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Optimization of Mucilage Extraction Conditions from (*Althaea officinalis*) Using Microwaves and Using the Response Surface Method

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ABSTRACT

Althaea officinalis is one of the plants that contain mucilage that therapeutic effect of its mucilage on the mucous membrane of the tissue and healing of stomach ulcers have been proven. The mucilage of this plant consists of L-rhamnose, D-galactose, galacturonic acid, and D-glucuronic acid. The polysaccharides found in this plant have antioxidant properties. The main antioxidant activity of it is related to its α-tocopherol composition. Gums extracted from different sources have functional and rheological properties different from each other, and the extraction conditions significantly affect these properties. This research studied the extraction efficiency of *Althaea officinalis* mucilage as a new hydrocolloid source. For this purpose, the effect of microwave power (250-850W), water-dry plant ratio (50-90), and time (2-10 minutes) on the extraction efficiency were optimized. The gum extraction yield ranged from 4.4% to 11.6%. It can be seen that the lowest amount of extraction was obtained at a ratio of water to dry plant of 70, time of 2 minutes, and power of 550 watts, and the maximum amount of extraction was obtained at a ratio of water to dry plant of 80, time of 4 minutes and microwave power of 700 watts. According to the results obtained from the analysis of variance, the quadratic model is the best model to describe data. In low powers, increasing the ratio of water to dry plant led to increased extraction efficiency. The increase in extraction efficiency by increasing the ratio of water to dry plant can be attributed to availability of more solvent, which intensifies the driving force for transferring gum mass from dry plant.

1- Introduction

Hydrocolloids are relatively simple compounds used to modify texture, control crystallization, prevent product weeping or syneresis, coat aromatic and flavorful substances, enhance physical stability, form films, produce gel structures, and increase viscosity in liquid, semi-liquid, semi-solid, and solid foods. Many are not metabolized in the human body and have low caloric value, making them useful in diet foods. Hydrocolloids usually do not directly affect the aroma and taste of foods but are effective in gel formation, water retention, emulsification, and aroma retention (1). From a chemical perspective, texture and stability in foods are attributed to a group of compounds composed of long-chain polysaccharides and proteins, which are extensively used today due to their essential functional properties such as thickening, gel formation, and emulsifying in food systems (2). Among hydrocolloids, mucilages are one of the best options for use in foods because they are compatible with other plant-derived hydrocolloids and starch, sugar, and proteins. Unlike most polysaccharide hydrocolloids, they resist low pH and find greater use in acidic conditions (3). Mucilage is a polysaccharide containing a molecular structure of up to 30,000 monosaccharides. This polymer has a branched structure containing residues of arabinose, galactose, galacturonic acid, rhamnose, and xylose (4). Dissolving mucilage and gum in water can be distinguished as mucilage forms a mass while gums dissolve in water (5). Today, India holds the first rank in the world by producing over 90% of the global demand for mucilage.

Althaea officinalis, belonging to the mallow family, is a perennial and wild plant whose flowers, fruit, and roots are used medicinally. *Althaea officinalis* has large pink, red, white, and yellow flowers, which are used for coating medicines. Besides having properties against cough, chest burning, stomach inflammation, tumors, and viruses, it also enhances the body's immunity (6). *Althaea officinalis* contains polysaccharide mucilage (6.2-11.6%), galacturonorhamnan, arabinan, glucuronan, arabinogalactan, carbohydrates (25-35%), flavonoids, glycosides, sugars (10% sucrose), amines up to 12% asparagine, fat (1.7%), calcium oxalate, coumarins, phenolic acids, and sterols. The pure homogeneous mucilage of this plant is composed of L-rhamnose, D-galactose, galacturonic acid, and D-glucuronic acid in a molar ratio of 3:2:3:3 (7). *Althaea officinalis* contains essential unsaturated fatty acids like omega-9 and omega-5, which can be a good substitute for common vegetable oils. Additionally, the flowers and leaves of *Althaea officinalis* contain essential oils and ascorbic acid (8). The continuous need of human society to extract effective plant compounds has led to extensive research in introducing more efficient and economical extraction processes (9). Hisarinejad and Tat (2019) studied the effect of adding *Althaea officinalis* mucilage on the physical, staling, and sensory properties of sponge cake, and according to the results, the sample containing 75% *Althaea officinalis* mucilage had the best quality and sensory properties (10). Delnavaz Hashemian et al. (2012) also stated in their research that the parts of *Althaea officinalis* have high mucilage, terpene, and phenol content (11).

Modern methods such as ultrasound and microwave have been studied due to their higher speed, adequate energy in extraction, and greater mass transfer (12). Microwave extraction is considered a practical step towards industrializing the extraction of native hydrocolloids for use in food products, though it still

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requires further research. Microwave is one of the most efficient modern methods with high efficiency for extraction. Therefore, it is used in many studies due to its high extraction efficiency, environmental friendliness, low cost, reduced recovery time, and ease of use on a large or small scale.

