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Maximization of TPC Content in Spray-Dried Dandelion Extract Powder Using Decoction and UAE Extraction Techniques

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Abstract
Dandelion (*Taraxacum officinale*) leaves are well known for their high content of phenolic compounds, which provide antioxidant, anti-inflammatory, and hepatoprotective benefits. This study investigated the effectiveness of traditional decoction and ultrasonic-assisted extraction (UAE) methods for maximizing the total phenolic content (TPC) in dandelion leaf extract powders, followed by spray drying. The UAE technique provides ultrasonic waves to enhance cell wall disruption and release phenolic compounds, while decoction relies on boiling water to extract bioactive.
The extracts were spray-dried under optimized conditions to get stable powders, and then TPC was determined by the Folin-Ciocalteu method. The UAE showed a significantly higher extract powder yield percentage than decoction, yielding up to 36.51 ± 0.36% extract at 15 minutes compared to 32.03 ± 0.28% of decoction extract at 45 minutes. Spray drying at 140°C showed a higher TPC content and achieved a significant outcome for extracted powder. In comparison, the temperature increases at 160°C indicated a decline in the TPC content for both extraction methods. The highest yield percentage of the dandelion leaf extract at 140°C was selected to determine the TPC content. It is suggested that the significantly higher TPC in all extraction time intervals (15 min,30 min, 45 min) showed 42.11 ± 0.51 mg GAE/g to 44.01 ± 0.62 mg GAE/g in UAE extraction. In contrast, traditional decoction extraction is simple and cost-effective, involving prolonged boiling, which degraded heat-sensitive phenolics and showed significantly lower TPC content 20.32 ± 0.31mg GAE/g to 25.11 ± 0.18 mg GAE/g in all intervals of extraction time. This research indicates that the UAE is more effective for commercially producing dandelion leaf extract powder to maximize total phenolic content. Further research could explore optimizing UAE parameters and the impact of stability conditions on phenolic content and antioxidant activity of the dandelion leaf extract powder production.
Keywords: Dandelion, Spray-dried extract, Anti-oxidant activity, Total Phenolic Content, UAE Extraction

INTRODUCTION

In the centuries, Dandelion (*Taraxacum officinale*) is well known for its medicinal and nutritional properties (Olas, 2022), commonly utilized in traditional medicine over various cultures for its antioxidant (Bakal, Ajmire, & Chavhan, 2021), anti-inflammatory (Hu, 2018), and hepatoprotective effects (Fan, Zhang, Song, & Zhang, 2023; Mahboubi & Mahboubi, 2020; Wirngo, Lambert, & Jeppesen, 2016). The dandelion leaves are especially known to be rich in phenolic compounds (Taha & Abdelwahab, 2024), that contribute distinctly to these advantageous properties(P. Chen et al., 2023). Phenolic compounds comprise phenolic acids, flavonoids, lignans, coumarins, and tannins compounds naturally occurring in plant products which are attractive to food science (Wang et al., 2023), pharmacology, and nutraceutical industries (Li, Chen, & Sun-Waterhouse, 2022)due to their capacities and potential in biological systems(Dedić, Džaferović, & Jukić, 2022). For the emerging utilization of these compounds efficient extract methods are essential to the highest yield while maintaining the integrity and biological activity of those compounds.

To date, ultrasonic-assisted extraction (UAE) has become a crucial and effective technique for extracting biological active compounds from plant materials (Sawant et al., 2023). Ultrasonic-assisted extraction uses the mechanical energy generated by ultrasonic waves with frequencies typically in the range of 20 – 100 kHz, which creates microbubbles in the solvent (Cao et al., 2023). This is known as cavitation, which leads to intense turbulence within the liquid medium and enhances the rupture of cell walls. The disruption of cell structures enhances the release of intracellular compounds to the solvent such as phenolic acids and flavonoids (Yang, Li, & Wang, 2018).

Ultrasonic-assisted extraction has many advantages over conventional extraction methods, including shorter extraction times, decreased solvent usage, and lower operating temperatures(Sawant et al., 2023) . For the extraction of heat-sensitive chemicals present in plant matrices, these features make ultrasonic-assisted extraction ideal while maintaining antioxidant qualities (F. Chen et al., 2023; Shen et al., 2023).

There are numerous key factors that affect how well UAE extracts phenolic chemicals from dandelion leaves. Temperature, extraction duration, solvent type and concentration, power, and ultrasonic frequency are the variables that affect the improvement of phenolic compound extract yield and purity. Numerous studies have demonstrated that particular frequencies and powers do more effectively promote cell wall rupture, increasing the release of phenolic chemicals without compromising their stability (Dzah & Dzigbor, 2023). In addition, the solvent selection for the extraction of phenolic compounds is quite important. Due to their capacity to efficiently disperse phenolic substances, polar solvents like ethanol, methanol, and water are frequently employed. The extraction procedure is the recommended approach with respect to industrial and research applications since it allows the UAE to maximize these variables and create a greater quantity of the phenolic compound (Bitwell, Indra, Luke, & Kakoma, 2023).

