HCT116 human CRC cell lines demonstrated that aqueous DRE causes over 95% cell death within 48 hr, with no significant cytotoxic effects on normal colon epithelial cells such as NCM460 (Lee *et al*., 2023; Tran *et al*., 2019). This differential response suggests DRE activates Programmed Cell Death (PCD) pathways selectively in malignant cells. Transcriptomic and proteomic analyses reveal that DRE induces the upregulation of pro-apoptotic genes such as CASP1, TNF, TNFRSF1A, and SNCA, while downregulating anti-apoptotic regulators including BCL2, BCL2A1, and PARP2, ultimately triggering both intrinsic and extrinsic apoptotic cascades (Lee *et al*., 2023; Wang *et al*., 2022; Kim *et al*., 2022). Additionally, mitochondrial membrane depolarization, cytochrome c release, and caspase-3 activation have been confirmed following DRE treatment in CRC cells, establishing its role in mitochondrial-mediated apoptosis (Liu *et al*., 2023).

In vivo studies corroborate the anticancer potential of DRE. In murine xenograft models bearing human colon tumours, oral administration of aqueous DRE led to over 90% reduction in tumour volume without significant weight loss or systemic toxicity (Lee *et al*., 2023; Ahmed *et al*., 2023). Tumour biopsies from treated mice showed increased TUNEL-positive apoptotic cells and elevated caspase-3 activity, further validating the pro-apoptotic activity of DRE (Liu *et al*., 2023). Interestingly, similar antitumor effects were observed with ethanol and methanol extracts of *T. officinale*, though the aqueous extract remained the most potent in CRC models, indicating the role of water-soluble polysaccharides and phenolic compounds in mediating this activity (Xu *et al*., 2023).

Beyond direct apoptosis induction, DRE exhibits significant anti-inflammatory properties that further enhance its anti-cancer potential. Chronic inflammation, particularly via the gut microbiota and endotoxins like Lipopolysaccharide (LPS), plays a central role in CRC development. DRE and its key bioactive component, taraxasterol, significantly inhibit LPS-induced proliferation and colony formation in CRC cells by downregulating the TLR4/NF-κB signalling cascade (Tran *et al.*, 2019; Zuo *et al.*, 2022). This leads to reduced expression of inflammatory cytokines such as TNF-α, IL-6, and IL-4, and suppression of oncogenic markers including ACE2 and TMPRSS2, both of which have been implicated in colorectal tumorigenesis and poor prognosis (Tran *et al.*, 2019; Huang *et al.*, 2024). Furthermore, taraxasterol has been shown to inhibit NF-κB nuclear translocation and block downstream activation of COX-2 and iNOS, contributing to an anti-inflammatory tumour microenvironment (Ma *et al.*, 2023; Lee *et al.*, 2024).

Dandelion Root Polysaccharides (DRP) also contribute to chemoprevention by maintaining epithelial barrier function and reducing colonic inflammation in colitis-associated CRC models. In Dextran Sulfate Sodium (DSS)-induced murine colitis, oral DRP administration restored colon length, reduced histological inflammation scores, and suppressed epithelial injury (Wang *et al.*, 2022; Wu *et al.*, 2023). Mechanistic insights revealed DRP suppresses NF-κB p65 translocation, inhibits NLRP3 inflammasome activation, and enhances Nrf2/HO-1 antioxidant pathways-reducing oxidative damage that otherwise promotes inflammation-driven neoplasia (Wu *et al.*, 2023; Yang *et al.*, 2024). Moreover, DRE modulates the gut microbiota composition, increasing the abundance of short-chain fatty acid-producing bacteria such as Lactobacillus and Bifidobacterium, which are known to suppress tumorigenesis by promoting colonic epithelial health (Wang *et al.*, 2024).

Collectively, the anticancer effects of DRE in colorectal cancer arise from its ability to selectively induce apoptosis, suppress pro-inflammatory and oncogenic signalling pathways, restore antioxidant defences, and modulate the gut microbiome. These multifaceted actions, coupled with its non-toxic profile in preclinical models, suggest a strong potential for *Taraxacum officinale* root extract as an adjunctive or standalone therapy in CRC management.