Optimizing the process is one of the most important activities in today's competitive industry. On the other hand, the high cost of research necessitates the use of methods that allow the determination of variables affecting a process with the fewest number of experiments, which is done using classical methods and statistical model designs (13, 14). The application of RSM (Response Surface Methodology) for design optimization reduces the cost of expensive analytical methods and the numerical irregularities associated with them. In RSM, convergence towards the optimal element is achieved as they reduce the effects of irregular factors (15). In experimental design, the goal is to identify and analyze the variables affecting the outputs with the fewest experiments. This method discovers the optimal amount of each design variable to achieve the best response level. Ghorbani (2015), optimized the extraction of *Althaea officinalis* mucilage using ultrasound and microwave pretreatment and studied its chemical structure and rheological behavior (16). Shima Moezzi Damghan Far (2015) also optimized the extraction of *Althaea officinalis* seed mucilage using ultrasound and microwave pretreatment and studied its chemical structure and rheological behavior (17). Despite initial studies on optimizing extraction conditions and characteristics of this mucilage, studies have not been yet published on optimizing the extraction of *Althaea officinalis* mucilage using microwave and response surface methodology. The main goal of the present study is to investigate the extraction efficiency of *Althaea officinalis* mucilage under the influence of microwave power, water-to-dry plant ratio, and treatment duration. Process variables were optimized using response surface methodology to achieve the optimal yield.

2. Materials and Methods

2-1. Sample Preparation

This study was conducted in 2022 at the Food Technology Laboratory, Department of Food Science and Engineering, Faculty of Animal Science and Food Industries, Khuzestan Agricultural Sciences and Natural Resources University. The raw material used in this research, *Althaea officinalis* flowers, was purchased from a local market in Ahvaz. The impurities were manually separated, and the samples were stored in a dry and cool environment until the tests were conducted.

2-2. Extraction of *Althaea officinalis* Mucilage

To extract the mucilage, the method by Moqbel *et al*. and Sokachaei *et al*.(12,18) was used with slight modifications. First, *Althaea officinalis* flowers were mixed with double-distilled water in specified ratios (50-90 times). Then, the mixture was subjected to microwave irradiation (250-850 watts) for the specified times (2-10 minutes). The mixture was left at room temperature for one hour to obtain more mucilage. The mixture was then filtered using a cloth sieve. The filtered mucilage was mixed with twice its volume of 96% ethanol to coagulate and left at room temperature for one hour. The coagulated mucilage was separated by filtration and dried in oven. The dried mucilage was weighed, and the extraction yield was calculated using Equation 1. The obtained mucilages were stored separately in a dry, cool place for further tests.

$$y=\frac{M_1}{M_2}\times 100$$

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where M_1 is the weight of the extracted mucilage, and M_2 is the weight of *Althaea officinalis* flowers.

2-3. Experimental Design and Data Analysis

Response Surface Methodology (RSM) is a set of statistical and mathematical techniques that is used for processes involving multiple variables or where the mechanisms are poorly understood and existing information is minimal, or when variables interact and the response is nonlinear. The main goal of RSM is to optimize conditions, which the central composite design being preferred. When selecting independent variables and their levels, influential factors are chosen, and their levels are determined. These levels are crucial for the success of the process as they directly affect the outcomes. Since these parameters have different units or ranges, regression analysis cannot be directly performed without normalization. Each coded variable ranges from -1 to +1 to make them dimensionless, and the levels are used coded in the design analysis.

Computer software generates optimal designs based on specific criteria and user inputs, differing in the number of experiments and blocks. After selecting the design, the model relationship is defined, and its coefficients are estimated. The model used in RSM is usually a full or reduced second-order polynomial, expressed as:

$$Y=b_0+\sum b_i x_i+\sum b_{ii}\, x_i^2 \sum b_{ij} x_i\, x_j$$

Where b_{ij} و b_{ii}، b_i، b_0 are regression coefficients for the intercept, linear, quadratic, and interaction terms, and xix_ixi and xjx_jxj are coded independent variables. The model coefficients are estimated using the least squares method, a multiple regression technique. After estimating the coefficients, the predicted response can be easily calculated using the model equation. Since the system behavior is often unknown, the model's fit to the experimental data must be evaluated using various techniques, including error analysis, scaled residuals, PRESS (Prediction Error Sum of Squares), and lack-of-fit tests. The overall predictive capability of the model is usually expressed by the coefficient of determination (R^2) calculated from PRESS. However, R^2 alone is insufficient to assess model accuracy (19).

Treatments were designed using RSM and based on the central composite design for independent variables, including water-to-dry plant ratio, microwave power, and exposure time (Table 1).

Table 1- Levels of independent variable

	Independent variable	Min	MAX	-Alpha	+Alpha
A	Microwave power(watt)	400	700	250	**850**
B	Time(min)	4	8	2	**10**
C	Water ratio	60	80	50	**90**

Table 2 – Experiments of central composite design

Independent variable			
Water ratio	Time(min)	Microwave power(watt)	**Treatment number**
80	8	700	**1**
80	4	700	**2**
80	8	400	**3**

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90	6	550	**4**
70	6	550	**5**
60	7	700	**6**
60	4	400	**7**
70	6	850	**8**
70	6	550	**9**
70	6	550	**10**
70	6	550	**11**
70	6	550	**12**
80	4	400	**13**
70	6	550	**14**
70	6	250	**15**
70	10	550	**16**
50	4	550	**17**
60	6	700	**18**
60	8	400	**19**
70	2	550	**20**

To select the empirical models for response prediction, linear, second-order, and third-order polynomials were fitted to the experimental data and then statistically analyzed to select the appropriate model. Model factors were evaluated at a 95% confidence level. Independent factors were added to the model sequentially, and their significance was tested. As shown in Table 3, the quadratic model is significant based on the results of the analysis of variance (ANOVA).

