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Review Article

Dandelion (*Taraxacum Officinale*) Leaf and Root Extraction: A Systematic Review

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ABSTRACT

This review critically assesses various strategies for the isolation of bioactive from dandelion (Taraxacum officinale), which covers both traditional methods such as maceration and decoction, as well as more advanced ones including ultrasonic and microwave-assisted extraction methods. The traditional methods are favorite for their simplicity and user-friendliness, a quality that makes them suitable even for resource-low settings in terms of efficiency; however, they frustrate due to slow extraction times. While on the one hand, advanced techniques rely on modern technology to greatly improve the previously insufficient and slow extraction process alongside a number of environmental benefits, such as solvent destruction and energy saving, the key strategies, on the other hand, isn't that effective to achieve the target. The paper follows this line by appraising the two methods of close efficiency, range fitting for different types of compounds, and given environmental impact in order to pinpoint a mix of ultimate practices for obtaining the valuable phytochemicals from dandelion. These results support observation of the tendency to use modern science and innovations to focus on efficiency and sustainability in phytochemical extraction from herbal resources.

INTRODUCTION

The Dandelion (*Taraxacum Officinale*) is the common name of an herbaceous perennial plant, native to Eurasia, but it can be found in the temperate regions all over the world [1]. Once, dandelion was an ignored weeds plant but things have changed both in scientific and herbal circles. The Medicinal value has been discovered; dandelion possesses bioactive compounds present in it and this may have a number of health benefits [2]. Such plant stands in the spotlight of aromatherapy and nutraceuticals with utilizing the different parts of the plant - leaves, flowers, and roots for different purposes such as treating

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diseases and supplement the body's needs. Taraxacum is the name of a genus including several species collectively known as dandelion, which share, among other characteristics, many morphological and chemical features [3]. The omnipresence of this flora and their ability to produce proliferately and for long periods [4], makes them auspicious sources for diverse uses. Among cultural healing practices of Europe, Asia, and North America, dandelion is applied in treating some of the several conditions like fatty liver disease or chronic inflammations [5]. Recent pharmacological studies identified some of the traditional herbal uses of this plant. They compared the healing effects of the plant to its complex structure of phytochemicals [6].

Dandelion stands out during assay for the high content of phenolic compounds, terpenoids, and flavonoids, which might be responsible for the anti-inflammatory, antioxidant, hepatoprotective, and diuretic effects of this plant [7]. These exercises not only show plants' beneficial effects in medicinal purposes but also their integration into preventive healthcare systems that are greatly sought after today being natural and safe [8]. The chemography of dandelion is entirely different between its parts, the root and the leaves of the plant they being labelled throughout for diverse types of the active products [9]. The tap roots are the wealthiest part of the plant in the inulin which also has the side effect of taraxacin [10], and taraxacerin which supplement the liver health and the body digestion [11]. But the leaves, which has a higher density of potassium and phenolic acids, are good in the foregoing of fluid [12].

Besides, the possibility of these compounds becoming bioactive is high and their demand from consumers with natural products growing [13], efficient extraction of these crucial compounds from the parts of the dandelion becomes critical [14]. Choosing the right extraction method affects heavily the yield, quality, and performance of the bioactive compounds that is obtained from it. Traditionally maceration and decoction techniques have been popular due to their simplicity and lower operational expenses [15]. Although these techniques are often unsuccessful because of their lengthy extracting times and low extraction efficiencies which also down regulate stability of these compounds. However, these methods have certain drawbacks; hence the more advanced ones which, for instance, involve both sonochemical extraction and microwave-assisted extraction have been designed [16]. Such methods relying on physical forces or electromagnetic radiation either use a gentle approach that is based on specific physical forces or meanwhile speed up the extraction process, reducing time and increasing productivity without sacrificing the quality of the extracted compounds [17]. These brightening up the technologies are not only helpful for the dandelion extract mass production reaching but also, they have some positive impact on the sustainability of extraction processes by reducing energy consumption and waste disposal solvents [18]. The fast-increasing number of studies and researchers identifying dandelion's phytomolecules and the overall benefits of dandelion for health symbolize the growing acknowledgment of the plant's worth. In addition to the scientific exploration, the chemical composition and therapeutic effects of dandelion, that uncovers the complexity, and presenting this steadfast herbal remedy with the self-evident solution for modern medicine and nutrition is also unforgettable. The present review is a summary on the current prominence of various techniques of extraction of the dandelion leaf and its root, a profusion that we shall compare and subsequently address the applications of the extracts in the industries. Attention is being paid to the development and assessment of extraction

