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Review Article

Taraxacum officinale (Dandelion Root Extract) in Oncology: Uncovering its Potential as a Natural Anticancer Agent

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ABSTRACT

Taraxacum officinale (dandelion), a common medicinal plant, possesses diuretic, anti-inflammatory and digestive properties. The potential use of dandelion root extract (DRE) for its anticancer effect has been established. This paper is a summary of existing evidence on its use in cancer management. *In-vivo* results show the selective toxicity of DRE towards different cancer cells while maintaining the normal cells. This is demonstrated in the preclinical studies. Its anticancer activity can be explained by bioactive compounds like sesquiterpene lactones and phenolic acids that are involved in the regulation of such critical signaling pathways as MAPK, PI3K/Akt, and NF-KB. These processes lead to suppression of tumor cell growth, activation of apoptosis, regulation of autophagy and inhibition of angiogenesis. Although there is promising preclinical evidence, there is limited clinical evidence. Hence, clinical trials ought to be conducted in a well-defined manner to prove their safety as well as therapeutic effectiveness. Comprehensively, DRE is one of the promising natural agents of anticancer therapy in the future.

Introduction

In recent years, natural products and traditional medicinal plants have become a growing focus as potential sources of safer and more effective anticancer treatment than conventional treatment. Cancer is among the major causes of deaths across the world and the available therapeutic interventions such that of surgery, radiation therapy, chemotherapy and immunotherapy are a common therapy in use or as a combination. Nonetheless, these methods have a mediocre effectiveness and are commonly linked with serious side effects as well as low specificity against cancer cells. The anticancer properties of plant-based phytochemicals have been well documented and include the ability to inhibit the growth of cancer cells and their programmed cell death (apoptosis), which could help slow the growth of cancer. Among them, dandelion (*Taraxacum officinale*, family *Asteraceae*) has become an attractive anticancer research candidate (Fig. 1).

Dandelion root traditionally has been used due to its diuretic, digestive and anti-inflammatory effects. In recent years, a number of preclinical studies have been conducted showing the anticancer effect of dandelion root extract (DRE) that specifically triggers the death of many cancer cell lines, such as colon, prostate, breast and leukemia. It is able to modulate crucial cellular pathways involved in cell survival, metabolism and programmed cell death.[1,2]

Overview of Extraction Techniques of *T. officinale* Root

The root of Dandelion (*T. officinale*) is widely studied in regards to its phytochemical composition and possible anticancer effect. Different extraction methods, such

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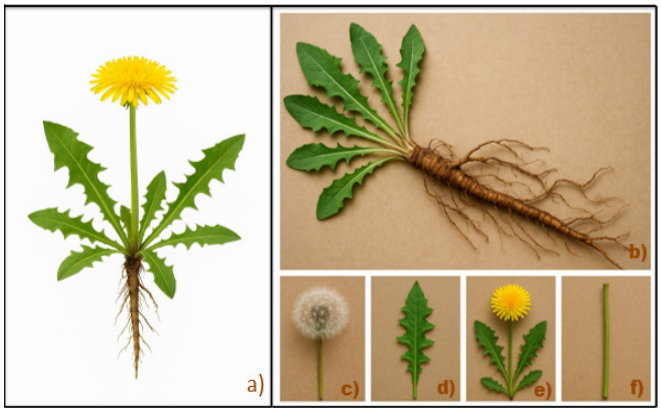

Fig. 1: Dandelion (*Taraxacum officinale*) and its different parts a) whole plant, b) root, c) seed, d) leaf, e) flower, f) stem.

