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Response Surface Methodology in The Optimization of Natural Product Extraction and Separation Techniques

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Abstract: This paper focuses on the research application of response surface methodology in the optimization of natural product extraction and separation technology, and reviews the common experimental design optimization methods, the basic concepts, classification and research methods of response surface methodology, as well as the research progress in the optimization of anthocyanin and flavonoids plant extraction; analyzes the research prospects of response surface methodology, and predicts the research hotspots and directions in the light of actual practice.

Keywords: Response surface methodology, Anthocyanin, Flavonoids, Separation optimization.

Natural products are components of animals, plant extracts or insects, marine organisms and microorganisms' internal components or their metabolites, as well as many endogenous chemical components in humans and animals that have multiple effects on the human body [1]. It has a rich and diverse chemical structure as well as a unique biological function. The effective ingredients of natural products from plant are mainly flavonoids, alkaloids, polysaccharides, volatile oils and so on. The effective ingredients of natural products from plant are mainly flavonoids, alkaloids, polysaccharides, volatile oils and so on. The extraction and separation technology of effective ingredients in natural products is an important research direction in natural product separation research, and its extraction purity directly affects the quality of the products. It is one of the research hotspots of natural product optimization design that how to optimize the design of optimization factors so as to obtain higher yields. There are many variables in the optimization design, and some variables have less influence on the optimization target, so that the increase in the number of experiments will bring about an increase in workload; or in the case of multivariate optimization, there are interactions between variables that directly affect the accuracy of the variables and so on [2].

The traditional analytical optimization methods are Single factor experiment method, orthogonal experiment method and response surface methodology. Single factor experiment method can only change one factor at a time, and when there are many test factors, multiple tests and long test cycles are needed to complete the optimization of each factor one by one. Although the orthogonal experiment method can consider multiple factors for design analysis, it cannot give visual graphs [3,4]; the response surface methodology is widely used in agriculture, chemical industry, and pharmaceuticals because it can optimize the response surface affected by multiple factors and has the advantages of fewer tests, good predictive performance, and high precision [5].

As an experimental design and optimization analysis method based on statistical principles, the response surface methodology can find the optimal conditions for an experiment more accurately by constructing a functional relationship between the response value of a system and multiple factors, so as to evaluate the interaction between the factors. This paper reviews the application of response surface methodology in the optimization of natural product extraction and separation techniques, so as to provide support for the optimal design of natural product separation and extraction protocols.

1. The Popular Experiment Design Optimization Methods

1.1. Single factor experiment method

The principle of single factor experiment design is the study of the effect of different test levels on the response values by assuming that there is no interaction between the factors, changing one factor at a time and ensuring that the other factors are maintained at a constant level.

1.2. Orthogonal experiment method

In production and scientific research, in order to reform the old process or to try out new products, it is often necessary to do many factor tests, orthogonal experiment method is a scientific method to study and deal with multi-factor tests. It is based on the principle of orthogonality to select some representative test conditions from the test, using a neatly arranged specification table, i.e., orthogonal table, to arrange the experiment, and strive to find the best production and research conditions through the minimum number of tests. Experience has proved that the orthogonal experiment method is an efficient, fast and economical method. Experience has proved that the orthogonal experiment method is an efficient, fast and economical method. The orthogonal test can consider several factors at the same time, and focus on scientific and reasonable arrangement of the test to find the best combination of factor levels. Experience has proved that the orthogonal experiment method is an efficient, fast and economical method. The orthogonal test can consider several factors at the same time, and focus on scientific and reasonable arrangement of the test to find the best combination of factor levels. It is significantly less than the number of trials with the same factor and the same level of single-factor test, can be obtained through analysis of variance to influence the test results of the primary and secondary factors, as well as consider the interaction between factors, etc.. However, when the scope of the test is large and the test factors need to consider multiple levels, the orthogonal experiment design requires more tests, which often makes the experimenter daunted.

1.3. Uniform Design Experimentation

Uniform design, also known as uniform design experiment method, or space-filling design, it is an experimental design method that considers only the test points in the test range of uniform dispersion. it is from the comprehensive test points selected part of the representative test points, these test points in the test range fully balanced dispersion, in the case of large changes in the range of conditions and the need for multiple levels of testing, uniform design can greatly reduce the number of tests, it only needs to be equal to the number of trials with the number of factor levels to achieve the test effect of the orthogonal design of at least one test can be achieved.

1.4. Simplex e optimization method

The simplex optimization method, referred to as the simplex method, is a method for solving linear programming problems. It is a dynamic apodization method that uses a convex graph (i.e., simplex) in a multidimensional space to move to achieve experimental parameter optimization, and the test conditions chosen each time are based on the results of the previous experiment.

