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Optimization of Extraction Method of the Natural Coagulant from *Descurainia Sophia* Seed: Minimization of Color Generation

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ABSTRACT

Background: Water treatment sometimes needs a coagulation and flocculation process to remove suspended and colloidal materials. Inorganic coagulants used create concerns about pollution of the environment and harmful effects on the human's health. The studies carried out previously indicated the capability of an active coagulant agent extracted from *Descurainia Sophia* seed to remove turbidity of water.

Methods: The purpose of this study was to investigate the effect of NaCl (0.05-1 gL^{-1}), NaOH (0.01-0.1 gL^{-1}), extraction duration (1-25 min) and the ultrasound frequency (0-45-75 kHz), used in the extraction of *Descurainia Sophia* seed, on the generation of color in purified water and to provide a model to predict the effects of the studied variables on color generation. Extraction was performed using water as solvent, supplemented with NaCl and NaOH and irradiated by ultrasound. Design of experiments and analysis of results were conducted by the D-optimal method based on the response surface methodology (RSM).

Results: The results demonstrated that only the effect of concentration of NaOH is significant in color generation (with $p<0.05$).

Conclusion: The effect of NaOH on color generation in purified water is predictable by the use of a statistically valid linear model at a confidence level of 95%.

1. Introduction

In order to remove organic pollutants, heavy metals, color and some anions in water and wastewater treatment, a coagulation and flocculation process is used [1]. Supply of potable water from raw water necessitates using the coagulation and flocculation process to remove suspended and colloidal material. Iron and Aluminum salts are among the commonly used coagulant materials. Of the problems caused by the use of Aluminum salts, remains of Aluminum in water, concern about a relation between

Aluminum and Alzheimer's disease and high management costs of the sludge containing metals can be mentioned. Thus, in recent years studies on the use of a variety of natural coagulants in water and wastewater industry have grown [2]. Natural coagulants have been used in water treatment for centuries. For example, *Nirmali* seed and *maize* [3], *mesquite bean* and *Cactus latifaria* [4], *chest-nut* [5], *Jatropha curcas* [6], *Moringa Oleifera* [7] and *leguminous species* [8] have been used to remove turbidity of water.

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Descurainia Sophia, whose growth is from the beginning of spring to late summer, is a plant with high stems that grows naturally [9]. *Descurainia Sophia* seeds, which are bright brown in color and have a length of 0.7 to 1.5 mm, contain mucilaginous substances [10]. The mucilage of the seed has been used in traditional medicine and the enrichment of some foods. The most common way of extracting mucilaginous substances is to use water [11, 12]. Recent studies have demonstrated that the *Descurainia Sophia* seed agent, extracted by the use of the water containing NaCl and NaOH, is capable of being used as a coagulant material to remove turbidity caused by water colloidal particles. Surveys also indicate that having passed the coagulation and flocculation stage, the agent generates color in purified water.

Therefore this study carried out to investigate the independent variables affecting the extraction of the Descurainia Sophia agent and the effect of each variable on generation of color in the water treated by the use of the obtained agent.

2. Materials and Methods

The salt of NaCl and NaOH used was purchased from the German Company of Merck. The Descurainia Sophia seed used was purchased from shops across the cities of Sanandaj, Dorood and Zanjan.

2.1. Design of experiments

Four variables of concentration of NaCl (0.05 to 1 gL^{-1}), concentration of NaOH (0.05 to 0.1 gL^{-1}), duration of extraction (1 to 25 minutes) and the ultrasound frequency (0-45-75 kHz) are considered independent variables and the color generated after the stage of coagulation and flocculation in water (jar test) is considered a dependent variable Design of experiments and analysis of the results was carried out by the D-optimal method based on the response surface methodology. Experiments to develop the model and validate it in optimal conditions were respectively conducted in 50 experiments and additional triplicate experiments.