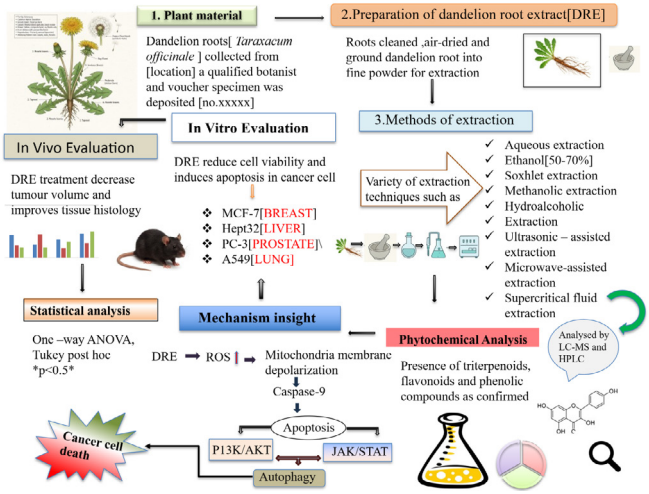

Fig. 2: Overview of Dandelion root extract

as aqueous, ethanolic, methanolic, hydroalcoholic, Soxhlet, ultrasonic-assisted, microwave-assisted and supercritical fluid extraction, have been utilized in different studies to isolate bioactive constituents. The yield and composition of phytochemicals are significantly affected by the extraction technique used. In recent years, dandelion root extracts have been investigated for their phytochemical composition using analytical methods like high-performance liquid chromatography (HPLC), gas chromatography-mass spectrometry (GC-MS), and liquid chromatography-mass spectrometry (LC-MS). The analyses are usually oriented at the discovery of phenolic compounds, flavonoids, and other secondary metabolites related to biological activity.[3,4]

Several *in-vitro* studies revealed dandelion root extract's anticancer properties. It was evaluated for its anticancer activity on human cancer cell lines such as MCF-7 (breast), HepG2 (liver), PC-3 (prostate) and other types of cancer cell lines. (prostate), and A549 (lung). These have been reported to cause a reduction in cell viability, apoptosis induction and oxidative stress changes. This association of such effects with the signaling pathways includes the PI3K/Akt pathway, JAK/STAT pathway and caspase-mediated pathway. Moreover, xenograft studies conducted *in-vivo* have also shown the possibility of dandelion root extract to suppress tumor growth, which further confirms its therapeutic potential. In sum, the existing evidence demonstrates that extraction techniques and analytic procedures are crucial in determining the biological activity of dandelion-derived compounds (Fig. 2) [5].

Bioactive Compounds and phytochemical profile of DRE

Triterpenoids

Taraxacum antungense Kitag and other species of dandelions produce a wide range of pentacyclic triterpenoids, among them taraxasterol, taraxerol, lupeol, and their acetates. It has also been reported that novel taraxastane derivatives like pseudo-taraxasterol and 2-amyrin are oleanane derivatives. These metabolites are formed through the mevalonate (MVA) pathway that is catalyzed by oxidosqualene cyclases (OSCs) and regulated by transcription factors like TaMYC2. Metabolic engineering has been proposed as an effective way to target the increased accumulation of taraxasterol and taraxerol in *taraxacum antungense kitag* through enhanced TaMYC2 expression [6]. These triterpenes possess great anticancer properties because of their ability to suppress PI3K/Akt and NF-kB signaling, induce apoptosis and regulate immune responses. This combined knowledge lays new possibilities of bioengineering *Taraxacum species* that have increased yield of triterpenoids to be used in pharmaceutical purposes [7].

Sesquiterpene

Sesquiterpenoid derivatives such as taraxinic acid 2 -D-glucopyranosyl ester (TA-G) were known to be major defense compounds in herbivores and environmental stress in *T. officinale* (dandelion). TA-G biosynthesis is mainly produced in the latex and roots, as a natural component of the chemical defense mechanism within the plant. In experiments, the silencing of the gene responsible for the biosynthesis of TA has been demonstrated and plants become more susceptible to herbivory by melolontha larvae, reducing the amount of the compounds by 90% [8].

Phenolic acids

Dandelion (*T. officinale*) is a useful medicinal plant and rich in polyphenolic bioactive components, the majority of which are phenolic acids, which are distributed in the flowers, plant leaves and roots. They have a significant contribution in antioxidant and therapeutic activity as hydroxycinnamic acids such as chlorogenic acid, chicoric acid, ferulic acid, caffeic acid and p-coumaric acid, as well as hydroxycinnamic acid derivatives. Chlorogenic

acid and chicoric acid are the best known phenolic acid compounds that have antioxidant, anti-inflammatory and anticancer properties. The phenolics content of flowers and leaves is significantly higher than that of roots (9.6 + 0.28 g/100 g and 0.086 + 0.003 g/100 g, respectively), indicating a tissue-specific distribution of phenolics. Overall, the phenolic acid profile of dandelion signifies the pharmacological potential of this bioactive in oxidative stress-related conditions, which implies that dandelion can be used in functional food and natural medicine (Fig. 3) [9].