A prominent conventional extraction technique for acquiring bioactive chemicals from plant sources is decoction (Chanioti, Katsouli, & Tzia, 2021; Isidore, Karim, & Ioannou, 2021). Plant materials, such as leaves, are boiled in water for a predetermined amount of time in order to effectively obtain water-soluble chemicals(Ali Redha, 2021; Stanković, Arsenijević, Planojević, Terzić, & Stefanović, 2022) . The decoction is an easy and effective method for extracting phenolic compounds, antioxidants, and other substances into the aqueous medium from dandelion leaves.

The approach is extensively used in the production of herbal medicines due to its simplicity and low demands on equipment. However, several heat-sensitive components can become decomposed by the high temperatures and extensive boiling time, which could affect the phenolic content and general effectiveness of the extract (Manousi, Sarakatsianos, & Samanidou, 2019).

The liquid extract of dandelion leaves is frequently turned into a stable powder adopting the spray drying techniques, which makes it perfect for long-term storage as well as consumption in various formulations. Regarding the material integration process, stability, and simplicity of management, spray drying offers several advantages. The liquid extract is dispersed as tiny droplets and subjected to heated air through the spray drying process, which causes the solvent to evaporate quickly as it turns into a powder (Kartini, Huda, Hayati, Sastika, & Nawatila, 2023). This powder is a robust, extremely potent mixture of chemicals rich in phenolics that retain their antioxidant qualities. Optimizing the spray drying circumstances, including the atmospheric speed of flow, feed rate, and inlet temperature, becomes essential (Kartini et al., 2023; Martinić et al., 2022). The variables have immediate effects regarding the powder's flow characteristics, moisture content, and phenolic retention.

The goal of this study is to optimize the total phenolic content of powdered dandelion leaf extract by optimizing ultrasonic-assisted extraction (UAE) and spray drying procedures. It also investigates the effectiveness of the conventional decoction technique for retrieving phenolic chemicals by using it serving as a comparator. With the investigation of the effects of several UAE variables, spray drying settings, and the efficacy of decoction, this investigation seeks to design a methodology for manufacturing phenolic-rich dandelion extract powder. Since a foundation for further study and the commercialization of dandelion extracts in the nutraceutical and advantageous healthcare industry, the outcomes will offer insightful information about the synergistic application of UAE and spray drying processes.

MATERIALS AND METHODS

Materials

Taraxacum officinale (Dandelion) leaves were picked and collected in the eastern region of Myanmar, Shan State. After being cleaned of contaminants leveraging demineralized water, the dandelion leaves were dried at 50 °C in an oven and milled into a fine powder via a pulverizing machine. The fine powder was kept at room temperature in airtight containers as long as it was needed.

Chemical and Reagents

Gallic acid, Folin-Ciocalteu reagent, and sodium Bicarbonate were purchased from Sigma-Aldrich to examine the total phenolic content. Ethanol and distilled water were used as solvents. UV spectrophotometer (model UV-1800, Shimadzu, Japan) was used to determine the total phenolic content of dandelion leaves extracted powder.

Methods

Optimization of Ultrasonic-assisted extraction (UAE)

The phenolic compounds from dandelion leaves were extracted using an ultrasonic bath (model Labtech 201, Korea). The Ultrasonic-assisted extraction parameters optimized in this study included extraction duration of 15, 30, and 45 minutes was evaluated based on preliminary trials. In each trial, 20 g of dried leaves powder was soaked in water 500 mL and the extract was filtered using a 200-mesh filter bag. Each extraction process was performed with the same parameters.

Optimization of Decoction extraction

The phenolic compounds from dandelion leaves were extracted using the decoction method under similar parameters to those used for ultrasonic-assisted extraction. In this process, 20 g of dried dandelion leaf powder was boiled in 500 mL of water for durations of 15, 30, and 45 minutes, as determined by preliminary trials. After boiling, the extract was filtered using a 200-mesh filter bag to remove solid residues. Each decoction trial was conducted under identical conditions to ensure consistency and enable a direct comparison of the extraction efficiency with the ultrasonic-assisted method.