2.2. Preparation of turbid water

In order to prepare the turbid water, 1 liter of Distilled water was added to 10 grams of kaolin powder and it was put on a magnetic stirrer so that they were completely mixed. Then, the mixture was put aside so particles subsided completely. The suspension was kept as a stock [13].

2.3. Preparation of the Descurainia Sophia seed

Descurainia Sophia seeds were collected from the supplying shops in market and were completely cleaned. Then, they were put in an oven with 100˚Cfor two hours to be dried. Having been dried, the seeds were turned into flour using a domestic grinder [14].

Five grams of *Descurainia Sophia* seed powder was added to 500 ml of the distilled water supplemented with NaCl (0.05 to 1 gL^{-1}) and NaOH (0.01-0.1 gL^{-1}) and was put on a magnetic stirrer for ten minutes to be mixed [15]. The mixture was left stand still for 48 hours. Then 50 samples of the soaked *Descurainia Sophia* seed powder were put in an ultrasound bath, model (LUC405-Korea), for a definite duration. The samples were cleared using a cloth filter. The cleared agent, as an effective coagulant substance, was used for the designed experiments.

2.4. Determination of turbidity

Having conducted each of the jar tests, the samples were immediately taken at a depth of 5 cm above the water surface, in order to measure turbidity of samples, the turbidity device model HACH-2100, made in Germany was used. The device was first calibrated using distille

2.5. Determination of the maximum absorption wavelength

Descurainia Sophia powder, soaked in the distilled water containing 0.1 g L-1 NaOH, was centrifuged at an rpm of 2000 for 20 minutes.

Then, absorbance was scanned from 250 to 700 nm with 10 nm increment using a spectrophotometer (HACH DR 5000).

The maximum absorbance wavelength (λmax) was at 349 nm was read before and after coagulation and flocculation (jar test).

3. Results

The results of the designed experiments are given in Table 1.

Fig. 1 shows normal distribution of residuals. Residual values are the difference between the

observed empirical values and those predicted by the model. The lower the residual values, the higher the accuracy of the model in prediction of results. Distribution of residual points along a direct line indicates normal distribution of residuals. If the distribution of residual points is as a S form or curved, the data transformation might lead to better results [16, 17].

Results of the analysis of variance (ANOVA) in table 2 show that, the only independent variable affecting the color creation at the end of the jar test is NaOH concentration (B). Also, the test of lack of a fit between the model and the data was not significant (p>0.05). The insignificance of lack of fit indicates that the values predicted by the model are well matched by the data obtained from empirical observations.

3.1. The model used to predict color

Using the statistical method of RSM, equation 1, which predicts the effect of the independent variable of NaOH concentration on the color creation at the end of the jar test, was obtained.

Equation 1: Final equation of the actual variable affecting the color investigation

Model

$$Y=0.0352+0.782\times B\ (NaOH)$$

The model presented by equation 1, which is first order, predicts, at a confidence level of 95%, the color generation caused by concentration of NaOH at the end of the jar test. The constant value is the model estimation coefficient. The positive sign of the coefficient of the term indicates the direct effect of the variable on the increase of color. The density of Sodium Hydroxide in water (NaOH) denoted by C and Y represents the absorbance due to color generated at a wavelength of 349 nm.

3.2. Optimum conditions

Optimum conditions predicted by the model to achieve the least absorbance due to generated color including NaCl concentration of 1 gL^{-1}, NaOH concentration of 0.03 gL^{-1}, duration of 5 minutes, an ultrasound frequency of 75 kHz, and the value of light absorption predicted as the response variable was equal to 0.007. The optimum conditions presented by the model were implemented repeatedly three times. Light absorption values caused by the color generated after the jar test were respectively obtained as 0.005, 0.007 and 0.006 (with a difference of less than 5%). The average efficiency of turbidity removal after the jar test was calculated as 95%±5%.

Investigation of the effect of NaOH on the color generated in water is shown in Fig. 2.