technologies as well to their influences on yield and quality of the dandelion extracts. The end result will be a paper with appropriate knowledge about this process, for instance, better use of dandelion as both medicinal and nutritional source.

LITERATURE REVIEW

The article "Iodine Biofortification of Dandelion Plants (*Taraxacum Officinale* F.H. Wiggers Coll.) with the Use of Inorganic and Organic Iodine Compounds" (2023) by Iwona Ledwożyw-Smoleń and Joanna Pitala.

Phytochemical Constituents

Dandelion (*Taraxacum Officinale*), as a perennial herb, is unique due to its very high levels of bio active constituents, all of which are contributory to its significant medicinal value. The phytochemical group of this endangered creeping herb contains a variety of components with established biological functions. Probably, the best known are chlorogenic acid (a type of phenolic acid), flavonoids, sesquiterpene lactones (another kind of terpenes), triterpenes and inulin.

Chicoric and chlorogenic acid, members of the phenolic acid group, are the richest substances in dandelion. This group is distinguished by excellent antioxidant activity. These phenolic compounds are in abundances within leaves and roots especially and contribute to dandelions' antioxidant properties and maintaining a healthy physique. Major flavonoids like luteolin and apigenin in dandelion are known to bring down inflammation, diminish the occurrence of cancer, and act as antioxidants contributing to the prevention and treatment of diverse long illnesses. Sesquiterpenic lactones, constituting taraxacolide and taraxinic acid glycosides, are the dominant compounds in the roots, and, due to their anti-inflammatory and antimicrobial effects, they can be used in the treatment of inflammatory conditions.

Aside from this, phytochemicals have unique healing powers and also determine the way of extracting these compounds in order to get an efficient yield.

Pharmacological Activity

Dandelion chemical components are as different in their pharmacological activities as the linguistic components are different in healing languages. Data has been shown that it works in cases of both diuretic and digestive functions as well as hepatoprotective role. Being a natural diuretic, dandelion has the feature to increase urine extraction and production. It has an additional advantage that it does not cause the loss of potassium which is a side effect of conventional diuretics. Sodium excretion and urinary output that are promoted by the diuretic makes it useful for managing these conditions.

In the human digestive tract, it was found that there is an appetite-regulating and organizing function, dandelion's bitter chemicals are used for this purpose. These impacts are related to sesquiterpene lactones (a class of compounds that increase the secretion of bile, thus allowing the easier digestion of lipids). Moreover, recent studies show that extracts of the dandelion root can be used as an alternative to anti-inflammatory medications including arthritis and eczema. It does so by the antioxidant compounds, mainly, the phenolic acids and flavonoids which defend cellular structures from the damage of oxygen exposure, hence, its role in the preventing of chronic illness especially the credited types of cancer.

EXTRACTION METHODS

The correctness of the extraction process of phytochemicals from dandelion significantly works on the appropriate method used. The method employed in the process determines the compounds that are extracted and how the nature of the extraction is influenced by aspects like the type of solvent, time, temperature, and the uniqueness of the extraction technique.