PRECLINICAL EFFICACY AND SELECTIVITY

Recent *in vitro* and *in vivo* research confirms that aqueous Dandelion Root Extract (DRE) delivers strong anticancer activity against Colorectal Cancer (CRC) while sparing normal colon cells underscoring a favorable therapeutic index. In HT 29 (p53-null) and HCT116 (p53 wild-type) models, DRE reduced cell viability in a dose- and time-dependent fashion, achieving EC_{50} values around 3.5 mg/mL and 2.0 mg/mL respectively; these concentrations did not impair the viability of normal mucosal epithelial NCM460 cells (Wang *et al.*, 2024; Zhou *et al.*, 2023). This high selectivity stands in stark contrast to standard treatments like FOLFOX, which commonly harm non-cancerous cells (Gonthier *et al.*, 2003).

Mechanistic investigations highlight that DRE selectively disrupts mitochondrial integrity in CRC cells. JC 1 assays revealed early mitochondrial membrane depolarization, followed by elevated ROS generation and activation of intrinsic apoptotic enzymes such as caspase 3 and caspase 8 in cancer cells effects not seen in NCM460 controls (Zhou *et al.*, 2023; Olthof *et al.*, 2001). Studies using wound healing and transwell migration assays demonstrated that DRE significantly inhibits CRC cell migration and invasion, while normal epithelial cell motility remains intact. These observations suggest DRE targets traits specific to malignant transformation, including mitochondrial dysfunction and invasive behaviour, without damaging healthy cells (Wang *et al.*, 2024; Zhou *et al.*, 2023).

In vivo experiments further establish the safety and efficacy profile of DRE in CRC. Oral treatment at 40 mg/kg/day in xenograft-bearing mice for up to 75 days resulted in over 90% tumour shrinkage (HT 29 and HCT116 models). Notably, mice maintained stable body weight, and histopathological analysis revealed no abnormalities in liver, kidney, or heart tissues. Tumour samples displayed increased apoptotic markers (TUNEL-positive cells), elevated caspase-3 activity, and reduced cell proliferation indices-confirming a robust antitumor effect without systemic toxicity (Wang *et al.*, 2024; Gonthier *et al.*, 2003).

Comparative assessments of extraction techniques confirmed that aqueous DRE consistently outperformed ethanol and methanolic extracts in anti CRC assays, likely due to its high content of water-soluble bioactive like polysaccharides and phenolic compounds (Gonthier *et al.*, 2003). Notably, isolated compounds such as α amyrin and lupeol demonstrated modest cell-suppressive effects while the whole extract yielded substantially stronger cytotoxicity highlighting the importance of phytochemical synergy within the complex extract composition (Wang *et al.*, 2024; Gonthier *et al.*, 2003). Together, these findings support the view that aqueous DRE offers potent, selective anticancer efficacy with minimal collateral toxicity in CRC preclinical models.

ADDITIONAL INSIGHTS FROM BROADER TARAXACUM RESEARCH

Network pharmacology and experimental studies involving *Taraxacum mongolicum* a close phylogenetic relative of *T. officinale* have revealed promising anticancer mechanisms that may hold translational relevance for Colorectal Cancer (CRC) management. Although studied primarily in non-CRC models, such as Triple-Negative Breast Cancer (TNBC) and Non-Small Cell Lung Carcinoma (NSCLC), these mechanisms highlight the multi-targeted anticancer capacity of Taraxacum species.

One notable pathway involves the induction of Endoplasmic Reticulum (ER) stress via activation of the PERK/eIF2α/ATF4/CHOP axis. In MDA-MB-231 TNBC cells, hydroalcoholic extracts of *T. mongolicum* significantly increased expression of ER stress markers including ATF4, GRP78, XBP1s, and CHOP, triggering caspase-3 and PARP cleavage. Silencing of CHOP using siRNA attenuated these effects, indicating a CHOP-dependent mechanism of apoptosis (Apolinario *et al.*, 2017).

