Journal of Food Science and Technology (Iran)

Homepage:www.fsct.modares.ir

Scientific Research

Optimization of Microwave-Assisted Extraction of Autumn-Grown Sugar Beet *(Beta vulgaris L.)* Leaf Extract and Evaluation of its Antioxidant Activity

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ARTICLE INFO

Article History:

Received: 2025/03/19

Review: 2025/08/01

Accepted: 2025/10/19

Keywords:

Natural antioxidants,
Plant extract,
Extraction optimization,
Sugar beet,
Microwave

DOI: **10.48311/fsct.2026.84011.0**

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ABSTRACT

This study examined the antioxidant properties of leaf extract from autumn sugar beet *(Beta vulgaris L.)* obtained through a microwave extraction method. The extraction utilized two solvents, water and acetone, with microwave power settings ranging from a minimum of 52/7 W to a maximum of 307/3 W, and extraction times varying from 5/86 minutes to 34/14 minutes. The optimal conditions for extraction, based on total phenol content and free radical scavenging activity, were identified as using water as the solvent, a power setting of 90 W, and an extraction duration of 10 minutes. The factors of extraction time and microwave power were found to significantly influence the yield of phenolic compounds ($P< 0.05$). An increase in both time and microwave power resulted in a higher phenol yield from both acetone and aqueous extracts, with the aqueous extract demonstrating superior performance. The assessment of the free radical scavenging capacity of the autumn sugar beet leaf extracts indicated a decline in this capacity over time for both types of extracts. Notably, the free radical scavenging activity of the acetone extract was lower than that of the aqueous extract. Furthermore, while the free radical scavenging ability of the acetone extract improved with increased microwave power, the aqueous extract exhibited a different trend in its scavenging capacity.

1- Introduction

Sugar beet, scientifically known as *Beta vulgaris L.*, is recognized as a biennial plant belonging to the goosefoot family (*Chenopodiaceae*). It is a tall and vigorous plant characterized by large, glossy leaves [1,2]. This plant is considered one of the most valuable crops, comparable to wheat and rice, and is also among the twelve major crops worldwide [3]. In addition, sugar beet contains numerous nutrients, including stearic acid, oleic acid, linoleic acid, palmitic fatty acid, saponins, ascorbic acid, flavonoids, folic acid, calcium, phosphorus, iron, and vitamins A, B, and C, as well as zinc. Furthermore, carotenoids and vitamin E, which possess antioxidant and protective properties, are also present in sugar beet [4,5,6].

Even though sugar beet is one of the important agricultural crops, in regions such as Iran that are characterized by arid and semi-arid climates and face limitations in water resources, the cultivation of crops with high water requirements during the spring and summer seasons, such as sugar beet, is associated with serious challenges. Therefore, in order to overcome this limitation and to take advantage of seasonal precipitation, autumn cultivation of sugar beet has been adopted. The results of a study conducted in Spain indicated that water consumption in autumn cultivation was reduced by 33% compared with spring cultivation [7,8]. Another reason for the preference for autumn cultivation is the increase in leaf area. In this regard, Diehim Fard and Rahimi Moghaddam reported that the leaf area parameter of sugar beet in the two cities of Mashhad and Neyshabur reaches its maximum value at approximately the same time; however, the yield of sugar beet cultivated in spring is lower than that of sugar beet cultivated in autumn [9]; In fact, with an increase in this index, sugar beet yield and its efficiency in utilizing light and radiation increase. Accordingly, the evaluation of sugar beet leaf extract demonstrated that with increasing intensity of ultraviolet B radiation and its absorption by this plant, the levels of the pigments betanin and betaxanthin, which produce red and yellow colors in the plant, respectively, increased. In addition, tannin, flavonoid, and total phenolic content increased. Overall, this radiation, which reaches the Earth's atmosphere at high intensity, stimulates the antioxidant capacity of sugar beet [10,11]. Indu and co-workers identified compounds in *Beta vulgaris* root extract that exhibited free radical scavenging activity. These compounds included gallic acid, coumarin, quercetin, syringic acid, sinapic acid, gallic acid, catechin, caffeic acid, p-coumaric acid, and chlorogenic acid [12]. A study on the bioactive compounds of sugar beet, with emphasis on its beneficial effects on gut microbiota, was conducted by de Oliveira and co-workers in 2021. The results indicated that sugar beet possesses outstanding nutritional value and contains various types of bioactive compounds, including dietary fiber, oligosaccharides, betalains, and phenolic compounds, which effectively modulate the composition and function of gut microbiota. In addition, sugar beet exerts stimulatory effects on the growth and metabolism of probiotic bacteria, indicating that, beyond its antioxidant and antibacterial properties, sugar beet also exhibits probiotic potential [13].