Polysaccharides

T. officinale (L.) F.W. Schultz: Dandelion is a medicinal plant, rich in bioactive polysaccharides, that play an important role in the therapeutic activity of dandelion. Generally, polysaccharides from dandelion are obtained by hot water extraction, etc. Extraction is done by pulse or ultrasound-assisted extraction (or by enzymatic methods) and afterward purified. This includes ethanol precipitation and chromatographic separation. The yield, structural properties, and biological activity of these compounds can be affected by variations in their extraction and purification methods. The polysaccharides of dandelion are structurally monosaccharides, including arabinose, galactose, glucose, mannose, rhamnose and uronic acids, which are linked together through α- and β-glycosidic bonds to form complex architectures. Their molecular weights range from several kilodaltons to over one million Daltons, which significantly affects their physicochemical properties, including viscosity, solubility, and biological activity. Chemical modifications, such as sulfation and carboxymethylation, have been reported to enhance their solubility, thermal stability, and antioxidant capacity.

In terms of their activity, these polysaccharides show a strong antioxidant activity, scavenging free radicals. The goal is to help reduce the presence of radicals (such as DPPH, ABTS and hydroxyl radicals) and boost the body's own antioxidant defense systems, including superoxide dismutase (SOD) and glutathione peroxidase (GSHPx). Furthermore, they have anti-inflammatory properties by regulating important inflammatory mediators like tumor necrosis factor-α (TNF-α), interleukin-1β (IL-1β), interleukin-6 (IL-6), and nitric oxide. Further studies are being conducted on the anticancer effect of dandelion polysaccharides. For instance, some fractions (DLP120) have been found to induce apoptosis and S-phase cell cycle arrest in liver cancer models, which suggest its anticancer preventive and therapeutic effects. Apart from the anticancer activity, dandelion polysaccharides have been shown to have beneficial effects in lipid metabolism regulation (in preclinical studies), including decreases in serum triglycerides, total cholesterol and low-density lipoprotein (LDL) and increases in high-density lipoprotein (HDL) levels.

Furthermore, these polysaccharides exhibit antimicrobial and immunomodulatory properties, including enhanced macrophage phagocytic activity. The properties of polysaccharides are closely linked to their structure, such as molecular weight and the presence of side chains. It is thus vital to understand their structure–activity relationship for their possible use in pharmaceuticals, nutraceuticals and functional foods [10].

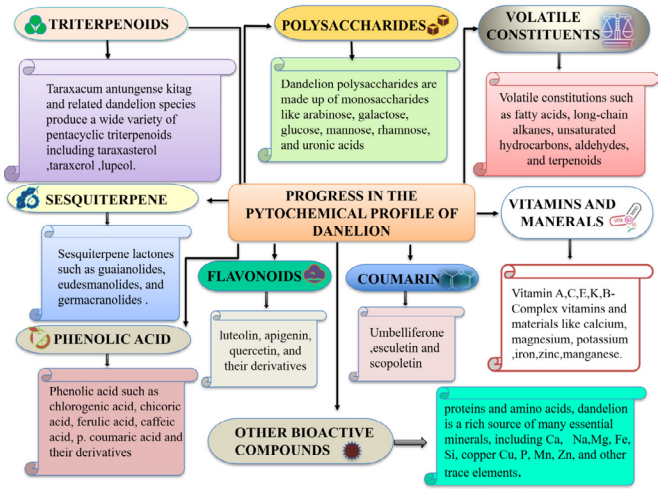

Fig. 3: Progress in the phytochemical profile of Dandelion root

Flavonoids

Flavonoids represent one of the most prominent classes of phytochemicals present in dandelion (*T. officinale*), contributing significantly to its biological and pharmacological activities. They are found as both aglycones and glycosides (luteolin, apigenin, quercetin and derivatives) throughout the plant, including in the roots, leaves and flowers [11].

The composition and concentration may differ in the case of flavonoids, which rely on species, plant part, as well as environmental factors such as soil conditions, light exposure, and growth stage. The number and quantity of them are usually determined by using complex analytical techniques. The separation and identification of lipids have been accomplished by various methods, including high-performance liquid chromatography (HPLC), ultra-performance and capillary electrochromatography (CE). Liquid chromatography (UPLC) is a common technique for separating and identifying lipids, and HPLC coupled with electrospray ionization mass spectrometry (ESIMS) [11].