Next, the chosen statistical design and the model relationship for prediction were fitted and evaluated. The experiments were designed using RSM and central composite design with Design Expert 11 software for the independent variables, and the graphs were drawn using Excel 2016 software. Table 2 shows 20 treatments based on the water-to-flower ratio, microwave power, and time.

3. Results and Discussion

3.1. Model Fitting

Table 3- ANOVA analysis of quadratic polynomial model for extraction yield

p-value Prob > F	F Value	Mean Square	df	Source
0.0225	11.28	6.01	9	**Model**
0.0167	28.13	13.32	1	**A-power**
0.5139	34.32	0.72	1	**B-time**

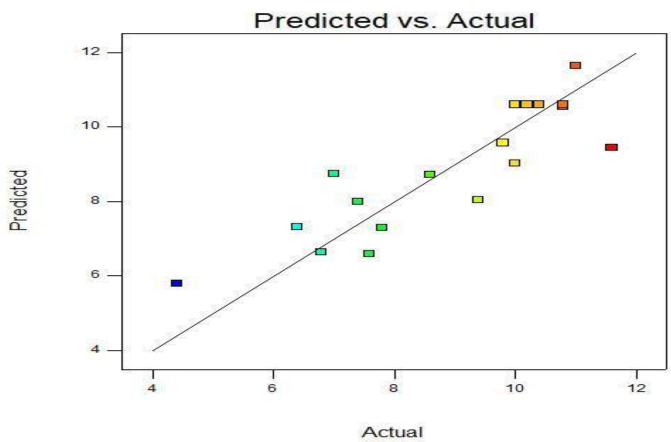
[DOI: 10.22034/FSCT.21.157.176]

0.2811	12.75	2.10	1	**C-water ratio**
0.5547	2.40	0.61	1	**AB**
0.3671	7.81	1.44	1	**AC**
0.3671	7.28	1.44	1	**BC**
0.4540	1.12	0.98	1	**A^2**
0.0015	8.32	30.30	1	**B^2**
0.0288	5.18	10.55	1	**C^2**
		0.52	10	**Residual**
0.0012	7.92	0.92	5	**Lack of Fit**

ANOVA was performed to evaluate the significance of the process variables in each response. The response functions for the measured parameters were compared using different models (linear, two-factor, and quadratic) based on the adjusted correlation coefficient. The model with the highest values of these factors has higher predictive power and accuracy. ANOVA was used to determine the lack of fit and the significance of the independent variables' linear and quadratic effects and interactions on the dependent variables. If the p-value for the lack-of-fit test in ANOVA is ≥0.05, the model is considered sufficient for predicting the desired response (20). In the model used for yield, the equation representing the contribution of each factor and their interactions on the percentage extraction yield of *Althaea officinalis* mucilage is as follows, where A, B, and C are, respectively, microwave power, time, and the water-to-seed ratio.

$$10.80+0.91A+0.21B+0.36C+0.28AB-0.42AC-0.42BC-0.2B^2+C^2$$

After analyzing the data and extracting the model for each dependent variable to assess the performance and accuracy of each model, existing charts can be used. One of these charts shows the predicted response values versus the actual values to help identify values or groups of values the model did not accurately predict. Figure 1 illustrates the actual and predicted values for the model under study. The closer the data points are to the line in this chart, the better the model fits the data and shows less misfit. Figure 1 demonstrates a relatively good fit for the data.



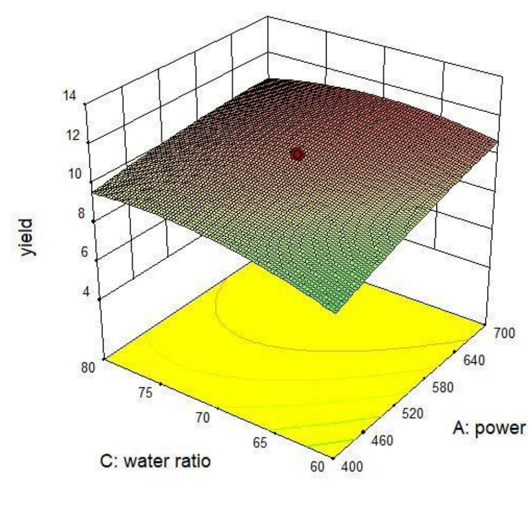
[DOI: 10.22034/FSCT.21.157.176]

Figure 1. Actual values of mucilage extraction versus values predicted by the model

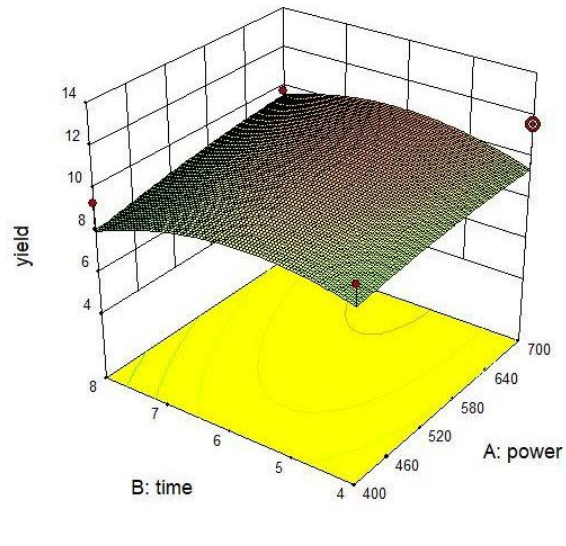
IIn this study, the minimum extraction yield was 4.4%, and the maximum extraction yield was 11.6%, corresponding to samples 20 and 2. These samples had water ratios of 70 and 80, extraction times of 2 and 4 minutes, and microwave powers of 550 and 700 watts, respectively. The value of these parameters varied according to the extraction conditions. Figure 2 shows the effects of the interaction of the independent variables on the gum extraction yield. Figure 2 shows the interaction effects of time and the water-to-dry plant ratio. The gum extraction yield decreased as time increased at constant water ratios and fixed power. Part b of the response surface chart shows the interaction effect of power and time. According to the figure, as microwave power increases at a constant time, the gum extraction yield increases; however, simultaneous increases in power and treatment time lead to a decrease in gum extraction yield. Increasing time while keeping power constant initially increases extraction yield, but after a certain point, it decreases. Part c of the response surface chart shows the interaction effects of power and the water-to-seed ratio. To achieve the highest extraction yield, an increase in microwave power must be accompanied by an increase in the water ratio.