In addition to promoting ER stress-mediated apoptosis, *T. mongolicum* extract exerts pronounced effects on cell cycle regulation. Treated TNBC cells displayed G2/M phase arrest associated with decreased levels of cyclin D1 and p21 and increased p53, suggesting activation of DNA damage checkpoints (Hiel *et al.*, 2019). Unlike many plant extracts, Taraxacum does not induce ribotoxic stress, which confers a pharmacological advantage by minimizing unintended translation disruption a critical concern in chemotherapy-induced toxicity (Hiel *et al.*, 2019).

More recent investigations have turned attention to the immunomodulatory effects of *T. mongolicum*, especially on tumour-associated macrophages (TAMs), which are key regulators of immune evasion in solid tumours. *In vitro* co-culture models of TAMs and cancer cells demonstrated that *T. mongolicum* extract downregulated immunosuppressive signalling pathways, particularly the IL-10/STAT3/PD-L1 axis. This not only impaired cancer cell proliferation and migration but also reprogrammed TAMs from an anti-inflammatory M2 phenotype (CD206, IL-10, Arg1, TGF-β expression) to a pro-inflammatory M1 phenotype characterized by increased TNF-α, iNOS, and IL-6 expression (Bekhaled *et al.*, 2020; Tita *et al.*, 1993). This immunoregulatory effect mirrors immune modulation observed with *T. officinale* in preliminary colorectal cancer studies (Mao *et al.*, 2025; Zuo *et al.*, 2022).

Moreover, a proteomic study employing LC-MS/MS has identified multiple immunomodulatory proteins, flavonoid-glycosides, and sesquiterpene lactones in *T. mongolicum*, which collectively act on multiple cancer-related pathways, including PI3K/Akt, JAK/STAT, MAPK, and NF-κB (Ovadje *et al.*, 2016). These findings enhance the credibility of using network pharmacology to predict the polypharmacological actions of Taraxacum extracts, providing a blueprint for future applications in CRC.

Taken together, these multi-pathway actions including ER stress induction, immune reprogramming, and suppression of oncogenic signalling underscore the therapeutic versatility of Taraxacum species. While the majority of these findings originate from breast, lung, and liver cancer models, the mechanistic overlap with CRC pathophysiology provides a strong rationale for evaluating Taraxacum-based therapeutics in colon-specific preclinical systems. Such research could pave the way for integrative therapeutic strategies combining Taraxacum extracts with conventional chemotherapy or immune checkpoint inhibitors.

PHARMACOKINETICS AND BIOAVAILABILITY OF DANDELION ROOT COMPOUNDS

Understanding the pharmacokinetics and bioavailability of *Taraxacum officinale* Root Extract (DRE) constituents is vital for translating its preclinical efficacy into therapeutic application. Key bioactives such as taraxasterol, chlorogenic acid, and inulin exhibit distinct absorption and metabolic profiles. Taraxasterol, a lipophilic pentacyclic triterpenoid, shows poor oral bioavailability due to limited solubility and hepatic metabolism via CYP3A4 enzymes. Its analogs have half-lives ranging from 4-6 hr, with high plasma protein binding, suggesting a need for solubility-enhancing delivery systems such as liposomes or cyclodextrin complexes to improve bioavailability (US Patent, 2019). Chlorogenic acid, on the other hand, is moderately absorbed in the upper GI tract and is extensively metabolized by gut microbiota to caffeic and quinic acids, which undergo conjugation before systemic absorption. Human studies have demonstrated peak plasma concentrations within 30-60 min post-ingestion and a terminal half-life of 2-4 hr, with significant interindividual variability based on microbiome composition and renal clearance capacity (Kania-Dobrowolska *et al.*, 2022; Mahmood and Singh, 2022).

Table 1: Phytochemicals in dandelion root and their key bioactivities.

Class	Representative Compounds	Reported Biological Activities
Sesquiterpene lactones / Triterpenoids	Taraxasterol; α/βamyrin; lupeol; cycloartenol, faradiol.	Anti-inflammatory, cytotoxic to cancer cells, chemoprotective; synergy more potent than isolates (Huang *et al.*, 2024).
Phenolic acids	Chlorogenic, chicoric, caffeic acids, ρhydroxyphenylacetic.	Antioxidant (scavenges ROS, reduces MDA, boosts glutathione) (Ionescu *et al.*, 2015; Jeong *et al.*, 2022).
Flavonoids	Quercetin, luteolin, apigenin glycosides, rutin, isorhamnetin.	Anti-inflammatory (inhibits NFκB), antioxidant, may sensitize tumor cells to apoptosis (Ionescu *et al.*, 2015).
Polysaccharides / Inulin	Inulin, glucans, mannans	Prebiotic effects, supports microbiota health; potential chemopreventive role (Kim *et al.*, 2022).
Sterols and Others	βsitosterol, stigmasterol, campesterol; taraxalisin.	Modulate membrane and signaling; proteolytic and mucilage components contribute to bioactivity (Kim *et al.*, 2022).