Maceration

The maceration technique is being practiced for quite a long period and the dandelion leaf and root are being seeped in a liquid at a room temperature level so as to remove the useful and desired phytochemical constituents [19]. This is easy to use and significantly cheap compared to other methods and at the same time does not require sharp objects. This phenomenon gives the solvent the ability to penetrate the plants cells and dissolve the essential compounds it is looking for and subsequently make them available in the solvent's phase [20]. Generally, the maceration process starts with the plant preparation which includes the chopping and crushing of dried plant matter [21]. Dandelion leaves and roots after first getting them washed then dried and ground them acquire a powder that enables extraction to a better surface area. The material is ignored, the container added and then a solvent appropriate to the systems spilled. Water is the solvent of choice for the maceration of dandelion due to its solubility of the extracted compounds while ethanol and methanol can also be used. After placing the green plant material inside the container, its lid is tightly closed and the whole plant stands at room temperature for several hours or even multiple days. During this time, the plant cells act as a source that the solvent dissolves being able to go into the solvent phytochemicals that are soluble which flow into the solvent. The process of agitation which involves the rotation of equipment can be used from time to time in order to mix content and make it more efficient in the extraction process [22]. Then a time-complying filtration step follows that aspirates the solid residues and presents the liquid extract on the surface. The filtrate comprising of the extracted phytochemicals plays the role of the final product but it can also further be concentrated, and evaporation or lyophilisation may be used, so as to obtain solid extract or kept as a liquid concentrate.

The main benefits of maceration include the ease of using it as it needs only little technical expertise which makes them useful for small-scale enterprises and people with long-term traditions [23]. It is also good, as it is a safe extraction method and it can easily use non-toxic solvents like water or ethanol and so it is possibly efficient for the preparation of dietary supplements and products for human consumption. In addition, this technique is ideal because it does not need higher temperatures, so it extracts thermolabile components, which might degrade if exposed to high temperatures [24]. While maceration possesses some benefits, it might also bring up several drawbacks. This means that it is less efficient and takes more input materials than newer extraction techniques. Maceration, in brief, is the least effective loss of bioactive components. It is in the passive diffusion process which is comparatively slower and may not extricate fully all possible phytochemicals [25]. Other than that, the longer solvent exposure can promote degradation of certain sensitive compounds and separate some unwanted substances, which affects the purity of the extract in both its quality and amount [26].

Different aspects can cause a variation of a degree of solubility, such as the selection of solvent, the size of plant particles, the ratio between solvent and the material, the time of extraction and

occasional stirring [27]. Refining these factors permits getting the most of the yield. In particular, the increased surface area by grinding of the plant material more precise may result in more intimate contact between the extract and phytochemicals. So as the solventity of selected solvent will be high, the extraction system will become more efficacious.

Aqueous Extraction

Water extraction, which is another term of aqueous extraction, is the most common method to isolate or purify the phytochemicals from dandelion flower (*Taraxacum Officinale*) or plants [28]. This type of procedure employs water as a solvent and usually involves boiling or simmering the plant material in order to extract the soluble bioactive compounds within it [29]. It can be successfully used to isolate an intended compound from an organic medium, as well as when the target compound is stable at higher temperatures and has a polarity towards water [30].

The process of water extraction originates with the supply of plants' materials. Dandelion suits and roots are dug up, cleaned and kept fresh or dried [31]. Most of the plant parts get cut or the grinding so that there is more space made for the extraction of the cannabinoids. In the conventionally boiling method, the plant material prepared is poured into a pot with an amount of water enough to cover the whole material [32]. Next, the two will combine and the mixture usually boils and simmers for a chosen time, which can take a few minutes to several hours, again, depending on the desired extraction strength and the natures of the target compounds. The second option involves "hot water infusion" which can be similar to making tea, cold water is finally poured over the plant material, and it is left to absorb the heat and hence steep [33]. Quickly, the former is boiled and the latter macerated for a while, in quite different timeframes from 10 to 30 minutes. Next comes filtering the brew (during boiling or infusion) in order to remove plant particles. This solution will remain liquid unless boiled it off to mildly concentrate by reducing volume through evaporation. For long-term storage, the extract could be either a freeze-dried or a sprayed-dried version and it became a powder.

Water extraction is preferred for its safety reasons, this is due to the fact that it uses water which we know to be safe and harmless, non-flammable, and readily abundance [34]. This virtue of the process entails that it is environment-friendly and compatible for the production of extracts meant for consumption in food and beverages as well as herbal remedies. That equals to the lowest price extraction techniques. Only generalized equipment is needed. As it is an operation that is conducted above water and heat temperatures, it is particularly efficient in denature proteins and extracts heat stable compounds. Through this, it may help to set free compounds that are otherwise not able to fulfil their functions due to them being bounded within the cellular framework of the plant tissue [35].