As indicated, increasing the water-to-dry plant ratio at constant powers leads to a decrease in gum extraction yield. Increasing the water ratio at lower powers shows an increase in extraction efficiency. The increase in extraction efficiency with increasing water ratio can be attributed to the greater availability of solvent, which enhances the driving force for the mass transfer of gum from the seeds. In other words, increasing the amount of water facilitates the necessary conditions for water osmosis into the seeds and diffusion of gum out. The negative effect of higher water-to-seed ratios on extraction efficiency has been reported by Singh Tang et al. (2009) for Yanang leaf gum [21] and Karajian et al. (2008) for Lepidium sativum gum [22]. With a further increase in the water ratio, the dilution effect reverses the osmosis process and gum diffusion, decreasing extraction efficiency [23]. Increasing power at fixed time and water ratios also increased mucilage efficiency.

a



b



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C

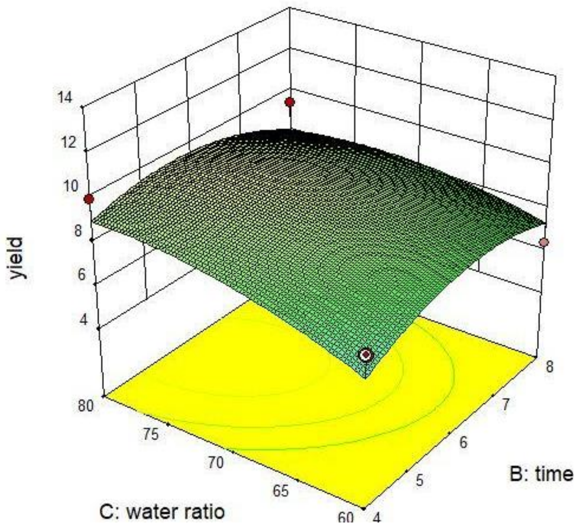

fig.2. Effect of power and water ratio (a), water ratio and time (b), power and time(c) on extraction yield of *Althaea officinalis*

The increase in extraction yield with increased microwave power is related to the direct effects of microwave energy on plant materials [24]. Microwave power is highly related to temperature during microwave-assisted extraction, and with increased microwave power, temperature rises [25]. When the material is exposed to microwave waves, the cell membrane structures break, and as a result, the mucilage enters the solvent. Therefore, increasing microwave power generally improves extraction yield because increased microwave power leads to higher temperatures (depending on the material's and solvent's ability to absorb microwave energy) and faster extraction (evaporation). Selecting a solvent with high extraction power and strong interaction with the material is also essential [26]. Polar solvents such as water and ionic solutions (usually acids) are suitable solvents in microwave-assisted extraction methods, unlike nonpolar solvents like hexane, because they absorb microwave energy well due to their permanent dipole moments. The absorption of microwave waves is related to the dielectric constant, which determines the material's ability to absorb microwave waves. For example, water has a high dielectric constant, which absorbs more microwave energy relative to its loss. Therefore, it increases the temperature and the penetration of compounds into the solvent [27].

Khameh et al. (2020) reported in their research that in the extraction of mucilage from the seeds of Echium amoenum using the microwave, the most influential factor was power (strength), followed by extraction temperature [28]. In the study by Goudarzi Shamsabadi et al. (2022), mucilage extraction from quince seeds was optimized. The results showed that some extraction parameters significantly affected the extraction yield. The reported range in this study was higher than other studies conducted using traditional methods [29]. Samavati and Eskandari (2016) obtained similar results in their study on the extraction of gum from the fruit of Acacia seyal, with the highest extraction yield achieved at the highest microwave power used (300 watts) and the longest time (80.67 minutes) [30]. Yan et al. (2010) also reported the highest extraction yield of gum from Astragalus using prolonged irradiation with these waves but stated that if irradiation continued for too long, the extraction yield decreased due to the decomposing effects of the waves on the extracted mucilage [31].

Alizadeh Behbahani et al. (2016) studied the optimization of extract from the leaves of Avicennia marina using the mixture method and examined its antimicrobial effects. In this study, the effects of solvents such as water, ethanol, methanol, and glycerin, each in five levels (0, 31.25, 83.33, 125, and 250 ml) using mixture design geometry, were evaluated for the extraction of the Avicennia marina leaf extract. The Scheffé polynomial model and numerical optimization were used to model and optimize the extraction. The Scheffé polynomial model could significantly predict the yield from the extraction of Avicennia marina leaf extract. Based on this, the optimal formulation consisted of glycerin (0 ml), water (28.22 ml), methanol (59.83 ml), and ethanol (161.95 ml). This study showed that Avicennia marina leaf extract had a significant antimicrobial effect on the strains under laboratory conditions [32].