The flavonoids of dandelion are potent antioxidants, mainly by acting as free radical scavengers. Anti-oxidation, chelation of metal ions and inhibition of lipid peroxidation. The flavonoids of dandelion are potent antioxidants, mainly by acting as free radical scavengers. Anti-oxidation, metal ion chelation and inhibition of lipid peroxidation. In addition, specific Luteolin and quercetin glycosides are flavonoids which have been linked to high anti-inflammatory, anticancer and antimicrobial activity. These compounds have been reported to possess potent anti-inflammatory activities by inhibiting the activation

of NF-κB and reducing the release of pro-inflammatory cytokines, like IL-6 and TNF-α [12]. Furthermore, certain flavonoids like luteolin glycosides and quercetin glycosides have been linked with strong anti-inflammatory, anticancer, and antimicrobial properties. It has been reported that these compounds have anti-inflammatory properties and inhibit activation of nuclear factor kappa B (NF-κB) and the production of pro-inflammatory cytokines such as tumor necrosis factor α (TNF-α) and interleukin-6 (IL-6) [12]. Moreover, the flavonoids from dandelion have shown activity for the health of the cardiovascular system, reduction of oxidative stress and improvement of liver and kidney function and activity of endogenous antioxidant enzymes. They also possess antidiabetic properties, mainly due to the inhibition of some major enzymes involved in carbohydrate metabolism such as α-glucosidase and α-amylase that play a role in the regulation of blood glucose levels [13].

Sterol

Dandelion (*T. officinale*) contains a range of bioactive phytosterols that contribute to its biological and medicinal properties. The sterols identified in dandelion include β-sitosterol, stigmasterol, and campesterol, with β-sitosterol being the most abundant. The composition of these sterols varies among different plant parts, with distinct profiles reported in pollen and root tissues. Phytosterols derived from dandelion have been widely associated with lipid-lowering effects, primarily through the inhibition of cholesterol absorption and modulation of cholesterol metabolism. In addition to their metabolic benefits, these compounds exhibit significant pharmacological activities, including antioxidant, anti-inflammatory, and anticancer effects [9]. Of these, the anticancer activity of β-sitosterol has been well investigated. It has been demonstrated to induce apoptosis in tumor cells through activation of caspase-3 in tumor cells and downregulation of antiapoptotic proteins like Bcl-2, which leads to mitochondrial-mediated cell death. Similarly, stigmasterol has been found to have anti-inflammatory, antioxidant properties, to inhibit angiogenesis and to suppress the proliferation of cancer cells [14].

In addition, non-polar components of dandelion root extracts, especially those containing sterol, were found to exhibit significant antioxidant activity and comparatively weak antibacterial activity. It emphasizes the use of dandelion sterols as natural components in lipid management, cancer chemoprevention and pharmaceutical and nutraceutical formulation [9-14].

Volatile constitution

The dandelion root (*T. officinale*) has been found to be an excellent source of an array of volatile phytochemicals that have been associated with the anticancer and antioxidant properties of dandelion. They are the fat acids, long-chain alkanes, unsaturated hydrocarbons, aldehydes and terpenoids. The most often reported constituents are n-heptadecane, n-eicosane, n-tetracosane, isohexadecane and nonacosane, as well as fatty acids like myristic, stearic and palmitic acids. When taken together, these bioactive compounds have part to play in the regulation of cellular activities associated with the initiation and progression of cancer. Aromatic alcohols, aldehydes, sesquiterpenes, monoterpenes and saturated and unsaturated fatty acids are present in the lipid fraction of dandelion root in minor amounts. These constituents have been associated with cytotoxic and antioxidant activities as like scavenging of reactive oxidant species and the regulation of oxidative stress, a key factor in carcinogenesis. Furthermore, these compounds have been reported to take part in apoptotic pathways, which have been shown to aid in the anticancer effects [15, 16].

Recent studies show that dandelion root volatile compounds have selective antineurotic action and are selectively toxic to cancer cells, not normal cells. They were found to be selective in different cancer cell lines, such as breast (MCF-7) and liver (HepG2) cells and were also discussed as potential complementary medicines in the treatment of cancer. In addition, these volatile *Staphylococcus aureus*, *Salmonella typhimium*, *Pseudomonas acrobium* and *Escherichia coli* exhibit antimicrobial properties against microbes such as *Staphylococcus aureus*, *Salmonella typhimium*, *Pseudomonas acrobium* and *Escherichia coli*. *Staphylococcus aureus* and *Bacillus subtilis* were isolated; this corroborates the statement of dandelion as a multi-purpose medicinal plant. Overall, the diverse volatile profile of dandelion root contributes to its therapeutic potential through combined antioxidant, anticancer, and antimicrobial activities [17, 18].