Water taking represents a great part of green water and blue water. Hence, it functions positively in many cases. However, it has some drawbacks. Method however, is relatively not as effective to extract hydrophobic or lipid-soluble compounds, which are better dissolved by organic solvents. Furthermore, through the high temperatures used these compounds may become unstable and may no longer be viable for the extraction process therefore reducing their biological activity. Water retrieval process could also contain water soluble such as polysaccharides and might results in the clogging of the solution if not properly controlled [36]. Such complexity may cause several

difficulties during the later component of purification and extraction processes.

When the extraction temperature is hiked up, it favours the solubility of some of the components and, consequently, facilitates the extraction process [37]. However, higher temperature must be utilized with caution to prevent the degradation of the sensitive components. An ideal particle size is also important since it decides the quantity extracted through the solvent that is its surface area; the smaller the particles are, the more surface area matters and also gives rise to complications in filtering.

Ethanol extraction

The technique of ethanol extraction is a major one for isolating the dandelion (*Taraxacum Officinale*) constituents responsible for the pharmacological effects [38]. This technique uses alcohol as the solvent. It is a versatile approach as it uses many bioactive compounds. Ethanol overcomes the persistent problem of the dissolution of both fat-soluble and water-soluble mixtures, hence, leads to an inclusive extraction process that infectious diseases and its treatment drugs can provide.

The first step in the ethanol extraction process is to get the plant ready for this [39]. Dandelion leaves and roots are then the harvested, cleaned thoroughly to eliminate the moist which can change the ethanol and therefore lower the extractives hence implying that the extraction processes will not be efficient. The dry plant material will be usually ground into a smaller pieces in order to bring out a higher surface area which will lead to a better solvent exposure and extraction. The plant material on the ground as pulp, is macerated and percolated in ethanol [40]. The choice of technique depends on the scale and specific requirements of the extraction. Steeping or the maceration process is made with the plant material of ethanol where it is kept at room conditions temperature for a long period of time [41], for example, a few days to weeks. Normally the container will be sealed, and the mixture will be stirred from time to time. Percolation is a rapid method in which ethanol is ever ceasing through a column packed up with remnant material of plants. The use of this method is not only less time consuming and is largely applied in more manufacturing kinds of business. Next, the raw material solution is filtered to remove the wispy plant residues. The ethyl comes next and is evaporated through droplet pressure (RE), or a similar technique, to get the ethanol back and only leaves an extract. This extract may be applied as is the liquid form or can be further extracted using drying techniques like spray drying or lyophilization to be turned into the powder form [42].

Ethanol extraction has been favored as it is known to have a wide spectrum of chemical constituents extracted by virtue of it being polar and capable of dissolving polar and non-polar chemical affairs. This is a good reason for ethanol to be the method of extraction for any plants that contain a complex assortment of bioactive ingredients [43], for example in the case of dandelion. Ethanol is also deemed to be an environmentally friendly organic solvent considered to be safer than other common organic solvents- namely hexane and benzene which are highly toxic and bear health risks. Ethanol is eco-friendlier besides being most commonly associated with food and drugs due to its safety levels in accordance with legislative requirements for consumer safety [44]. On the other hand, is ethanol extraction handy and fast, it is not flawless. Ethanol contains water and on one side, this fact is advantageous because that water-soluble compounds like sugar and certain polysaccharides can be extracted from ethanol. However, it is a disadvantage on the other side

because it may result in extracting salutary substances which may lead to the insertion of difficulties in the process of purification [45]. Also, ethanol is more volatile and when used on large scales there is a need for such a careful approach and conditions for storage, which in the case of ethanol is even more complicated.

Decoction extraction

The decoction is one of the ancient methods of extraction that were mostly employed for herbal healing to extract the active compounds from the fibrous extracts of the plants such as the root, bark, and woody stems [46]. The method is through prolonged boiling of the plants parts in water creating break down premises which allows water-soluble compounds to solubilize in the water. Bark tea is prepared from dandelion roots that possess not only preparation properties but some specific sesquiterpene lactones soluble in water only at high temperatures [47].

