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# Optimization of Parameters for Supercritical Carbon Dioxide Extraction of Mongolian Sea Buckthorn Oil

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## INTRODUCTION & AIM

Sea buckthorn (Hippophae rhamnoides L.) is a deciduous shrub native to cold and arid regions of Eurasia and is particularly abundant in Mongolia, China, and Russia. Mongolian sea buckthorn has long been recognized as a valuable medicinal and nutritional resource, traditionally used for treating burns, wounds, gastrointestinal disorders, and cardiovascular ailments. The seeds and pulp of sea buckthorn contain an exceptionally rich array of bioactive compounds—unsaturated fatty acids, tocopherols, carotenoids, phytosterols, flavonoids, and phenolic compounds—that endow the oil with significant anti-oxidants, anti-inflammatory, and regenerative properties [1-2].

Understanding and optimizing extraction parameters specifically for Mongolian-grown sea buckthorn is essential to fully exploit its industrial and therapeutic potential. Therefore, this study aims to optimize the parameters for supercritical carbon dioxide extraction of Mongolian sea buckthorn seed oil using Response Surface Methodology (RSM). The effects of pressure, temperature, and extraction time on oil yield are investigated. Furthermore, compositional analysis (fatty acid profile, tocopherol content, and phenolic compounds) will be performed to assess oil quality, and an economic evaluation will be conducted to estimate the feasibility of large-scale production. The optimized results are expected to provide a scientific basis for developing a sustainable, high-value extraction process for Mongolian sea buckthorn oil, supporting its applications in the pharmaceutical, cosmetic, and functional food industries.

## MATERIALS

The dried seeds were milled using a laboratory grinder, custom-designed at the Technical Research Center of the School of Mechanical Engineering and Transportation, Mongolian University of Science and Technology, to achieve a controlled particle size distribution. The milled seed powder was subsequently sieved using an OCTAGEN-200 sieve analyzer to ensure uniformity. Approximately 10 kg of ground seed material was weighed for each extraction run. The powdered samples were stored in airtight, opaque containers at 4°C to prevent oxidation and degradation of thermolabile bioactive compounds such as tocopherols and unsaturated fatty acids [3-4]. All experimental extractions in this study were performed using sea buckthorn seeds prepared as described above. The preparation process, including the grinding and sieving of seeds before extraction, is illustrated in Figure 1. Proper seed particle preparation is a crucial factor for the efficient extraction of sea buckthorn seed oil using supercritical $CO_2$, as supported by several previous studies.

Figure 1. (a) Dried sea buckthorn seeds; (b) Appearance of the seeds after grinding, i.e., powdered sea buckthorn seeds.

## Machine Design

Supercritical carbon dioxide extraction of Mongolian sea buckthorn seed oil was carried out using a pilot-scale SE series supercritical fluid extraction system (Taiwan Super-critical Technology Co., Ltd., Taiwan).


Figure 2. Front view of supercritical CO2 extraction equipment: 1-feed tanks; 2-extraction control system, 3-valves, 4-extracted sample collection valves, 5-CO2 tanks, 6-cold water tank, 7-CO2 level meter.

## RESULTS & DISCUSSION

The oil yield was taken as the response variable for the optimization study. Thus, the experimental conditions were established based on the Central Composite Rotatable Design (CCRD) within the framework of Response Surface Methodology (RSM). A three-factor, five-level CCRD was employed to optimize the supercritical $CO_2$ extraction parameters for Mongolian sea buckthorn seed oil. The independent variables were pressure (psi), temperature (°C), and extraction time (h), each examined at five coded levels (−1.682, −1, 0, +1, +1.682), as shown in Table 1.

**Table 1.** Uncoded and coded levels of independent factors used in the experiment.

| Symbols | Independent variables | Coded levels | | | | |
|---|---|---|---|---|---|---|
| | | -1.682 | -1 | 0 | 1 | 1.682 |
| $X_1$ | Pressure (psi) | 3130.55 | 3625 | 4350 | 5075 | 5569.45 |
| $X_2$ | Temperature (°C) | 29.77 | 40 | 60 | 70 | 80.23 |
| $X_3$ | Extraction time (h) | 7.318 | 8 | 9 | 10 | 10.682 |

The Pareto chart of standardized effects (Figure 3) demonstrates the relative importance of each parameter on the extraction yield of sea buckthorn seed oil. The red reference line at t = 2.228 (α = 0.05) represents the threshold for statistical significance. Among the tested variables, pressure (A) had the most pronounced effect, followed by the interaction between pressure and temperature (AB) and extraction time (C), all of which exceeded the significance threshold. This finding is consistent with the ANOVA results, which indicate that pressure ($P < 0.001$), extraction time ($P = 0.021$), and the interaction between pressure and temperature ($P = 0.014$) are significant factors.

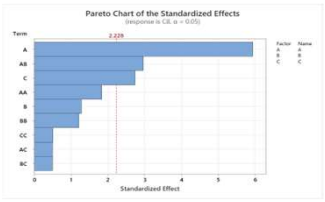


Figure 3. Pareto Chart of the Standardized Effects.

As shown in the Figure 4, (AB) and (AC) combinations exhibit an increasing trend, indicating their significant correlation with oil yield. In contrast, the (BC) combination shows a relatively minor effect.

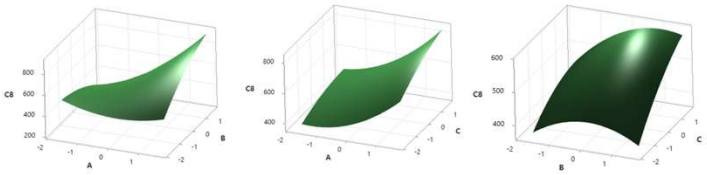


Figure 4. Response surface showing the interactive effect of different extraction conditions of sea buckthorn seed oil: pressure and temperature (AB), pressure and extraction time (AC), and temperature and extraction time (BC)

The experimental data were fitted to a second-order polynomial equation to describe the relationship between the independent variables and the oil yield:

$$Y=b_0+b_1x_1+b_2x_2+b_3x_3+b_{12}x_1x_2+b_{13}x_1x_3+b_{23}x_2x_3+b_{11}x_1^2+b_{22}x_2^2+b_{33}x_3^2$$

## CONCLUSION

The optimization of supercritical $CO_2$ extraction parameters for Mongolian sea buckthorn seed oil demonstrated that pressure is the dominant factor influencing oil yield, followed by the temperature and extraction time. Experimental and statistical analyses confirmed that oil yield is highly dependent on the extraction parameters, with significant interaction effects observed between pressure and temperature as well as pressure and extraction time. The experimental results indicated that the maximum oil yield (800 g/10kg) was achieved under the optimized conditions of 5075 psi pressure, 70°C temperature, and 10 hours extraction time. The regression model predicted a yield of 755.1 g, closely matching the actual yield, which validated the model's predictive accuracy and robustness. Overall, these findings suggest that optimizing the pressure–temperature–time interaction is crucial for maximizing oil yield in the supercritical $CO_2$ extraction of sea buckthorn seeds, providing a reliable basis for process optimization in industrial applications.

## FUTURE WORK / REFERENCES

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