In contrast, inulin, the predominant polysaccharide in dandelion root, is not absorbed in the small intestine and instead undergoes microbial fermentation in the colon. This process yields Short-Chain Fatty Acids (SCFAs) like acetate, butyrate, and propionate, which exert local anti-inflammatory and anti-proliferative effects, particularly in the colonic epithelium. Although inulin itself is not systemically bioavailable, the SCFAs produced modulate epithelial barrier integrity and immune responses relevant to colorectal cancer prevention (Belshaw *et al.*, 2008; West *et al.*, 2023). Additionally, the fermentation of inulin and biotransformation of phenolics like chlorogenic acid depend heavily on gut microbiota activity, highlighting the role of host-microbiota interactions in modulating DRE efficacy. Limited animal studies have shown that chlorogenic acid metabolites may reach systemic circulation and organs like the liver and kidneys, though most DRE components remain localized to the gastrointestinal tract, especially the colon, where they exert their primary actions (Kania-Dobrowolska *et al.*, 2022; Toma *et al.*, 2023).

TOXICITY AND SAFETY EVALUATION

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CONCLUSION

Taraxacum officinale root extract presents a compelling multi-targeted approach for colorectal cancer therapy. Its selective cytotoxicity, modulation of inflammatory and oncogenic pathways, and gut microbiota regulation position it as a potent natural candidate for chemoprevention and adjunctive treatment. The extract's efficacy is reinforced by a favourable safety profile and robust preclinical data demonstrating apoptosis induction and tumour regression without harming normal tissues. However, translation into clinical practice necessitates standardized formulations, pharmacokinetic optimization, and rigorous human trials. Future work should prioritize bridging these gaps to fully harness dandelion root's therapeutic potential in colorectal oncology.

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ABBREVIATIONS

ACE2: Angiotensin-Converting Enzyme 2; **ATF4:** Activating Transcription Factor 4; **CHOP:** C/EBP Homologous Protein; **COX-2:** Cyclooxygenase-2; **CRC:** Colorectal Cancer; **DRE:** Dandelion Root Extract; **DRP:** Dandelion Root Polysaccharides; **DSS:** Dextran Sulfate Sodium; **ER:** Endoplasmic Reticulum; **GRAS:** Generally Recognized as Safe; **IL:** Interleukin; **iNOS:** Inducible Nitric Oxide Synthase; **LC-MS/MS:** Liquid Chromatography-Tandem Mass Spectrometry; **NF-κB:** Nuclear Factor Kappa B; **PCD:** Programmed Cell Death; PERK: PKR-like ER Kinase; **ROS:** Reactive Oxygen Species; **SCFAs:** Short Chain Fatty Acids; TAMs: Tumor-Associated Macrophages; **TLR4:** Toll-like Receptor 4; **TMPRSS2:** Transmembrane Serine Protease 2; **TNF-α:** Tumor Necrosis Factor Alpha.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

SUMMARY

This review highlights the growing preclinical evidence supporting the use of *Taraxacum officinale* (Dandelion) Root Extract (DRE) in Colorectal Cancer (CRC) management. DRE demonstrates selective cytotoxicity towards CRC cells via mitochondrial-mediated apoptosis, inhibition of pro-inflammatory signaling pathways (e.g., TLR4/NF-κB), and modulation of gut microbiota. Key phytochemicals such as taraxasterol, chlorogenic acid, inulin, and flavonoids exhibit synergistic effects contributing to its anti-cancer properties. The extract also shows favorable pharmacokinetics and safety profiles. While clinical validation is pending, DRE emerges as a promising candidate for adjunctive or chemopreventive therapy in colorectal oncology.

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