In recent years, novel extraction methods have attracted considerable attention due to advantages such as reduced cost,

increased extraction yield, and shorter extraction time. These advanced techniques include microwave-assisted extraction, ultrasound-assisted extraction, and supercritical fluid extraction [14]. In the past, microwave technology was mainly used for drying, concentration, and inactivation of bacteria and enzymes. However, in recent years, these systems have been increasingly applied for the extraction of bioactive compounds from plant and animal tissues [15]. Microwave waves are electromagnetic waves with frequencies ranging from 0.3 to 300 GHz. These waves penetrate plant tissues and, through interaction with polar molecules, generate heat that disrupts plant tissue cells [16]. Selecting an appropriate solvent for microwave-assisted extraction is of great importance. Polar solvents such as water, due to their higher microwave absorption capacity and faster heating, contribute to more efficient extraction of bioactive compounds. In contrast, nonpolar solvents such as hexane are not suitable for this extraction method. To enhance the efficiency and performance of microwave-assisted extraction, the use of a combination of polar and nonpolar solvents is recommended [17,18]. Microwave technology has been employed in numerous studies for the preparation of extracts. The results of a study comparing different extraction methods, including microwave-assisted extraction, ultrasound-assisted extraction, conventional extraction, and Soxhlet extraction, on the extraction efficiency of phenolic compounds and DPPH radical scavenging activity from cherry leaf and fruit extracts showed that the highest extraction yield for both parameters was obtained using the Soxhlet method. However, the extracts obtained by microwave-assisted extraction contained the highest levels of phenolic compounds and exhibited the strongest antioxidant activity. A strong correlation was observed between phenolic content and antioxidant activity in both extracts [19]. In several other studies, the application of this novel extraction method improved the quality of the resulting extracts compared with other extraction techniques [20,21,22]. Given concerns about the use of synthetic antioxidants and their potential side effects, the use of natural antioxidants derived from plant sources has attracted considerable attention. Sugar beet leaves, an accessible source rich in bioactive compounds, have high potential for the extraction of antioxidants.

Although numerous studies have been conducted on the extraction of antioxidant compounds from plant sources, the investigation of sugar beet leaf extract obtained by microwave-assisted extraction and the effect of the solvents used on extraction yield and antioxidant activity has received limited attention. Therefore, considering the advantages of autumn cultivation of sugar beet and the beneficial effects of this valuable plant, the present study aimed to optimize the extraction process and to evaluate the antioxidant potential of microwave-assisted extracts obtained from autumn-cultivated sugar beet leaves.

2-Materials and Methods

2-1-Sample Preparation

Initially, sugar beet leaves were collected from Khuzestan Province and thoroughly washed with tap water to remove soil and impurities. The leaves were dried at room temperature and subsequently stored in sealed plastic containers in a cool and dry place until extraction.

2-2-Extraction of the Extract

Microwave-assisted extraction was employed to prepare the extract from sugar beet leaves. Initially, 5 g of sugar beet leaf powder was accurately weighed using a balance and transferred into a 250 mL flask. Distilled water and acetone were used separately as extraction solvents. A volume of 25 mL of the selected solvent was precisely measured and added to the flask containing the sugar beet leaf powder. The flask was then placed in the microwave apparatus for extraction. Experimental optimization was performed using response surface methodology and a central composite design (Table 1). Subsequently, the required microwave power levels (watts) and extraction times (minutes) were set according to Table 2, and the extraction process was initiated. After the extraction time was completed and the extract obtained, it was filtered through Whatman No. 1 filter paper and stored in dark-colored containers at refrigerator temperature until further analyses were conducted.

Table 1. Factors selected for optimizing microwave-assisted extraction from sugar beet leaves

Factor	Name	Units	Type	SubType	Maximum	Minimum
A	Time	Minute	Numeric	Continuous	34/14	5/86
B	Power	Watt	Numeric	Continuous	307/30	52/70
C	Solvent	-	Categoric	Nominal	Water	Acetone

Table 2. Defined runs using Response Surface Methodology and Central Composite Design for microwave-assisted extraction from sugar beet leaves

Run	Factor 1	Factor 2	Factor 3
	A: Time	B: power	C: Solvent
	minute	Watt	milliliter
1	20	180	Water
2	10	90	Aceton
3	20	180	Water
4	20	180	Aceton
5	34/14	180	Water
6	20	180	Water
7	5/86	180	Aceton
8	10	90	Water
9	20	307/3	Aceton
10	20	307/3	Water
11	20	180	Aceton
12	20	180	Water
13	20	180	Aceton

12	20	52/7	Aceton
11	30	90	Aceton
12	30	90	Water
13	10	270	Water
14	20	52/7	Aceton
15	20	180	Aceton
16	30	90	Aceton
17	30	90	Water
18	10	270	Water
19	34/14	180	Aceton
20	20	180	Aceton
21	30	270	Water
22	30	270	Aceton
23	20	52/7	Water
24	20	180	Water
25	5/86	180	Water
26	10	270	Aceton

2-3-Evaluation of Antioxidant Activity of the Obtained Extracts

2-3-1-Determination of Total Phenolic Content

A volume of 100 µL of each extract was mixed with 500 µL of 60% Folin–Ciocalteu reagent. After 3 min, 400 µL of 7.5% sodium carbonate solution was added. The mixture was incubated in the dark for 30 min, and the absorbance of the samples was measured using a spectrophotometer at a wavelength of 765 nm [23].