Ghorbani (2020) optimized mucilage extraction from *Althaea officinalis* flowers using ultrasound and microwave pretreatment and then investigated its chemical structure and rheological behavior. For optimizing the extraction of *Althaea officinalis* flower mucilage, ultrasound pretreatment (fixed frequency of 37 kHz, power 100-160 watts, time 1-20 minutes, and temperature 30-50°C) and microwave pretreatment (power 180-540 watts, time 5-10 minutes, and powder weight of 30-50 grams) were used. The results showed that extraction with ultrasound had the lowest protein content and was ranked second in viscosity after the microwave method, which had the highest viscosity but even higher protein content than the conventional method [16]. In the study by Salahi et al. (2021), optimization of the extraction conditions of glucomannan from Eremurus root was investigated. For this purpose, the effects of temperature (30-80°C), water-to-solid ratio (50-100), and time (1-4 hours) on extraction yield, apparent viscosity, and solubility were modeled and optimized using the response surface method. The results showed that the quadratic model was best for describing the data. The optimal extraction conditions were a temperature of 79°C, a water-to-solid ratio of 98.3:1, and a time of 3 hours and 12 minutes [33].

Alizadeh Behbahani and Imani Fouladi (2021) evaluated the effects of independent parameters such as the water-to-seed ratio, temperature, time, and ultrasound intensity on the extraction yield of Plantago major using the response surface method. The optimal conditions for achieving maximum extraction yield (13.1%) were an extraction temperature of 70°C, extraction time of 40 minutes, water-to-seed ratio of 10:1, and ultrasound power of 90%. The results showed that at a constant extraction temperature, the yield significantly increased with increasing extraction time, while it showed a slight increase with increasing ultrasound power [34]. Karajian et al. (2011) stated that increasing Lepidium sativum's water-to-seed ratio to

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1:45 increased the extraction yield. They attributed the increase to the availability of sufficient solvent and the driving force needed to mass transfer a certain amount of polysaccharides. However, increasing the water-to-seed ratio to 1:60 resulted in a decrease in extraction yield [35].

Campos et al. (2015) optimized mucilage extraction from chia seeds and evaluated its application in ice cream. They reported that the effects of temperature (30-80°C) and time (2-4 hours) on extraction yield were significant, with both parameters leading to an increase in extraction yield [36]. Dehghan et al. (2017) found that increasing the temperature increased the extraction yield but decreased the apparent viscosity in their study on optimizing quince seed gum extraction using ultrasound and the response surface method [37]. Another study by Yang et al. (2019) showed that increasing extraction time and temperature significantly increased the extraction yield of pectin from potato peels [38].

Vasiei et al. (2019) optimized the extraction conditions of gum from Lepidium sativum seeds using the response surface method. The effects of three independent variables (water-to-seed ratio, extraction time, and temperature) on extraction yield, apparent viscosity, and light transmittance were investigated. The results showed that increasing the water-to-seed ratio and extraction time increased extraction yield while increasing the temperature decreased yield. The optimal conditions were determined as a water-to-seed ratio of 44:1, extraction time of 120 minutes, and temperature of 40°C, resulting in the highest extraction yield [39]. Zamani et al. (2020) optimized the extraction of *Althaea officinalis* seed using the response surface method and concluded that increasing the temperature enhances the extraction yield [40]. Gholali Khani et al. (2014) optimized the conditions for mucilage extraction from flixweed seeds. They found that a temperature of 94°C for 2.9 hours with a water-to-solid ratio of 44.2 at pH 7.5 was the optimal extraction point [41]. Mittal et al. (2016) optimized the extraction of galactomannan from guar (Leguminosae order). They investigated the effects of adding NaOH and MCA, temperature, and time on the extraction yield and solubility. The results showed that increasing the pH from 1.2 to 10 increased the solubility percentage [42]. Alizadeh Behbahani et al. (2017) demonstrated in their study that the optimal conditions for extracting Plantago seed gum are a temperature of 75°C, pH of 6, and a water-to-seed ratio of 1:60. They reported that the gum extracted from Plantago seeds is a high molecular weight polysaccharide (1.2×10^6) containing 85.59% carbohydrates, 76.79 mg of gallic acid equivalents per gram of dry sample total phenolic content, and 97.8 mg per gram total flavonoid content [43].

The optimization of Plantago seed gum extraction with ultrasonic pretreatment was conducted by Niknam et al. (2018). According to their results, the optimal conditions for ultrasonic-assisted extraction were 400 W power, 35°C temperature, and 30 minutes, with a seed-to-distilled water ratio of 1:20, extraction temperature of 75°C, and 40 minutes extraction time. After extraction, purification, and optimization of Plantago seed gum, the moisture, ash, protein, and carbohydrate contents were measured. The results showed that the moisture content was 6.20%, ash 3.23%, protein 2.03%, and carbohydrate 88.47% [44].

The optimization of quince seed gum extraction using microwave power (250-850 W), water-to-seed ratio (20-60), and extraction time (2-9 minutes) was conducted by Goudarzi Shamsabadi et al.