1.5. Response surface methodology

Response surface methodology is the result of the close connection and development of statistics, mathematics and computer science. It is to optimize and evaluate the level of each factor and its interaction by analyzing the functional response surface and contours through designing reasonable experiments, thus establishing the functional relationship between each factor and the response value, and quickly determining the optimal conditions for a multi-factor system. The response surface methodology is mainly divided into central composite design, Box-Behnken design method, secondary saturated D-optimal design, and uniform design method. The commonly used methods are central composite design and Box-Behnken design method. The central composite design is an experimental design method for the quadratic polynomial response surface model for batch testing. The central composite design is an experimental design method developed on the basis of 2-level full factorial and divisional experimental design, which is based on adding a design point to a 2-level test (equivalent to an additional level) so that the nonlinear relationship between the evaluation index (output variable) and the factors can be evaluated

2. Application of Response Surface Methodology in The Optimization of Natural Product Separation and Extraction

2.1. Application in the extraction of plant anthocyanins

Anthocyanins are a class of compounds formed by combining anthocyanins and sugars with glycosidic bonds. They are widely found in the cytosol of flowers, fruits, stems, leaves and root organs of plants, giving them different colors ranging from red, purple-red to orchid. Due to its unique functionality, it is widely used in the food and pharmaceutical industries, such as scavenging free radicals, proliferating lutein, anti-tumor, anti-cancer, anti-inflammatory, weight loss, vision protection, etc. Passiflora pericarp contains anthocyanins, and the prerequisite for their industrial application is their efficient extraction, and there are differences in the structure and properties of anthocyanin from different plant. The extraction efficiency has become one of the difficulties in the preparation of anthocyanin on a large scale, and it is also a hot spot of research in recent years. The application of response surface methodology can efficiently obtain the optimized conditions for its separation and extraction, which provides a theoretical basis for the process production of anthocyanin extraction [7].

2.2. Application in flavonoids extraction

Flavonoids are a class of compounds with the structure of 2-phenylchromone that exist in nature. Flavonoids are usually combined with sugars to form glycosides in plants, and a small proportion exists in the free state (glycosides). Most plants contain flavonoids, which play an important role in plant growth, development, flowering and fruiting, as well as antibacterial and disease prevention. Mi Zhi et al [11] extracted the flavonoids from Brassica juncea, and optimized the Soxhlet extraction method of Brassica juncea flavonoids by single factor experiment combined with response surface methodology. The extraction process conditions were: extraction time of 2.5 h, ethanol concentration of 90%, and material-to-liquid ratio of 1:20 (g/mL), which provided a reference for the extraction and comprehensive utilization of Brassica juncea flavonoids and other components. Wu Jing [12] used ethanol as the solvent to optimize the ultrasonic extraction of flavonoids from lobster brain, and obtained the best extraction conditions as follows: extraction temperature was 60°C, ultrasonic extraction time was 15 min, solvent volume was 46 mL/g, ethanol volume fraction was 50%, and the predicted extraction amount of flavonoids was 161.86 mg/g. which provided theoretical support for the development and utilization of the flavonoids of Quercus fern, and further improve the comprehensive utilization value of Quercus fern. Duan Xiaohua et al [13] used response surface methdolpgy to optimize the extraction material-liquid ratio, ultrasonic power and ethanol volume fraction of total flavonoids of Quercus fern on the basis of single-factor experiments, which provided a basis for the extraction of total flavonoids of Quercus fern.

3. Summary and Prospect

Response surface optimization methodology is an effective statistical method that can examine the combination of factors and the effect on response values over a wide range. Response surface optimization methodology overcomes the shortcomings of other optimization analysis methods that are unable to give intuitive graphs, unable to observe their optimal points intuitively, and difficult to discern the optimization region. The outstanding advantages of response surface methodology that can give an intuitive graph and continuous optimization point play an more and more important role in the experiment design, and is more widely used.

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References

[1] Wang Conghui, Ren Na, Wei Wei, et al. New technologies for separation and purification of natural products [J]. Applied Chemistry, 2019(8):1940-1943.

[2] Cai Zhengxiang . Research on the application of response surface method to mechanical structure optimization problems. 2019.5.

[3] Li Li, Zhang Sai, He Qiang, et al. Application of response surface method in experimental design and optimization [J]. Laboratory Research and Exploration, 2015,34 (08): 41-45.

[4] Zhang Yan, Li Yongzhe. Response surface methodology and its application in the field of pharmacology [J]. Journal of Jilin Institute of Chemical Technology, 2012, 29 (07): 20-26.

[5] Qi Chaoyang, Wang Yaqi, Guo Haoran. Application of response surface methodology in the optimization of chemical production process [J]. 2017 , 10 .

[6] He Wei, Xue Weidong, Tang Bin. Optimization of experimental design methods and data analysis [ ]. Chemical Industry Press.2012

[7] Song Yuye, Wang Yu, Zhu Qianlin, et al. Research progress on the sources and extraction methods of anthocyanins in plants [J]. Food Research and Development, 2022, 43(16): 199-208.

[8] Li Mingzhi, Xie Yuting, Jiang Haiwei, et al. Optimization of ultrasonic-assisted extraction process of purple potato anthocyanin by response surface methodology and its stability study [J]. Food Science and Technology, 2015 Vol. 40 No. 07.

[9] Xiaoju Zhang, Yian Cai, Xinyue Li, et al. Optimization of anthocyanin extraction process and antioxidant properties in purple kale by response surface methodology[J]. Food Research and Development, 2019, 40 (1): 85-91

[10] Huo Yan, Zhao Ziyi, et al. Optimization of alcohol extraction process of anthocyanin in black bean seed coat by response surface methodology[J]. Feed Res. 2020,43(03).

[11] Mi Z, Liu Lizhen, et al. Optimization of flavonoid extraction process and antioxidant activity of Brassica juncea by response surface methodology[J]. China Seasoning. 2022,47(07)

[12] Wu Jing. Optimization of the extraction process of total flavonoids from Lobelia camphora by response surface methodology[J]. Biochemistry.2022,8(05)

[13] Duan Xiaohua, Luo Shijing, et al. Optimization of the extraction process of total flavonoids from Quercus fern by response surface methodology and its antioxidant activity[J]. Journal of Jiangxi Normal University (Natural Science Edition).2022,46(05).