2-3-2-Determination of Free Radical Scavenging Activity

Five milliliters of each extract were mixed with 1 mL of DPPH solution and incubated for 30 min at room temperature in the dark. After this period, the absorbance was measured at 517 nm using a spectrophotometer [24].

2-4-Statistical Analysis

The experimental design was carried out using response surface methodology and a central composite design in Design-Expert software, version 13. In this design, the independent variables or factors included solvent type (water and acetone), extraction time, and microwave power (Table 1). After conducting the experiments, the results were analyzed using the software, equations were derived, and the significance of the variables' effects on the model was evaluated.

3-Results and Discussion

In the past, compounds present in plant extracts were primarily used as flavoring agents. However, it has now been established that many of these extracts possess antioxidant and antimicrobial properties. In particular, extracts containing phenolic compounds generally exhibit greater antioxidant and antibacterial activities. Therefore, such extracts can be used as natural preservatives instead of harmful synthetic

preservatives to enhance the shelf life of food products [25,26]. The incorporation of sugar beet leaf extract into chitosan coatings and its application as an edible coating for beluga sturgeon fish resulted in a reduction in total volatile basic nitrogen (TVBN), free fatty acids, peroxide value, thiobarbituric acid, as well as microbial indices in samples coated with higher concentrations of chitosan (2%) and sugar beet leaf extract (1.5%) compared with the control sample during seven days of storage. Moreover, this treatment received higher sensory scores from the evaluators [27]. In another study, Sadeghi and co-workers reported that the addition of 30% mallow leaf extract obtained by percolation improved the quality of the Indian white shrimp fillet marinade, as assessed by sensory attributes, TVBN, and water-holding capacity [28]. In the present study, the optimal conditions for extract preparation and the effects of solvent type, microwave power, and extraction time on the antioxidant capacity of the resulting extracts were investigated.

Determination of the Optimal Microwave-Assisted Extraction Conditions for Sugar Beet Leaves Based on Antioxidant Activity

The results of the analysis of the data obtained from measuring two parameters, namely total phenolic content and DPPH free radical scavenging capacity, indicated that the proposed models for evaluating the effects of three factors, including solvent type, extraction time, and microwave power, followed, respectively, a second-order (quadratic) model and a two-factor interaction model. According to the developed models for extraction optimization, solvent No. 1, water, the most polar solvent, exhibited the highest efficiency for extracting phenolic compounds. In addition, the two factors, extraction time and microwave power, had significant effects on the extraction of phenolic compounds. Table 4 presents the optimal conditions for extracting sugar beet leaves, with 15 experimental conditions based on minimum extraction time and power, and maximum total phenolic content and DPPH free radical scavenging capacity. The first run, with the highest desirability value, was selected in the first row. The constraints used for determining the optimal conditions are presented in Table 3.

Table 3. Summary of Experimental Design set for determining the optimal extraction conditions

Name	Goal	Lower Limit	Importance	Upper Weight	Lower Weight	Upper Limit
A: Time	minimize	10	3	1	1	30
B: power	minimize	90	3	1	1	270
C: Solvent	is in range	Water	3	1	1	Aceton
DPPH	maximize	218/77	3	1	1	251/18
Total Phenol	maximize	2/57	3	1	1	2/74

Table 4. Determination of optimal extraction conditions from sugar beet leaves based on three factors time, power and solvent type using a microwave-assisted device

Number	Time(min)	Power(W)	Solvent	DPPH(µg/mg)	Total Phenol(mg/5ml)	Desirability
1	**10/000**	**90/000**	**Water**	**249/611**	**2/624**	**0/740**
2	10/127	90/000	Water	249/565	2/623	0/737
3	10/000	92/920	Water	249/485	2/623	0/733
4	10/294	90/000	Water	249/505	2/622	0/733
5	10/000	98/066	Water	249/266	2/621	0/721
6	10/000	211/500	Water	244/369	2/637	0/564
7	**10/000**	**90/000**	**Aceton**	**233/416**	**2/601**	**0/534**
8	10/000	90/987	Aceton	233/478	2/600	0/532
9	10/000	207/532	Aceton	240/850	2/612	0/491
10	10/000	206/808	Aceton	240/804	2/611	0/491
11	10/000	208/490	Aceton	240/911	2/612	0/491
12	10/000	210/110	Aceton	241/013	2/613	0/491
13	10/000	204/527	Aceton	240/660	2/610	0/491
14	10/000	210/883	Aceton	241/062	2/614	0/491
15	10/000	201/539	Aceton	240/534	2/609	0/490

Figures 1, 2, and 3 illustrate, respectively, the plots emphasizing the optimal point, the effect of microwave power × extraction time, extraction time × solvent type, and solvent type × microwave power, with the desirable points highlighted.