[DOI: 10.22034/FSCT.21.157.176]

(2022) using the response surface method. The physicochemical properties of the gum, including ash, moisture, protein, and fat, were measured, and the antioxidant properties were evaluated. The extraction yield ranged from 8.9% to 15.2%. Increasing the microwave power at a constant time increased the gum extraction yield, but simultaneous increases in power and time led to a decrease in extraction yield. Increasing time at a constant power initially increased extraction but decreased gum yield. The antioxidant properties and inhibitory power were evaluated using DPPH, FRAP, ABTS, and beta-carotene bleaching tests, resulting in 53.19 µg/mL, 1.06 µg/mL, 69.61 µg/mL, 2.92 mg per 100 g, total phenolic content of 74.66 mg gallic acid equivalents per gram of sample, and 670.21 mg quercetin per gram of dry sample [29].

4-Conclusion

Mucilages are secondary plant metabolites. Due to their antioxidant activities, application of mucilages such as *Althaea officinalis* mucilage increases the shelf life of food products. They are recommended and usable in diets as health-promoting fiber compounds. In the present study, the improvement of *Althaea officinalis* mucilage extraction with microwave assistance was investigated using the response surface method to achieve optimal extraction conditions based on independent variables such as microwave power, treatment duration, and water ratio, which resulted in maximum extraction yield. The extraction yield ranged from 4.4% to 11.6%, corresponding to samples 20 and 2, with water ratios of 70 and 80, treatment durations of 2 and 4 minutes, and microwave powers of 550 and 700 watts, respectively. Increasing the water ratio at lower powers led to an increase in extraction yield. Modern methods such as microwave waves, due to their higher speed and effective energy in extraction and mass transfer, can be effective in optimizing the extraction of plant metabolites.

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6-Reference

[1] Farhataki, A., Majzoubi, M. and Mesbahi, G.H., (2013). Characteristics and application of hydrocolloids in food and pharmaceuticals, Agricultural Sciences Publication, Shiraz University. [In Persian].

[2] Etemadi, A. and Atai Salehi, E., (2018). A review of the use of hydrocolloids in dietary food formulation, the first national conference of food science and industry, Karaj. [In Persian].

[3] Rahaty Ghochani, Sh. and Arabshahi Deloui, S, 2013, Investigation of the effect of flax seed mucilage on the sensory chemical and color properties of semi-fat molded yogurt, National Conference of New Sciences and Technologies in Food Industries, Torbat Heydarieh. [In Persian].

[4] Felkai-haddache, l., dahmoun, f., remini, h., lefsih, kh, 2016. Microwave optimization of mucilage extraction from *opuntia ficus*. International

journal of biological macromolecules.84.24-30.

[5] AbbasTabar, B. (2013). Extraction and Investigation of physio-chemical and rheological characteristics of seed gum. Master's Thesis. Tarbiat Modares University.

[6] Zomorodi, Sh., Agdar ghare aghaji, M., Gharekhani, M., Hanifian, Sh, 2022. The effect of *Althaea Officinalis* mucilage coating containing orange (*Citrus Sinensis*) peel essential oil on the oxidative spoilage of rainbow trout (*Oncorhynchus Mykiss*) fillet. Food Engineering Research. Volume 21, Issue 1. Pages 179-192.

[7] Kumar, S. S., Sudhakar, S., Kapil, S. and Snigdha, T. 2016. Ethno pharmacological review on *Althae*a *officinalis*. World Journal of Pharmacy and Pharmaceutical Sciences. 5(7): 425-432.

[8] Mousavi Baighi, S.F, Razavi S.M and Kochaki, A. (2014). Functional properties of mucilage extracted from Althaea officinalis. Master's Thesis.

[9] Elmastas M, Ozturk L, Gokce I, Erenler R, Aboul- Enein Hy. Determination of antioxidant activity of Marshmallow flower (Althaea officinalis). Anal Leh 2004; 37: 1859-69

[10] Yasamani Farimani,T , Hesarinejad , M , Tat, M.2019. A new study on cupcakes' quality and physical and sensory characteristics with Althaea officinalis mucilage. Iranian Food Science and Technology Research Journal, Volume:16 Issue: 3, 2019. Pages 25 – 35.

[11] Delnavazhashemloyan, B. and Shabani, S and Atai Azimi, E, 2013, extraction and determination of terpene content of phenolic mucilage of petal leaf stem and medicinal marshmallow seed *Althaea officinalis L*., First National Conference of Biological Sciences, Flowerjan. [In Persian].

[12] Dehghan Sekachai, A, 2014. Doctoral Thesis with the title of optimizing the extraction of quince gum and investigating the physicochemical, functional properties, and interaction of this gum with whey protein.

[13] Fallah, f., Vasiee, A.R, Alizadeh Behbahani B., Tabatabaei Yazdi F., Mortazavi S. A., 2021. Optimization of gamma-aminobutyric acid production by Lactobacillus brevis PML1 in dairy sludge-based culture medium through response surface methodology. Food Science & Nutrition. 2021; 9:3317–3326.

[14] Alizadeh Behbahani B., Jooyandeh, H., Fallah, f., Vasiee, A.R. 2020. Gamma-aminobutyric acid production by Lactobacillus brevis A3: Production optimization, antioxidant potential, cell toxicity, and antimicrobial activity. Food Science & Nutrition. 2020; 8:5330–5339

[15] Jabroti, A, Ghofrani, A.A. 2014. Introduction of response level methodology. The fourth national conference of new technologies of chemistry and chemical engineering. [In Persian].