According to the diagram, as the concentration of Sodium Hydroxide in the stage of extraction of the coagulant increases, so does the color generated in water after the coagulation and flocculation (after the jar test). Similar results were reported in a study conducted on the effect of soda on wheat seed color. Having soaked in the Sodium Hydroxide solution, red and white wheat respectively changed color to dark red and yellow [18].

As a result, it can be said that the Sodium Hydroxide used for the extraction of the coagulant material causes the color change in *Descurainia Sophia* seed extract.

4. Discussion and Conclusion

The results of the ANOVA indicated that among the studied variables, Sodium Hydroxide concentration in water (p<0.05) is the only effective variable on generation of color in water after the coagulation and flocculation stage.

The first order model is statistically valid and capable of predicting, with a confidence level of 95%, the color generated in water after the jar test caused by different values of NaOH used in the extraction stage of *Descurainia Sophia* seed.

Table 1: Observed and predicted values of absorbance at a wavelength of 349 nm.

RUN	NaCl g L^{-1}	NaOH g L^{-1}	Time Min	Ultrasound KHz	Absorbance at a wavelength of 349 *nm*		
					Initial Observed	Final Observed	Predicted Value
1	1.00	0.10	25	0	0.238	0.120	0.089
2	1.00	0.01	13	45	0.090	0.012	0.039
3	0.05	0.01	17	75	0.091	0.014	0.110
4	1.00	0.10	25	75	0.238	0.123	0.039
5	1.00	0.10	1	0	0.230	0.120	0.039
6	0.05	0.01	1	75	0.089	0.020	0.064
7	0.05	0.10	25	0	0.163	0.140	0.039
8	0.53	0.05	19	75	0.059	0.042	0.064
9	0.05	0.10	1	0	0.206	0.173	0.110
10	1.00	0.07	1	75	0.080	0.062	0.089
11	0.68	0.01	25	45	0.078	0.058	0.076
12	1.00	0.07	1	75	0.074	0.067	0.110
13	0.53	0.10	1	45	0.170	0.150	0.110
14	0.68	0.01	1	75	0.090	0.012	0.039
15	0.68	0.07	25	0	0.101	0.080	0.039
16	0.68	0.01	9	0	0.099	0.075	0.110
17	1.00	0.10	1	45	0.238	0.123	0.039
18	0.05	0.05	1	45	0.104	0.087	0.076
19	0.05	0.10	17	45	0.238	0.124	0.110
20	0.76	0.05	7	45	0.059	0.056	0.064
21	1.00	0.01	17	75	0.127	0.053	0.039
22	1.00	0.10	25	75	0.064	0.053	0.110
23	0.05	0.05	25	75	0.157	0.061	0.110
24	0.37	0.10	25	45	0.156	0.068	0.039
25	0.05	0.04	9	0	0.047	0.045	0.039
26	0.05	0.10	1	45	0.145	0.120	0.110
27	1.00	0.10	9	75	0.164	0.122	0.110
28	1.00	0.01	1	0	0.127	0.053	0.089
29	1.00	0.10	25	45	0.177	0.170	0.058
30	0.29	0.05	19	45	0.183	0.047	0.110
31	0.29	0.05	7	75	0.012	0.002	0.076
32	0.29	0.08	19	0	0.140	0.050	0.039
33	1.00	0.07	9	0	0.049	0.142	0.095
34	1.00	0.01	1	0	0.059	0.053	0.110
35	0.76	0.03	19	0	0.174	0.179	0.039
36	0.05	0.10	25	75	0.031	0.240	0.110
37	0.05	0.01	25	0	0.047	0.017	0.039
38	0.37	0.10	9	0	0.118	0.093	0.110
39	0.53	0.01	25	75	0.062	0.039	0.110
40	0.68	0.10	1	75	0.062	0.051	0.039
41	0.05	0.01	1	0	0.047	0.042	0.076
42	0.05	0.10	1	75	0.106	0.101	0.076
43	1.00	0.04	25	45	0.057	0.052	0.076
44	0.37	0.04	1	0	0.052	0.050	0.039
45	1.00	0.01	1	45	0.049	0.045	0.110
46	1.00	0.01	25	0	0.059	0.057	0.089
47	1.00	0.10	9	75	0.067	0.060	0.039
48	0.37	0.01	9	45	0.060	0.056	0.076
49	0.05	0.01	25	45	0.065	0.060	0.110
50	0.05	0.05	25	75	0.061	0.059	0.110