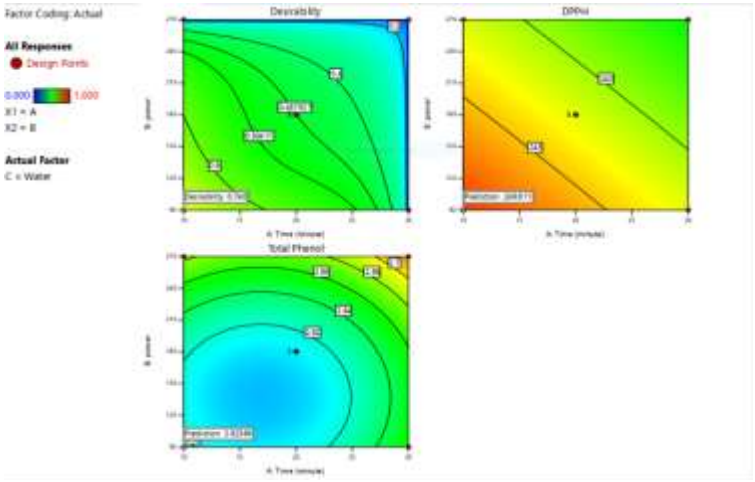

Figure 1. Graph emphasizing the optimal point in the interaction between the factors of time ×power

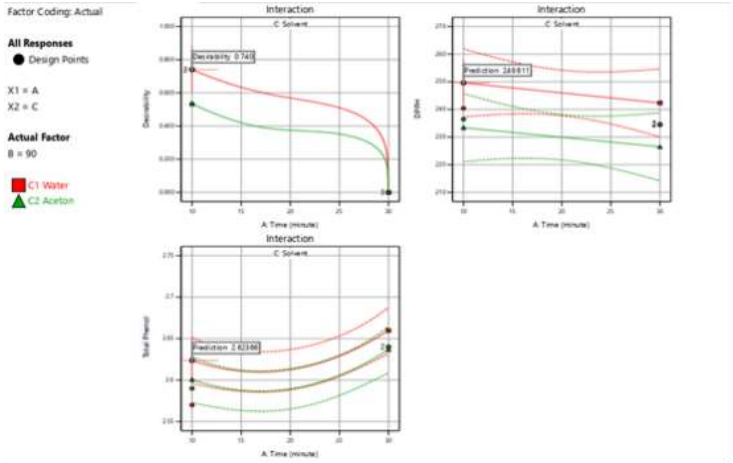

Figure 2. Graph emphasizing the optimal point in the interaction between the factors of time ×solvent type

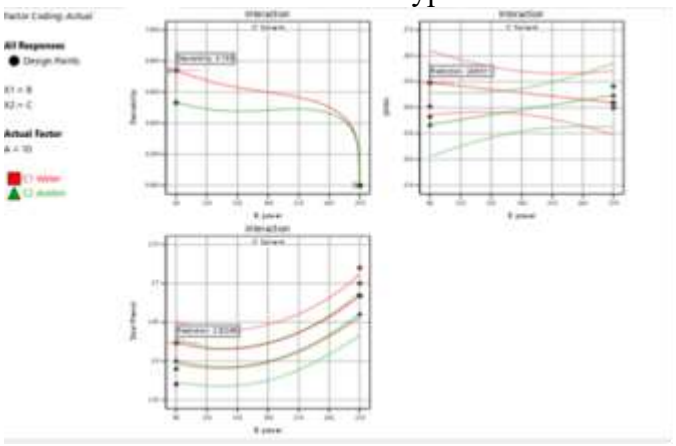

Figure 3. Graph emphasizing the optimal point in the interaction between the factors of power ×solvent type

3-1-Total Phenolic Content

Initially, the data distribution was examined using normality plots and Box–Cox plots (Figures 4 and 5), which indicated that the data followed a normal distribution.