The decoction process begins with making the herbal carrier into a form that produces the desired effect. The shallow roots of dandelion are usually washed, chopped or ground into powder so that the surface of the particles will enlarge, the water absorption which is then often given the task to penetrate deeper into the particles will increase, as a result [48]. Following this, the prepared material is recently added to the pot filled with (precise) amount of water. The ratio of water to plant material can differ depending on the particular need of the concentration of the decoction but it is traditionally higher to compensate for the water vaporized during the heating process. The broth gets boiled and then reduced over a low heat for a long time covering approximately 30 minutes; overnight or even more commonly to few hours. Consequently, the longer extraction is necessary because it enables the removal of the not running off easily water-soluble pills that do not leach at lower times or shorter time periods. When performing one of the ancient options, the water volume decreases and the final mixture comes in a higher concentration [49]. After boiling is finished, the hot liquid is filtered out to eliminate all solid plant with, only the extract remains. These resources can be directly used in the classroom or saved for future occasions. Similar to long-term storage, the decoction may also be concentrated by spray drying or even dehydration into powder form. Hence, you can have either the camomile decoction as concentrate or powder.

Among the most effective features of decoction is that it can pull out really difficult water-soluble compounds which can otherwise become missing with other techniques of extraction [50]. Such solvent does not use other chemical substances and water is used as a solvent. It is safe and harmless, particularly for applications in these fields which other chemical substances may not be desirable such as food and medicine. These preparations do not involve any advanced appliances for preparation, which allows people to choose between traditional and home use. The decotactify aspect has simply positive effects but also some limitations. Such a long process is energy intensive because the needed boiling takes too long to obtain [51]. In addition, there is the possibility that the heat-sensitive compounds should suffer from the decomposing process caused by these high temperatures over a long period. Volatile compounds might get evaporated along with the steam during the boiling process and hence another drawback in this method is the presence of compounds that would make it lose [52]. That might lead to the loss of even those components that are relatively difficult to extract and present chemically on the original plant. This might reduce the therapeutic effectiveness compared with the case of methods that maintain all the parts of the plant in the final extract.

Ultrasonic assisted extraction

In recent years, the ultrasonic-assisted extraction (UAE) technique has been implemented to expedite the extraction of useful substances from plant tissues; for the introduction, the dandelion (*Taraxacum Officinale*) [53]. Here the mechanical effects of sonication are used so that the solvent penetrates plant tissues more thoroughly and thus better mass transfer of compounds into the solvent, faster and more efficiently than in traditional methods [54].

The extraction procedure encompasses the preparation of plant material that is primarily sanitized, dried and partially grinded to enhance the contact area with a solvent [55]. The plant material has been prepared and then it is contacted with an appropriate solvent for the extraction of the targeted compounds. The solvents can be easily adapted to the needs by the use of water, ethanol or even methanol. The mixture is sent into the ultrasonic bath or is equipped with ultrasonic probe. It serves the purpose as tissue disruptor as the cell membrane is activated by the ultrasound. Typical frequencies of ultrasonic waves are in the range of 20 kHz - 40 kHz and these waves are thus used for the mix of ingredients. These ultrasonic waves cause a phenomenon known as cavitation, which is the partial deletion and collapsing of microscopic bubbles in the enclosing fluid. Since the rupture of bubbles promotes the surrounding area to be heated up, an explosion and mechanical shear produced, the cell walls are disrupted and thus release of phytochemicals is enhanced. Typical ultra-sonication duration usually varies from a few minutes up to an hour depending on the by-product getting yielded and the structure of the compound being extracted. A vital point of emphasis is parameters, such as temperature, ultrasonic power, and solvent-to-material ratio, as these parameters can be utilized to get the optimal extraction efficiency [56]. Washing the mixture through the process known as ultra-sonication, we get rid of the plant solids producing a clean extract. The extract can be condensed using either evaporation or lyophilization method to form either powdered form or liquid concentrate alternative.