Coumarin

Dandelion root (*T. officinale*) has been put on the radar of scientists conducting phytochemical studies on the plant with regards to oncology, due to the large variety of bioactive compounds that it contains, especially coumarins such as umbelliferone, esculetin, and scopoletin. These benzo-α-pyrone derivatives represent an important component of the extract and are extensively implicated in its pharmacological effects. Coumarins exhibit anticancer activity through several mechanisms including cell cycle arrest (usually at the G_2/M phase), down-regulation of antiapoptotic members of the Bcl-2 family and activation of intrinsic mitochondrial apoptotic pathways. Additionally, they have been shown to block important survival signaling pathways, including PI3K/Akt/mTOR, decrease the expression of multidrug resistance proteins, and inhibit metastasis-related enzymes, including matrix metalloproteinases (MMP-2 and MMP-9). Initial testing has revealed that dandelion root extract (DRE) has selective activity against various cancer cell lines, including models of melanoma, colorectal, pancreatic and breast cancer,

while also being relatively non-toxic to non-cancerous cells.

These effects are likely attributed to the synergistic interactions among multiple phytoconstituents, including coumarin derivatives. Despite these promising findings, several limitations remain. Current evidence is largely restricted to preclinical studies, with limited data on pharmacokinetics, metabolism, and oral bioavailability of coumarins derived from DRE. Furthermore, well-designed clinical studies evaluating safety, efficacy, and optimal dosing are lacking. Given their multitargeted mechanisms of action, dandelion-derived coumarins hold potential as adjunctive agents in anticancer therapy, especially its role in regulating tumor proliferation, migration, invasion and signaling in tumor microenvironment. Future studies should be directed towards the identification and characterization of individual coumarin derivatives, elucidation of their mechanisms of action both separately and together, and optimized development to improve bioavailability and targeted delivery. Formulations are being developed [19].

Vitamins and minerals

T. officinale (Dandelion) has antioxidant and anticancer properties due to the presence of large amounts of vitamins, minerals and bioactive phytochemicals in its root extract. The root of the dandelion is said to contain vitamins, such as vitamin A (or beta-carotene), vitamin C (ascorbic acid), vitamin E (tocopherols), vitamin K and B complex (thiamine, riboflavin and niacin). These vitamins modulate the immune system, cellular defence and redox balance, which helps to decrease oxidative stress, linked to cancer occurrence. The minerals present in the dandelion root are calcium (Ca), magnesium (Mg), potassium (K), iron (Fe), zinc (Zn) and manganese (Mn). These are the necessary cofactors in DNA repair and enzyme antioxidant activity [20]. These compounds have been shown to exhibit very high cytotoxic activity on most cancer cell lines through their ability to induce apoptosis, inhibit cell proliferation and suppress metastasis. Vitamins C and E also exist in the extract as radical scavengers, which neutralize and inhibit the production of the REOS and block the production of cellular oxidative damage associated with cancer development. Such minerals as iron and zinc influence the immunological reaction, enzyme flows associated with tumor immunity, and gene control. All these nutritional and phytochemicals in *T. officinale* root extract have made its multi-target mechanism beneficial in cancer prevention and for potentially therapeutic applications (Fig. 3) [21].

Other bioactive compounds of dandelion root

In addition to proteins and amino acids, dandelion (*T. officinale*) is also extremely rich in most trace elements including calcium (Ca), sodium (Na), magnesium (Mg), iron (Fe), silicon Copper (Cu), phosphorus (P), manganese (Mn), zinc (Zn) and others. Nevertheless, the poisonous heavy metal accumulations such as nickel (Ni), cadmium (Cd) and lead (Pb) in roots of dandelion plants which may be influenced by environmental changes. Perhaps, consuming the dandelion tea in large quantities using the contaminated plants regularly may be detrimental to the health of human beings. It has been reported that nickel and cadmium enhance the build-up of potassium in roots of dandelions. The main environmental factors that affect the enrichment of the dandelion trace elements in various habitats are considered to be temperature and precipitation as well as soil composition [22]. The enhancement of heavy metal adsorption, specifically lead (Pb), has been demonstrated for the carboxy-modified and amino-modified polystyrene microplastics. These interactions can diminish the medicinal effects of dandelion extracts and detoxify some of the active phytochemicals such as flavonoids, polyphenols, and polysaccharides [23]. The dandelion roots are rich in minerals and phytochemicals, including polysaccharides, flavonoids, terpenoids, phenolic acids and inulin. They also have nutrients such as vitamins A, B, C, D and E among other secondary nutrients such as choline, inositol and other secondary nutrients. These constituents are mainly responsible of dandelion hepatoprotective, immunomodulatory, anti-inflammatory and antioxidant effects and these are the reasons that support the use of dandelion in both traditional and modern phytotherapy [24].