Total Phenolic Content Determination

The Total Phenolic Content Determination was investigated by using the Folin-Ciocalteu method. For this analysis, gallic acid was used as standard, and total phenolic content was expressed as mg of gallic acid equivalents per gram of extract (mg GAE/g). The concentration (100 ug/mL) of gallic acid and leaf extracts (1 mg/mL) were prepared in methanol. 0.5 mL of each sample was combined with 2.5 mL of 10% Folin-Ciocalteu's reagent and 2 mL of (7.5 %) sodium carbonate (Na_2CO_3) solution, followed by stabilization at room temperature for 30 minutes. The absorbance at 760 nm was then measured in triplicate using a UV spectrophotometer (Model – UV 1800, Shimadzu). To establish the standard gallic acid curve, a parallel process was followed. A stock solution was prepared by dissolving 10 mg of gallic acid in 100 mL of methanol (100 μg/mL), and various concentrations (0.08, 0.16, 0.312, 0.625, 1.25, and 2.5 μg/mL) of gallic acid were derived from the stock solution (Khan et al., 2019). The absorbance of each solution was measured using a similar approach as described earlier. The total phenolic content of both leaf and root extract powders, as well as dried powders, was quantified using the regression equation obtained from the calibration curve ($y = 0.1968x + 0.1059$ $R^2 = 0.9981$) as shown in Figure 1.

Optimization of Spray Drying temperature

To get the highest yield of extracts and TPC content from the ultrasonic-assisted extraction process the filtrate was transformed into stabilized powder form using a laboratory-scale spray dryer (model YC-015, Shanghai, China). The spray drying parameters were optimized based on the inlet temperatures 120° C, 140° C, and 160° C, the feed flow rate was the same condition at 10 mL/min, and maltodextrin was used as a carrier to improve powder stability. Both extraction methods followed identical spray drying conditions to establish a reliable comparison of the efficiency and quality of the powdered extracts.

Statistical Analysis

The data are expressed as the mean ± SD and analyzed by SPSS 20.0 statistical analysis software. Analysis of variance (ANOVA) was applied to assess the significance of each parameter and model interaction, with a significant level of $p < 0.05$.

RESULTS AND DISCUSSION

Different stages of extraction (15, 30, and 45 minutes) were used to assess the impact of extraction techniques (decoction and ultrasonic-assisted extraction) and spray drying temperatures on extracted yield. The findings demonstrate significant variations in the yield of extraction as well as the influence of spray drying conditions.

Extraction Yield Comparison

The ultrasonic-assisted extraction (UAE) approach continuously produced larger quantities than the decoction approach during the extraction periods and spray drying temperatures. According to the table 1, the UAE approach recorded a maximum yield of 36.51 ± 0.36% after 15 minutes of extraction with a temperature of 140°C to supply spray drying. In contrast, the decoction method showed a maximum yield of 26.32 ± 0.14% under the same conditions. The mechanical effects of ultrasonic waves, particularly facilitating solvent penetration into plant cells while encouraging cell wall breakdown, may be responsible for the improved yield shown in UAE. This mechanism facilitates the release of phenolic chemicals more efficiently than traditional decoction, which relies on heat and absorption to trigger extraction (Manousi et al., 2019). Research has demonstrated that, in comparison to traditional extracting methods, ultrasonic energy greatly speeds up the extraction of bioactive chemicals through enhanced mass transfer, leading to better yields. At 160 °C, the yield proportion decreased for both techniques, from the decoction falling to 19.87 ± 0.39% and the UAE to 21.43 ± 0.52%. The extracted chemicals' thermal breakdown and reduced drying effectiveness at higher temperatures are probably the causes for that drop. The best compromise between yield and reliability was achieved by spray drying at 140°C.

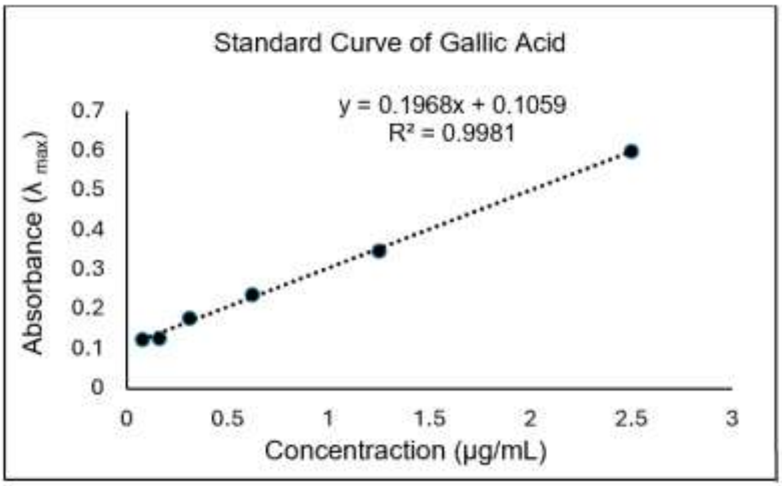
Influence of Extraction Time

The yield for UAE was not significantly increased by increasing the processing interval between 15 to 45 minutes; at 140°C, the results stabilized at about 35.95%. This implies that the majority of phenolic compounds were extracted in just 15 minutes and therefore the benefits of longer processing times decreased. Conversely, the decoction approach exhibited greater temporal variations, peaking at 26.03% yield after 45 minutes at 140°C.