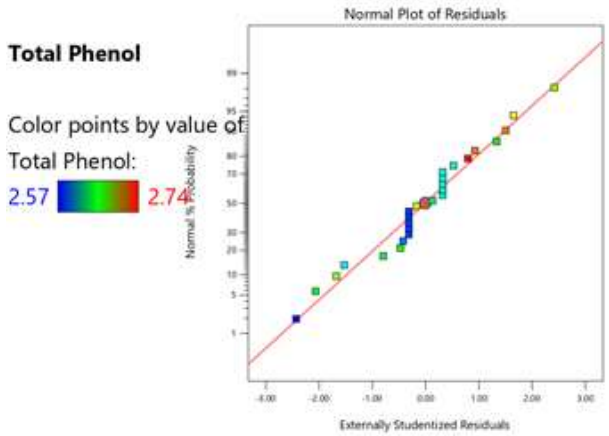

Figure 4. Visualization of the Normal Distribution of Residuals

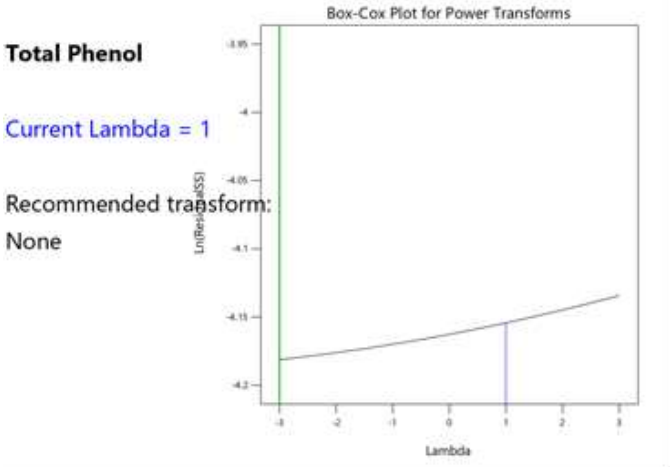

Figure 5. Box-cox

Table 5. Results of the one-way ANOVA for the second-order model

Source	Sum of Squares	Degrees of Freedom	Mean Square	F-value	P-value
Model	0.0455	5	0.0091	11.58	< 0.0001*
A–Time	0.0052	1	0.0052	6.58	0.0185*
B–Power	0.0146	1	0.0146	18.57	0.0003*
C–Solvent	0.0035	1	0.0035	4.41	0.0486*
A^2	0.0115	1	0.0115	14.68	0.0010*
B^2	0.0135	1	0.0135	17.19	0.0005*

*Significant at the level of ($p < 0.05$)

The numerical value of the F-statistic indicates that the model is statistically significant, with only a 0.01% probability that the observed F-value is due to noise. It should be noted that, in this model, components that did not have a significant effect were excluded. The following equation presents the relationship between the investigated factors and the response variable.

Total Phenolic Content=
+ 2/60
+ 0/0181 A
+ 0/0302 B
_ 0/0115 C
+ 0/0292 A^2
+ 0/0312 B^2

The results of the present study indicated that, based on the evaluation of the antioxidant activity of the obtained extracts by determining total phenolic content, water, as the most polar solvent, exhibited higher efficiency in extracting phenolic compounds than acetone. In the extraction of phenolic compounds, the polarity of the solvents used significantly affects extraction efficiency [29]. In a study, water was identified as the optimal solvent for microwave-assisted extraction of phlorotannins from three brown algae, and *C. flexuosum* exhibited the most potent antioxidant activity, with a value of 62.1 mg gallic acid per gram [30]. In an evaluation conducted by John and co-workers in 2017, the antioxidant and antimicrobial activities of methanolic and acetonic extracts of *Beta vulgaris L.* peel were investigated. The phenolic and flavonoid contents of the methanolic extract of red beet peel were reported as 99.1 µg/mg GAE and 76.4 µg/mg QE, respectively. In contrast, for the acetonic extract of red beet peel, these values were measured as 46.53 µg/mg GAE and 51.4 µg/mg QE, respectively [31]. This study is consistent with the present research in that acetone extracted lower amounts of phenolic compounds than a more polar solvent, as acetone performed less well than water in extracting phenolic compounds from sugar beet leaves. However, contrary to the results of the present study, in the evaluation conducted by Fandreski and Ardastani, the aqueous extract of rue exhibited the lowest phenolic compound extraction yield compared with ethanol [32]. As shown in Figure 6, extraction time and microwave power also had significant effects on the extraction of phenolic compounds. Another study evaluating microwave-assisted extraction of avocado *(Persea americana Mill.)* seed extract found that both extraction time and microwave power significantly affected the extraction of phenolic compounds and antioxidant activity [33]. Phenolic compounds in extracts are strongly influenced by extraction time [34]. In the extraction of bioactive compounds from plant materials, high microwave power can reduce extraction efficiency because these compounds are heat-sensitive. Temperature and microwave power are interrelated, and an increase in microwave power leads to a rise in temperature. Moreover, prolonged exposure of samples to microwave radiation, even at low power levels, may degrade bioactive compounds. For this reason, microwave-assisted extraction time is usually less than 30 minutes [35,36]. In this regard, Golmakani and co-workers reported that the highest total phenolic content of bitter orange seed kernel extract was obtained at the lowest microwave power (100 W) and the shortest extraction time (5 minutes) [37]. However, in the present study, increasing

extraction time and microwave power resulted in higher phenolic content in both acetonic and aqueous extracts, with the aqueous extract exhibiting superior performance. Keshavarz and co-workers reported that increasing microwave power enhanced the extraction of phenolic compounds from jujube fruit [38]. In contrast to these findings, Singh and co-workers reported in 2011 that increasing microwave power reduced phenolic compounds in potato peel [39]. Latifi and co-workers employed three extraction methods, namely microwave-assisted, maceration, and ultrasound-assisted extraction, for lemon peel extract. The results showed that higher levels of phenolic compounds were observed in ultrasound-assisted extracts compared with microwave-assisted and maceration extracts. In fact, the lower phenolic content of microwave-assisted extracts in that study compared with the other two methods could be attributed to the microwave chamber temperature of 100 °C [40].