[16] Ghorbani, A. 2019.Doctoral Thesis . Optimizing the extraction of Malva mucilage by ultrasound and microwave pretreatment

Investigation of its chemical structure and rheological behavior

[17] Meghazi Damghan Far, Shima .2014. Ph.D. Thesis: Optimization of extraction of ***Althaea officinalis*** seed mucilage (Althaea officinalis) by pretreatment

Ultrasound and microwave and Investigation of its chemical structure and rheological behavior

[18] Maqbal, A., Tayibi, M. 2013. Extraction, preparation of dry powder, and physio-chemical investigations of *Quince Seed* mucilage. Jundishapur Scientific Journal of Medicine, Volume 13, 5, 572-557.

[19] Bas, D., and Boyanci, I.H. 2007. Modeling and optimization I: Usability of response surface methodology. Journal of Food Engineering, 78: 836-845.

[20] Alizadeh Behbahani B., Jooyandeh, H., Fallah, f., Vasiee, A.R, 2021. Optimization of Whey Powder Production Yield Using Spray Dryer and Assessment of Physicochemical Characteristics of the Whey Powder. Iranian Journal Nutrition Science Food Technology. 2021; 15 (4):115-122

[21] Singthong, J., Ningsanond, S., and Cui, S.W. 2009. Extraction and physicochemical characterization of polysaccharide gum from Yanang (*Tiliacora trainers*) leaves. Food Chemistry, 114: 1301-1307.

[22] Garajian, H. (2008). Optimizing the conditions of extracting gum from watercress seeds Examining its functional properties, PhD thesis of the Ferdowsi University of Mashhad.

[23] Globoid, Elnaz, Varidi, Mehdi, Varidi, Mohammad Javad and Kochaki, Arash. 2017. Fenugreek seed gum: optimization of extraction and evaluation of antioxidant properties. Quarterly journal of new food technologies. Volume 5, No. 3, 447-468 .[In Persian].

[24] S. Karimi. S. Sharifzadeh. and H. Abbasi (2020), "Sequential ultrasound-microwave assisted extraction as a green method to extract essential oil from *Zataria multiflora*." Journal of Food and Bioprocess Engineering. 3(2), 101-109.

[25] Elez Garofulić. V. Kruk. A. Martić. I. Martić. Z. Zorić. S. Pedisić. and V. Dragović-Uzelac (2020) "Evaluation of polyphenolic profile and antioxidant activity of Pistacia lentiscus L. leaves and fruit extract obtained by optimized microwave-assisted extraction." Foods. 9(11), 1556.

[26] Hossein Alizadeh, Z, & Danafar, F. (2022). Optimize essential oil extraction from *Ferula assa-foetida* gum using microwave distillation and identify essential oil compounds. Journal of Separation Science and Engineering, 15(1), 90-105. doi: 10.22103/jsse.2023.3864. [In Persia].

[27] H. S. Kusuma. and M. Mahfud (2017) "Microwave hydro distillation for essential oil extraction from Pogostemon cablin Benth: analysis and modeling of extraction kinetics". Journal of Applied Research on Medicinal and Aromatic Plants. 4, 46-54.

[28] Khame, Maryam, Hanrour, Masood and Hamadi, Shokoh Al-Sadat. 2019. Investigate the efficiency of mucilage extraction from Tighal Nishdar using different extraction methods. Food industry engineering research. Volume 19. Number 68. Page 65-78. [In Persian].

[29] Goodarzi ShamsAbadi B, Mehrnia M A, Noshad M, Alizadeh Behbahani B, Barzegar H.2022. Optimization of Microwave Extraction of *Quince Seed* mucilage using Response Surface Methodology. Journal of Food Science and Technology. 2022; 19 (131):101-115. [In Persian].

[DOI: 10.22034/FSCT.21.157.176]

[30] Samavati, V, & Skandari, F. 2014. Recovery, Chemical and rheological characterization of gum from Assyrian palm. International Journal of Biological Macromolecules, 67, 172 - 179. [In Persian].

[31] Yan, M, M, Liu, W, Fu, Y, J, Zu, Y G, Chen, C. Y, & Luo, M. 2010. Optimization of the microwave-assisted extraction process for four minastragalosides in Radix Astragali. Food Chemistry, 119 (4), 1663 -1670.

[32] Alizadeh Behbahani B., Alghooneh, A, Tabatabaei Yazdi F., Shahidi F., Mortazavi S. A., Mohebbi M, 2016. Optimization of mangrove leaf extraction by mixture design and Investigation of its antimicrobial effect on Listeria innocua, Enterococcus faecium, and Escherichia coli. Iranian Food Science and Technology Research Journal Vol. 12, No. 2, June. July. 2016, p. 201- 213.

[33] Sadegh Amiri, M., * Razavi S. M.A. and Salahi, M. 2021. Optimizing the conditions for extracting the gum of the root of *Eremurus spectabiils* by the response surface method and investigating its physicochemical properties. Optimal sample. Journal of Food Science and Technology, No. 112, Volume 18. [In Persian].

[34] Alizadeh Behbahani, B and Imani Fooladi, A.A, 2021. Modeling of Ultrasound-Assisted Extraction, Chemical Composition, Antioxidant Activity, Rheological Aspects, and Biological Properties of “Barhang-e-Kabir” Mucilage. Iranian Journal of Chemistry and Chemical Engineering. Vol. 40, No. 6, 2021.2087-2103.