Microwave-assisted extraction

Microwave-assisted extraction (MAE) is an advanced approach that uses microwave energy to provide a shortcut [57], by rapidly heating the solvent mixture and plant material, with the objective of increasing the yield of bioactive compounds. This one of the noble technologies has gained attention a lot for its incredible efficacy and capacity to extract the desired compounds in less time while maintaining high-level yields [58]. Microwave assisted extraction technology (MAE) is in a very high demand from ferrying phytochemicals among different varieties of plant, such as dandelion for this being inclusive of speed, efficiency, and friendliness to the environment. The MAE method starts with the cleaning of the herbal material. The plant parts are usually air-dried and ground, (to reduce the surface area of the final product). This pre-treatment is therefore the key reason for improving the efficiency of microwave-based heating and can be regarded as an important achievement [59]. The plant material that has been previously prepared in this extraction device able to face microwave irradiation is soon added to a suitable solvent in an extraction vessel [60]. Solvents employed in MAE can be either water, ethanol, or both; their selection is specific to solubility of targeted compounds or process objective [61]. Then, the extraction vessel is positioned in microwave extractor that is a device which functions as an instrument to generate microwave radiation, which when controlled, can be useful in extraction [62]. After the activation of

microwaves, what follows is that they rapidly heat up both the solvent and the herbs. This can be explained that fast heating helps to destroy the plant cell walls and the molecules gain the more diffusion potential. MAE is affected by power from microwave and the extracting time, which are created for a better result of the plant material and the active compound withdrawal. The average time for extracting the enzymes from the sources we utilize is between a few minutes to half an hour [63]. This is significantly shorter compared to other methods commonly used. In doing that, the solutions are cooled down to separate the liquid extract from the solid residue. The filtering out of the extract will follow through evaporation or freeze drying to attain the targeted concentration of ingredient.

One of the main benefits associated with MAE is the fact that it can perform approximately 22 times fast as traditional methods do [64]. Microwave heating is greatly enhanced in terms of efficiency because it simply heats the solvent and plant extraction directly [65], which results in less energy loss and higher delivery of desired bioactive compounds. Heat isolation of certain parts of plant materials achieves a more selective heating, which can be programmed through infantry thermal control technology and leads to the more refined collection of molecules at risk [66]. Wavy paths between flexible gas breakthroughs and energy efficiency further MAE's environmental friendliness. The use of microwave extraction tools is expensive at the beginning, but it is cheaper to run compared to conventional extraction methods. Therefore, microwave extraction should be adopted by companies.

CONCLUSION

The traditional to cutting-edge methods of biologically active compounds extraction from dandelion (*Taraxacum Officinale*) as a result of an octave is a rather complicated area that contains a number of techniques with each of them possessing its own benefits and shortcomings. The conventional type of processing including maceration and decoction is still being brought forth for its unmatched simplicity and availability that is suitable for small-scale applications and places where it is not possible or affordable to have high-tech equipment. Although these techniques are highly effective, there are some bottlenecks that impede their efficiency and isolation in extracting substances which involve longer time of completion and lower outputs. However, advanced methods like ultrasonic -assisted extraction and microwave-assisted extraction also show considerable upgrading in efficiency and speed, respectively. The utilization of modern technology is the underlying principle giving an additional boost in extraction efficiency, which is normally recognized by higher yields and qualitative preservation of bioactive compounds, including the heat-sensitive ones. The application of UAE technologies and by-products in a petroleum refinery setting results in environmental benefits through solvent reduction and energy conservation. Such benefits are in line with the ever-growing demand for sustainability in industrial practices. In a nutshell, selection of a suitable extraction method is a tedious task that depends on the particular application of interest, including the chemistry and nature of bioactive compounds, the scale of extraction, applications, and environmental concerns. Scientific research should concentrate on improving the utility of these techniques because they will help increase their efficiency and sustainable benefits. Alternatively, by investigating hybrid techniques that integrate the optimal characteristics of ancient and modern techniques, advanced extraction methods could be born. They may be both productive and environmentally friendly

techniques for the purification of the phytochemicals present in dandelion.

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