Anti- cancer Mechanism of the Extract

In the case of dandelion root extract, the action of this extract is primarily through the extrinsic apoptotic pathway (mechanism) activation of caspase-8 and caspase-9 that results in apoptosis of the cancer cells, and intrinsic ability to release cytochrome c from the inner mitochondrial membrane cytochrome-c [25, 26]. It also increases intracellular ROS which causes mitochondrial inability to function and oxidative stress-driven tumor-suppression [26]. Besides, dandelion root it inhibits tumor cell proliferation, survival signal and cell-cycle arrest by the following mechanisms of modulation of important oncogenic pathways, such as PI3K/Akt, JAK/STAT and MAPK [27]. DRE suppresses migration and invasion of cancer cells in addition to inducing cancer cell apoptosis by which it is achieved by downregulating degrading proteins and interrupting the ability to decrease in the risk of metastasis is a consequence of metabolism in choline and fatty acid synthesis (Fig. 4) [27, 28]. The safety and selectivity of DRE over conventional chemotherapeutics are emphasized by the fact that DRE inhibits the growth of xenograft tumor with a high degree of toxicity. These findings, that the dandelion root extract has a potential OF natural multi-target anticancer agent but needs further clinical investigation to determine its safety as a medicine in humans (Fig. 5).[29,30]

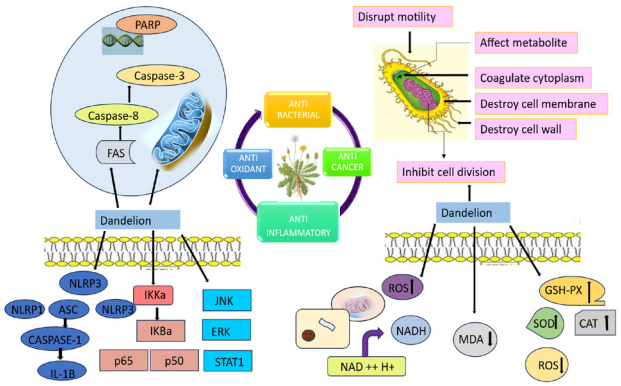

Fig. 4: Pharmacological activities relevant to cancer

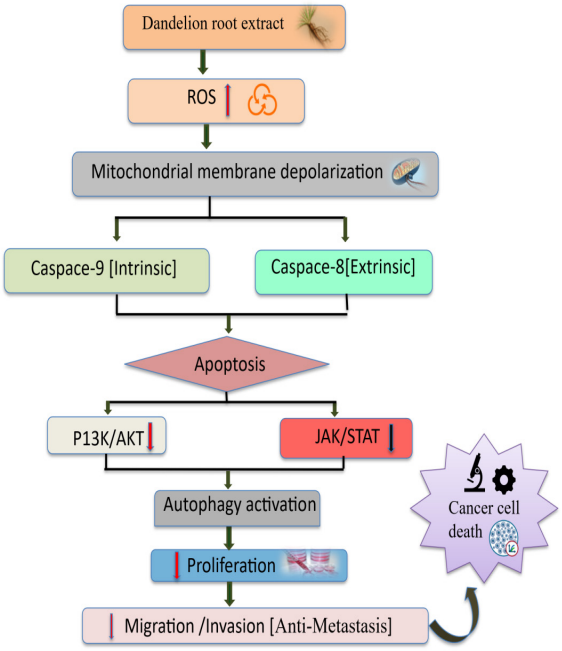

Fig. 5: Anticancer mechanism of Dandelion root extract

In-vitro Evidence

Dandelion (*T. officinale*) root extract (DRE) has been shown to have significant anticancer properties in multiple human cancer model systems, such as breast, gastric, pancreatic, colon, prostate, and leukemia cell lines, and with a relatively low toxicity to normal cells. DRE preclinical trials have shown that DRE causes apoptosis by activating caspase-8 and caspase-3, as well as, induction of mitochondrial membrane depolarization, which causes a large decrease in cancer cell viability. In addition, DRE has been shown to kill colorectal cancer models (HT-29, HCT116) independent of p53 status, suggesting its potential use in all genetic backgrounds. In addition, DRE has been shown to inhibit cancer cell migration, invasion and proliferation in breast and prostate cancer models by modulating certain of the key signaling pathways including, PI3K/Akt and ERK [31].