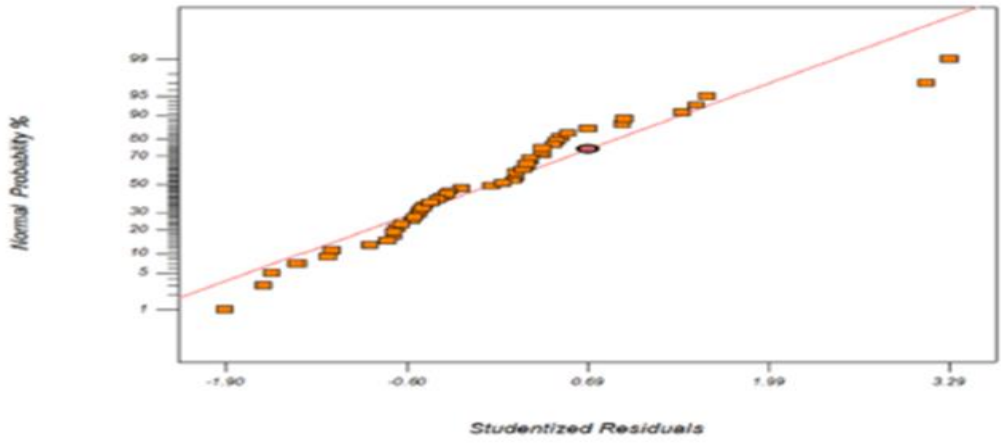

Fig. 1: Normal distribution of remaining and predicted color values.

Table 2: Analysis of variance (ANOVA) for the linear model of color prediction.

ource	Sum of Squares	DF	Mean Square	F Value	Prob> F	
Model	0.049	1	0.049	31.18	< 0.0001	significant
B(NaOH)	0.049	1	0.049	31.18	< 0.0001	
Residual	0.075	48	1.560			
Lack of Fit	0.070	43	1.640	1.86	0.2524	Not significant

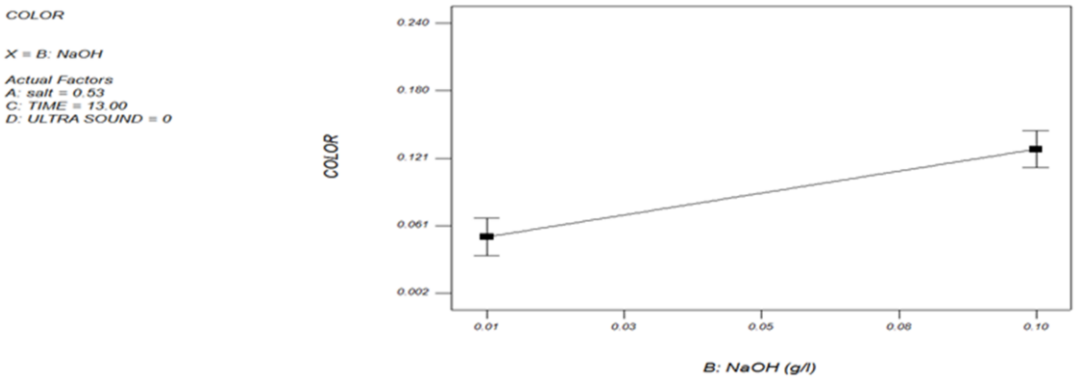

Fig. 2: Effect of Sodium Hydroxide on generation of color (Absorbance at 349 nm).

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