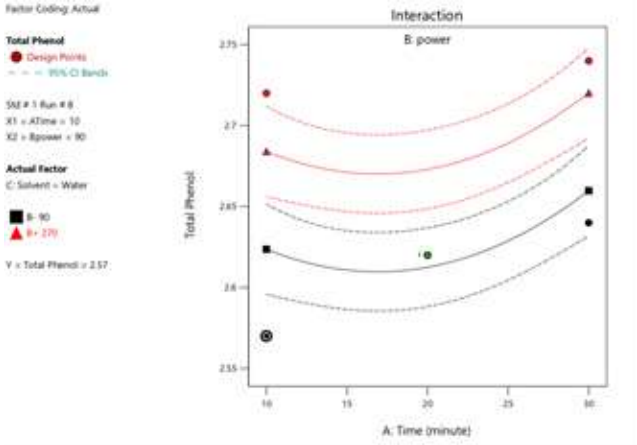

Figure 6. Interaction between time, microwave power, application of the used water solvent and total phenol content

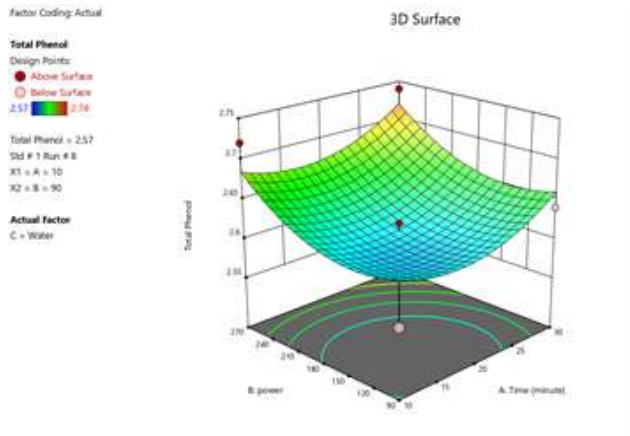

Figure 7. 3D plot of the effect of time and microwave power with water as a solvent on the total phenol content

3-2-Free Radical Scavenging Capacity Assessed by the DPPH Assay

Initially, the data distribution was evaluated using normality plots and Box–Cox plots (Figures 8 and 9), which indicated the distribution of the data.

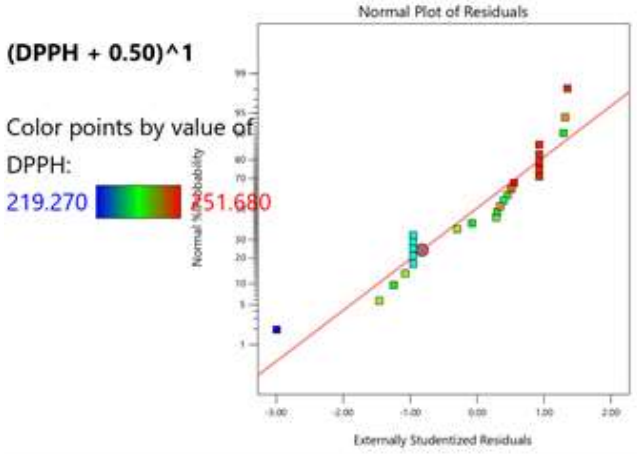

Figure 8. Visualization of the Normal Distribution of Residuals

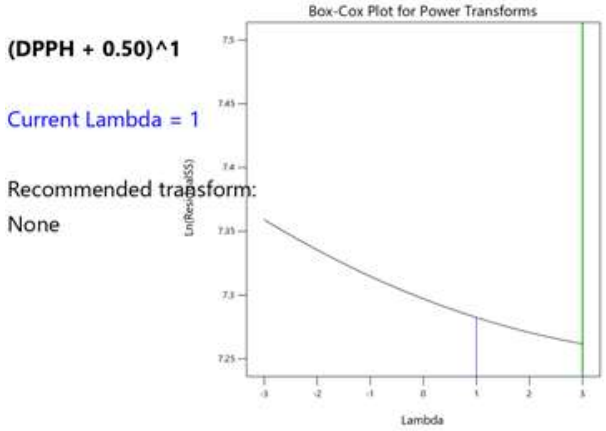

Figure 9. Box-Cos

Table 6 presents the results of one-way analysis of variance (One-way ANOVA) for the two-factor interaction response surface model.