New findings also emphasize the contribution of oxidative stress and autophagy to the action of the DRE in anticancer. Bioactive triterpenoids, including taraxasterol and lupeol are deemed to be significant players in these processes. Moreover, DRE has anti-inflammatory and immunomodulatory effects, in part by inhibiting signalling pathways of TLR4/NF-KB and gene expression related to inflammation. DRE also has a role in metabolic reprogramming as the anticancer effect. Downregulation of major metabolic enzymes, such as choline kinase-alpha (CHKA) and fatty acid desaturase 2 (FADS2) especially in triple-negative breast cancer models has been reported leading to loss of lipid metabolism and growth of tumors. DRE has been phytochemically profiled to reveal various phytoconstituents like caffeic acid, apigenin, vanillic acid and triterpenes like 8-amyrin and 11-amyrin, which are probably the sources of its antioxidant and anticancer effects. On the whole, the existing *in-vitro* data indicate that DRE has multi-targeted anticancer activity, by modulating apoptosis, autophagy and cellular metabolism. These results justify its possible use as an adjunctive anticancer agent but more clinical validation and standardization studies are needed (Fig. 6) [32].

In-vivo evidence

Anticancer potential of *T. officinale* was because of its numerous studies on various cancer models. In a 2016 study in Oncotarget, it was shown that DRE triggers several cell deaths through signaling pathways in colorectal cancer cells, resulting in apoptosis and preventing tumor growth. Moreover, *in-vivo* results of the same study indicated that oral administration of DRE had a significant suppressive effect on tumor development in human colon xenograft models [33]. Further studies have also pointed to the therapeutic value of DRE. One of the 2017 studies

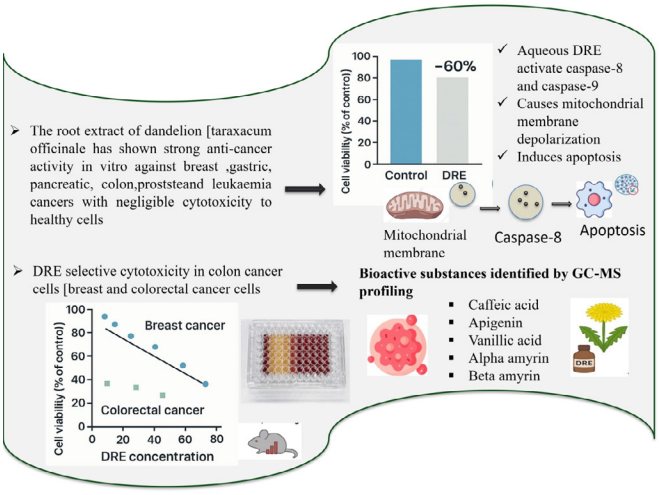

Fig. 6: *In-vitro* evidence of Dandelion root extract

indicated that DRE suppresses the growth and migration of human gastric cancer cells [34]. Most recently, a 2023 study showed that the interaction of DRE with all-trans retinoic acid (ATRA) improves anticancer activity in triple-negative breast cancer models by regulating apoptotic and metastatic-related gene expression [35]. Moreover, a 2024 study published in Experimental and Therapeutic Medicine demonstrated that DRE has anticancer effects by inhibiting the TLR4/NF-KB signaling pathway and suppressing ACE2 and TMPRSS2 expression in colorectal cancer cells, thus lowering the cell viability and colony formation caused by lipopolysaccharide (LPS) [36]. Moreover, the research has found out that dandelion-polysaccharides have a great antiprolliferative and pro-apoptotic effect on hepatocellular carcinoma models, which also confirmed the anticancer properties of dandelion-based compounds [37]. In sum, the existing preclinical data show that DRE has multi-targeted anticancer effects by regulating the actions of apoptosis, proliferation, metastasis, and inflammatory signaling pathways. Even though additional clinical trials are required to determine efficacy and safety in humans, when combined as a block such experiments can show a significant amount of evidence about the therapeutic efficacy of dandelion root extract in cancer treatment (Fig. 7).