Effects of Spray Drying Temperature

Both the quantity and the quality of the extract were significantly influenced by the spray drying temperature. While phenolic degradation at 160°C decreased the total extract yield, inadequate condensation at 120°C may have impacted yield reliability. For both extraction techniques, an intermediate temperature of 140°C worked best, maintaining compound integrity and guaranteeing reliable powder formation. The findings provide credence to the idea that the most effective way to maximize extract yields during aggressively brief extraction times is to combine UAE with 140°C spray drying. The decoction method is still a straightforward and affordable option to accomplish moderate yields, despite its reduced productivity in general. These revelations offer the basic adjustments to extraction and drying methods for industrial application, particularly in the extraction of powdered dandelion extract that is high in phenolics for the nutraceutical sector.

Figure 1. Standard Curve of Gallic Acid mg GAE/g



Total Phenolic Content Determination

The highest yield percent of extract powder spray drying temperature 140 °C was selected to determine the total phenolic content. According to Table 2, a notable difference was observed in the total phenolic content in dandelion leaves extracted powder from decoction and ultrasonic-assisted extraction (UAE) followed by spray drying. TPC of decoction extraction demonstrated that it went up to the highest peak of 20.32 ± 0.31mg GAE/g to 25.11 ± 0.18 mg GAE/g in all intervals of extraction time (15 min, 30 min, and 45 min). In contrast, UAE showed significantly higher TPC in all time intervals, from 42.11 ± 0.51 mg GAE/g to 44.01 ± 0.62 mg GAE/g. The result revealed that ultrasonic wave extraction is more effective than traditional decoction extraction to extract phenolic compounds because ultrasonic waves increase the solvent penetration and ability to enhance the cell wall disruption. These findings supported that UAE extraction followed by spray drying of dandelion extract powder commercial production will be able to maximize the total phenolic content.

Table 1. Extraction Yield Percentage of Dandelion extract powder using Decoction and UAE extraction

Extraction Time	Spray Dried Temperature	Decoction Extraction Yield Percentage	Ultrasonic-Assisted Extraction Yield Percentage
15 min	120 °C	21.34 ± 0.17	32.56 ± 0.28
	140 °C	26.32 ± 0.14	36.51 ± 0.36
	160 °C	19.51± 0.16	22.43 ± 0.57
30 min	120 °C	22.42 ± 0.25	31.45 ± 0.14
	140 °C	30.63 ± 0.19	35.63 ± 0.35
	160 °C	20.11 ± 0.34	21.91 ± 0.14
45 min	120 °C	20.25 ± 0.41	30.51 ± 0.18
	140 °C	32.03 ± 0.28	35.95 ± 0.31
	160 °C	19.87 ± 0.39	21.43 ± 0.52

Values are presented as mean ± SD (n=3)

Table 2. Total Phenolic Content determination of spray drying temperature 140°C of Dandelion extract powder

Extraction Time	TPC Content mg GAE/g	
	Decoction Extraction	Ultrasonic-assisted Extraction
15 min	20.32 ± 0.31	42.11 ± 0.51
30 min	21.18 ± 0.42	43.22 ± 0.19
45 min	25.11 ± 0.18	44.01 ± 0.62

Values are presented as mean ± SD (n=3)

CONCLUSION

The purpose of the current investigation was to determine how well decoction and ultrasonic-assisted extraction (UAE) techniques, accompanied by spray drying, produced powdered dandelion leaf extract having a high total phenolic content (TPC). The effects of both extraction methods on the yield, quality, and efficiency of the phenolic content extraction process were compared. According to these results, UAE showed clear advantages over decoction in terms of conserving and optimizing the phenolic components, even though both techniques had certain benefits. Plant cell walls were successfully broken down by the application of ultrasonic waves, which improved the extraction of bioactive compounds faster and at lower temperatures. However, despite being straightforward and popular, the decoction approach required extended boiling, and this would have broken down several heat-sensitive phenolic compounds. The liquid extracts were successfully transformed into stable, fine powders by the ensuing spray drying process. The preservation of total phenolic content was impacted by the inlet temperature in spray drying conditions, underscoring the necessity of a parameter optimization procedure. The best method for optimizing the phenolic content of powdered dandelion leaf extract was the combination of UAE and spray drying. This approach not only increased the effectiveness of extraction but also provided a scalable and energy-efficient alternative in contrast to the more traditional decoction technique. The result highlights how crucial it is to choose cutting-edge extraction techniques and adjust procedure parameters in order to maintain the functional and nutritional properties of plant-based extracts. This research contributes to the innovation and development of dandelion leaf extract that promotes health and provides valuable insights into the manufacturing of premium plant extract powders. Additional research could examine the stability and bioavailability of the dandelion leaf extract in other applications, as well as the enhancement of UAE parameters.

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