Table 6. Results of the one-way analysis of variance of the linear model

Source	Sum of Squares	Degrees of Freedom	Mean Square	F-value	P-value
Model	843.38	6	140.56	1.84	0.1454
A–Time	190.14	1	190.14	2.48	0.1315
B–Power	15.57	1	15.57	0.2034	0.6571
C–Solvent	271.51	1	271.51	3.55	0.0751
AB	0.0545	1	0.0545	0.0007	0.9790
AC	0.0971	1	0.0971	0.0013	0.9720

BC	366.01	1	366.01	4.78	0.0415*

*Significant at $p < 0.05$

The F-value indicates that the model is statistically significant, and there is only a 14.54% probability that the observed F-value is due to noise. In this model, none of the factors were considered statistically significant ($p > 0.05$).

(DPPH+0/50[1])=
+ 239/45
_3/46 A
+ 0/9874 B
_ 3/23 C
+ 0/0825 AB
+ 0/0783 AC
+ 4.79 BC

One of the methods used to determine the free radical scavenging ability of extracts obtained from various plants is the DPPH assay [41]. As shown in Figure 10, evaluation of free radical scavenging in the present study indicated that, over time, this index decreased in both extracts, and the free radical scavenging activity of the acetonic extract of sugar beet leaves was lower than that of the aqueous extract. However, with increasing microwave power, free radical scavenging increased in the acetonic extract, whereas it decreased in the aqueous extract of sugar beet leaves. The scavenging capacity of extracts depends on the number and position of hydroxyl groups and the molecular weight of phenolic compounds. In phenolic compounds with lower molecular weight, hydroxyl groups are more readily accessible [42]. Following the evaluation of the antioxidant activity of the extracted sugar beet leaf extracts, among the applied power levels, a microwave power of 90 W and an extraction time of 10 min were selected as the optimal parameters. In a study conducted by Fayaz and co-workers, methanol showed higher efficiency than water. Based on their results, the optimal conditions for carotenoid extraction were a microwave power of 90 W and an extraction time of 10 min, whereas the optimal conditions for extracting chlorophyll a and b were 180 W and 20 min [43]. Prolonged microwave extraction and the use of solvents such as water, ethanol, and methanol may increase temperature and consequently damage heat-sensitive compounds [44]. In 2021, Salami and co-workers, in optimizing microwave-assisted extraction of *Eruca sativa* leaf extract, found that extracts obtained using water, as a solvent with a high dielectric constant, exhibited the highest antioxidant activity compared with ethanol and methanol, and that using the lowest sample-to-solvent ratio (1:5) reflected an advantage of this method [45]. Aghajani and co-workers reported that the highest radical scavenging activity of microwave-assisted extracts from *Ferulago angulata* leaves was observed in extracts prepared with a 100:0 ethanol-to-water solvent ratio [46]. DPPH measurements of grape seed extracts indicated that antioxidant activity increased with increasing extraction time, decreasing microwave power, and decreasing solvent concentration [47]. whereas in the present study, increasing extraction time led to a reduction in free radical scavenging activity.

Green walnut husk extract was obtained using ethanol at concentrations of 0%, 50%, and 100%, under microwave powers of 90, 450, and 900 W, and extraction

times of 1, 8, and 15 min. It was observed that at a constant ethanol concentration, increasing the extraction time from 8 to 15 min at a constant microwave power reduced the DPPH value of walnut husk extracts from 348.9% to 274.08%. In addition, at a fixed extraction time of 8 min, increasing microwave power from 495 W to 900 W increased the free radical scavenging activity of the ethanolic walnut husk extract from 348.9% to 384.53% [48]. In 2022, Safdari and co-workers found that increasing microwave power from 400 to 800 W reduced radical scavenging activity in red beet extracts. Similarly, in the present study, increasing microwave power reduced the free radical scavenging ability of the aqueous sugar beet leaf extract [49].

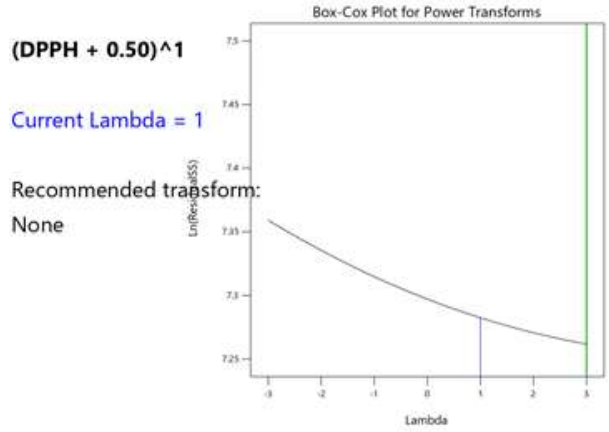

Figure 10. Interaction between time, microwave power, application of the used water solvent and DPPH