Synergistic potential with Chemotheraphy

High possibility of dandelion root extract (DRE) when used in combination with conventional chemotherapeutic drugs has rendered dandelion root extract an attractive adjunctive agent in the treatment of cancerous conditions. According to preclinical studies, DRE may be used to enhance the anticancer activity of chemotherapy agents such as cisplatin by making the cancer cells susceptible to them. Importantly, DRE can selectively kill cancer cells without damaging normal cells, which can probably help to minimize the adverse effects of chemotherapy that are so often associated with it [38,39]. Mechanistically, DRE induces

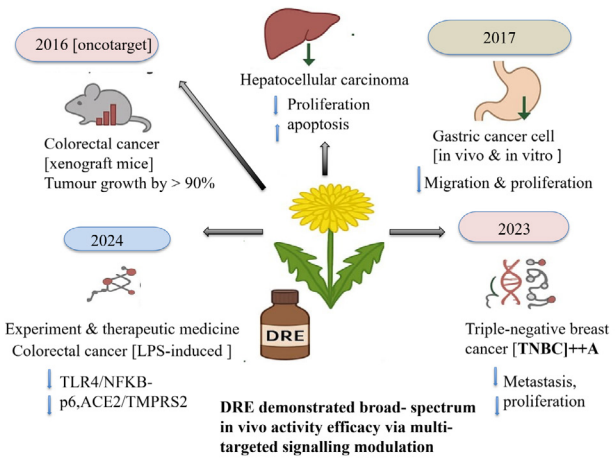

Fig. 7: *In-vivo* evidence of dandelion root extract

apoptosis, or programmed cell death, in numerous types of cancer cells and modulates key signalling pathways that mediate cell survival, proliferation, and metastasis that include PI3K-Akt and JAK-STAT [40, 41]. It would be logical to use DRE along with standard chemotherapy because of its dual effect of directly destroying cancerous cells and disrupting their survival programs. Although most of these findings are *in-vitro* and *in-vivo* research, they prove that DRE has the potential of being a safe and effective adjuvant in cancer treatment and hence further research in the form of clinical studies is necessary to verify its efficacy in human beings [42].

Recent Clinical studies and human evidences

Despite most of the research on dandelion root extract (DRE) being *in-vitro* and in vivo, emerging clinical and human evidence suggests that DRE has potential to be used as a supplemental treatment of cancer. The potential of DRE in the treatment of leukemia was also brought to light by a case report which was also remarkable where a patient with chronic myelomonocytic leukemia (CMML) had attained complete remission after taking DRE in conjunction with papaya leaf extract [43]. Human-cell-line data (MCF-7 and MDA-MB-231) has demonstrated that DRE can induce cytotoxicity, inhibit proliferation and suppress metastasis in breast cancer, with all-trans retinoic acid (ATRA) altering the expression of genes involved in the progression of the disease [44]. On the same note, transplantations on colorectal cancer cells indicate that DRE is able to block cell mobility as well as proliferation, which indicates potential benefits as a treatment [45]. The anticancer activity of aqueous dandelion seed extract was confirmed by the inhibition of the migration, proliferation and angiogenesis of oesophageal squamous cell carcinoma (ESCC) [46].

Conclusion

Among the phenolic acids, flavonoids, coumarins and sesquiterpene lactones, the dandelion root extract (DRE) is a traditional herbal remedy with a high level of phenolics, flavonoids, coumarins, and sesquiterpene lactones possessing the potential to become a multi-target anticancer agent. Its diversity of phytochemicals is linked to strong antioxidant, anti-inflammatory, antiproliferative, pro-apoptotic, and anti-metastatic activity. Accumulating *in-vitro* and *in-vivo* data have confirmed these effects, showing that inhibitors of key oncogenic signalling pathways, including PI3K/Akt, MAPK and JAK/STAT, and activators of caspase dependent apoptosis and autophagy, have been demonstrated. DRE causes inhibition of tumour growth and migration, in addition, it shows positive synergy with conventional chemotherapeutics, meaning it has a great potential as an adjuvant to enhance the efficacy and reduce the toxicity. DRE is a potential candidate in the translational oncology in the future because of

its low toxicity and favourable safety profile, despite the absence of clinical information. Nevertheless, such problems as enormous human experiments, optimization of doses, bioavailability improvement, and standardization should be addressed. The innovations in the field of nanotechnology, molecular targeting, and phytochemical standardization have offered DRE a great opportunity to evolve into an evidence-based supplemental approach to cancer treatment in the future. This would offer a more secure and all-encompassing method to enhanced therapeutic outcomes.[47]

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