[35] Karazhiyan, H., Razavi, S. M. A. and Phillips, G. O. “Food Hydrocolloids Extraction optimization of a hydrocolloid extract from cress seed (*Lepidus sativum*) using response surface methodology,” Food Hydrocoll., vol. 25, no. 5, pp. 915–920, 2011

[36] Campos, B. E., Ruivo, T. D., Mônica, R., Scapim, S., Madrona, S. and Bergamasco, R. D. C.,2015, Optimization of the mucilage extraction process from chia seeds and application in ice cream as a stabilizer and emulsifier,” LWT - Food Sci. Technol., vol. 15, 2015.

[37] Dehghan Sekachaei, A., Mahoonak, A. S., Ghorbani, M., Kashaninejad, M. and Maghsoudlou, Y.,2017, Optimization of ultrasound-assisted extraction of quince seed gum through response surface methodology," vol. 19, pp. 323–333, 2017.

[38] Yang, J., Mu, T. and Ma, M.,2019, Optimization of ultrasound-microwave assisted acid extraction of pectin from potato pulp by response surface methodology and its characterization,” Food Chem., vol. 289, no. March, pp. 351–359, 2019.

[39] Vasiee, A.R, Alizadeh Behbahani, B, Tabatabaei Yazdi, F, Moradi, S.2016. Optimization of the production conditions of the lipase produced by Bacillus cereus from rice flour through Plackett-Burman Design (PBD) and response surface methodology (RSM). Microbial Pathogenesis. Volume 101, December 2016, Pages 36-43.

[40] Zamani, Z., Razavi, S. M. A. and Amir, M. S. “The determination of physicomechanical properties of Nettle seed (*Urtica pilulifera*) and optimization of its mucilage extraction conditions using response surface methodology,” JRIFST, pp. 143–160, 2020.

[DOI: 10.22034/FSCT.21.157.176]

[41] Golalikhani, M., Khodaiyan, F. and Khosravi, A.,2014, Response surface optimization of mucilage aqueous extraction from flixweed (*Descurainia sophia*) seeds," Int. J. Biol. Macromol., vol. 70, pp. 444–449, 2014.

[42] Mittal, N., Mattu, P. and G. Kaur, 2016, extraction and derivatization of Leucaena leucocephala (Lam.) galactomannan: Optimization and characterization," Int. J. Biol. Macromol., vol. 92, pp. 831–841, 2016.

[43] Alizadeh Behbahani B., Tabatabaei Yazdi F., Shahidi F., Hesarinejad M. A., Mortazavi S. A., Mohebbi M., Plantago major Seed Mucilage: Optimization of Extraction and Some Physicochemical and Rheological Aspects, Carbo. Poly., 155: 68-77 (2017).

[44] Niknam R, Ise A, Qanbarzadeh B. Extraction, purification and optimization of Barhang seed gum by ultrasonic pretreatment. Iranian journal of food science and industry. 1397; 15 (84): 89-100.

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مقاله علمی_پژوهشی

بهینه‌سازی شرایط استخراج موسیلاژ از گل ختمی(*Althaea officinalis*) به کمک امواج مایکروویو با استفاده از روش سطح پاسخ

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چکیده

گل ختمی یکی از گیاهان حاوی موسیلاژ است که اثر درمانی موسیلاژ آن بر غشای مخاطی بافت و بهبود زخم معده به اثبات رسیده است. موسیلاژ این گیاه از L–رامنوز، D–گالاکتوز، اسید گالاکتونونیک و اسیدD– گلوکورونیک تشکیل شده است. پلی‌ساکاریدهای یافت شده در این گیاه خاصیت آنتی‌اکسیدانی دارند. عمده فعالیت آنتی‌اکسیدانی این گیاه مربوط به ترکیب آلفا – توکوفرول آن می‌باشد. صمغ‌های استخراج شده از منابع مختلف دارای خصوصیات عملکردی و رئولوژیکی متفاوتی نسبت به یکدیگر بوده که شرایط استخراج تأثیر بسزایی بر این خواص دارد. در این پژوهش راندمان استخراج موسیلاژ گل ختمی به عنوان یک منبع جدید هیدروکلوئیدی مورد مطالعه قرار گرفت. برای این منظور اثرات توان مایکروویو (۸۵۰–۲۵۰وات)، نسبت آب (۹۰–۵۰) و زمان (۱۰–۲ دقیقه) بر راندمان استخراج بهینه‌سازی شد. راندمان استخراج صمغ در دامنه ٪٤/٤ تا ٪۱۱/٦ به دست آمد. کمترین میزان استخراج در نسبت آب ۷۰، زمان ۲ دقیقه و توان ۵۵۰ وات به‌دست آمد و بیشترین میزان استخراج در نسبت آب به دانه ۸۰، زمان ٤ دقیقه و توان مایکروویو ۷۰۰ وات بود. با توجه به نتایج حاصل از تجزیه واریانس داده‌ها، مدل درجه دوم بهترین مدل برای توصیف داده‌ها می‌باشد. در توان‌های پایین افزایش نسبت آب به دانه منجر به افزایش راندمان استخراج شد. افزایش راندمان استخراج با افزایش نسبت آب به دانه را می‌توان به وجود حلال بیش‌تر نسبت داد که نیروی محرکه برای انتقال جرم صمغ از دانه‌ها را تشدید می‌نماید.

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