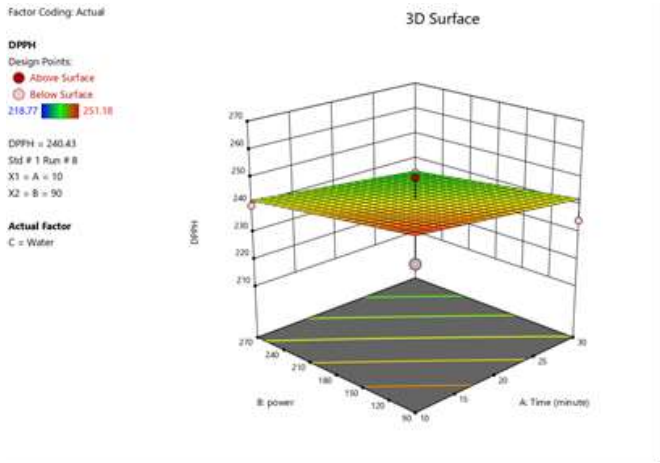

Figure 11. 3D plot of the effect of time and microwave power with water as a solvent on the DPPH

4-Conclusion

In this study, water was selected as the effective solvent due to its high polarity, and a microwave power of 90 W and an extraction time of 10 min were determined as the optimal parameters. Evaluation of the antioxidant capacity of aqueous and acetonic extracts of autumn-cultivated sugar beet leaves showed that, in both

types of extracts, increasing extraction time led to an increase in total phenolic content and a decrease in free radical scavenging activity. Furthermore, increasing microwave power resulted in higher extraction of phenolic compounds from sugar beet leaves and decreased free radical scavenging capacity in the aqueous extract, while increasing this capacity in the acetonic extract. Overall, only slight differences were observed between water and acetone as solvents in terms of phenolic compound extraction and free radical scavenging activity.

Funding

The author declares that he / she has not received any funding.

Author Contributions

All activities were carried out by the author.

Competing Interests

The author confirms that he / she has no financial conflicts of interest or competing interests in this study.

Acknowledgements

The authors would like to express their sincere gratitude to the Vice-chancellor for Research and Technology of Agricultural Sciences and Natural Resources University of Khuzestan for supporting this study (1403.38).

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سایت مجله: www.fsct.modares.ac.ir

مقاله علمی_پژوهشی

بهینه سازی استخراج عصاره برگ چغندر قند (*Beta vulgaris L.*) کشت پاییزه به روش مایکروویو و ارزیابی فعالیت آنتی اکسیدانی آن

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اطلاعات مقاله

تاریخ های مقاله :

تاریخ دریافت: ۱۴۰۳/۱۲/۲۹

تاریخ داوری: ۱۴۰۴/۰۵/۱۰

تاریخ پذیرش: ۱۴۰۴/۰۷/۲۷

کلمات کلیدی:

آنتی اکسیدان طبیعی،
عصاره گیاهی،
بهینه سازی استخراج،
چغندر قند،
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DOI: 10.48311/fsct.2026.84011.0

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چکیده

در مطالعه حاضر، خاصیت آنتی اکسیدانی عصاره برگ چغندر قند (*Beta vulgaris L.*) پاییزه استخراج شده به روش مایکروویو بررسی شد. عصاره‌ها با استفاده از دو نوع حلال آب و استون با توان‌های حداقل ۵۲/۷ وات وحداکثر ۳۰۷/۳ وات در زمان‌های حداقل ۵/۸۶ دقیقه و حداکثر ۳۴/۱۴ دقیقه توسط مایکروویو استخراج شدند. شرایط استخراج بهینه با توجه به محتوی فنل کل و مهار رادیکال آزاد، با کاربرد حلال آب، توان ۹۰ وات و زمان ۱۰ دقیقه معرفی شد. دو فاکتور زمان و توان ماکروویو به طور معنی دار بر استخراج ترکیب‌های فنلی موثر بودند ($P< 0.05$). با افزایش زمان و قدرت مایکروویو، میزان فنل استخراج شده از هر دو نوع عصاره استونی و آبی افزایش یافت، که در این پژوهش عصاره آبی بهتر عمل کرد. ارزیابی توانایی مهار رادیکال‌های آزاد در عصاره‌های برگ چغندر قند پاییزه نشان داد که با گذشت زمان، مقدار این شاخص در هر دو عصاره روند کاهشی داشت. فعالیت مهار رادیکال‌های آزاد در عصاره استونی برگ چغندر قند کمتر از عصاره آبی آن بود. با افزایش توان مایکروویو، توانایی مهار رادیکال‌های آزاد در عصاره استونی افزایش یافت، در حالی که این توانایی در عصاره آبی برگ چغندر قند کمتر بود.