Current Science
CS 5 (2), 1572-1591 (2025)
Received 11 **Dec** 2024 | **Revised 22 Jan** 2025 | **Accepted 20 Feb**. 2025 | **Online Available 18 March** 2025
https://doi.org/ 10.52845/CS/2025-5-2-23

Current Science

Current Science

OPEN ACCESS

ISSN(O)2795-8639

ORIGINAL ARTICLE

Process of Extracting Three Edible Components from *Rosa Roxburghii* Fruit Residue

Meixia Wang[1], Shenglian Yang[2], Qixiu Wei[3], Yongfang Peng[4], Xianzhi Pan[5], Li Zhu[6], Yujun Lu[7], Shuting Li[8], Xianqiao Mei[9], Jianghua Xiong[10], Dingbang Hu[11]

[*]Corresponding Author: Dingbang Hu

Abstract

This process was designed to optimize and extract three edible components from *Rosa roxburghii* fruit residue. The effects of different extraction conditions on the extraction rates of polysaccharides, microcrystalline cellulose and soluble dietary fiber from *Rosa roxburghii* fruit residue were investigated by single factor experiments, and the extraction process was optimized. The results showed that polysaccharide, microcrystalline cellulose and soluble dietary fiber contents were 1.4g, 13.03g and 0.523g, respectively, from 50g of *Rosa roxburghii* fruit residue, and the extraction effect was significant. The process realized the efficient separation and purification of three edible components from *Rosa roxburghii* fruit residue, and provided technical support for the comprehensive application of *Rosa roxburghii* fruit residue.

Keywords: *Rosa roxburghii* Fruit Residue; *Rosa roxburghii* Polysaccharide; Microcrystalline Cellulose; Soluble Dietary Fiber

Introduction

Rosa roxburghii Tratt, a unique plant belonging to the genus Rosa in the Rosaceae family, has fruits that can be considered as a "treasure trove" of nutrition. *Rosa roxburghii* has been documented as a medicinal herb that promotes digestion and strengthens the stomach in several ancient books. For example, "*Collection of Guizhou Folk Prescriptions*" records that *Rosa roxburghii* "strengthens the stomach, aids digestion of food stagnation and fullness, and has the effect of nourishing and tonifying the body." "The *Compendium of Sichuan Traditional Chinese Medicine*" mentions that *Rosa roxburghii* "relieves heat and aids in digestion."As a fruit with both medicinal and edible properties among the characteristic resources of Guizhou, *Rosa roxburghii* is hailed as the "Three - King Fruit" owing to its high content of vitamin C (VC), superoxide dismutase (SOD), and flavonoids [1]. It also enjoys the reputation of the "King of VC" [2]. *Rosa roxburghii* is rich in nutritional value. In recent years, it has been developed into a variety of health products. The continuous growth in market demand has promoted the large-scale artificial cultivation of *Rosa roxburghii* in Guizhou and other places, making it a local industry.

At present, the processing and utilization of *Rosa roxburghii* are mostly limited to primary use, with a low degree of secondary development and utilization. During the production and processing, most of the remaining fruit pomace is either discarded or composted and fermented to return to the soil [3]. Some enterprises also use it as boiler fuel. However, these practices do not fully exploit the value of *Rosa roxburghii* and cause significant waste of *Rosa roxburghii* resources. According to the literature reports, *Rosa roxburghii* polysaccharide is an important water - soluble component in *Rosa roxburghii*, and a large amount of this polysaccharide remains in the *Rosa roxburghii* fruit pomace. This is because polysaccharides have beneficial effects such as anti - fatigue, antioxidant, hypoglycemic, and liver-protective effects [4 - 6].The weight of the

Rosa roxburghii fruit pomace remaining after juicing accounts for approximately half of that of the fresh *Rosa roxburghii* fruits [7]. The dietary fiber content in the fruit pomace after juicing exceeds 70% [8]. Zhou Yujia et al. [9] reported that the total dietary fiber content in the *Rosa roxburghii* fruit pomace is 60.40 g/100g DW (dry weight, DW), and the soluble dietary fiber content is 5.21 g/100g DW. Moreover, the *Rosa roxburghii* fruit residue has been proven to have functions such as reducing blood lipids, lowering blood sugar, softening blood vessels, reducing blood pressure, antioxidation, and promoting bowel movement [10 - 11], indicating that the *Rosa roxburghii* fruit residue still has great potential for development and utilization.

Current research on *Rosa roxburghii* fruit residue has focused mainly on the extraction of single active ingredients, exploration of their functions, and applications in the fields of feed and fermentation [12 - 16]. In general, the existing research lacks consideration from a systematic and comprehensive perspective. In particular, the multilevel extraction and utilization of active ingredients in *Rosa roxburghii* fruit residue have not received sufficient attention.The aim of this study was to overcome the existing limitations, and to construct a multistage extraction and utilization system of edible components from the *Rosa roxburghii* fruit residue from the perspective of system synthesis. In view of the waste of *Rosa roxburghii* fruit residue, a multistage extraction and utilization strategy was proposed in this paper. In this study, a multistage extraction and utilization strategy was proposed. *Rosa roxburghii* fruit residue was used as a raw material to extract the *Rosa roxburghii* polysaccharide (RrP), and the soluble dietary fiber (SDF) and microcrystalline cellulose (MCC), so as to maximize the utilization of the components of *Rosa roxburghii* fruit residue, reduce the discharge of solid waste, and further achieve a win-win situation of economic and environmental benefits.

1.Materials and methods

1.2 Experimental Materials and Reagents

Rosa roxburghii fruit residue (purchased from Huaxi District, Guiyang City, Guizhou Province), NaOH solution (Chongqing Maoye Chemical Reagent Co., Ltd.), HCl (Sinopharm Chemical Reagent Co., Ltd.), H_2SO_4 (Chongqing Chuandong Chemical (Group) Co., Ltd.), glucose (Tianjin Kemiou Chemical Reagent Co., Ltd.), anhydrous sodium sulfite (Chengdu Jinshan Chemical Reagent Co., Ltd.), a sulphur dioxide test tube (Wuhu Jingwei Biotechnology Co., Ltd.), absolute ethanol (Shandong Fuyu Chemical Co., Ltd.), polyamide (Sinopharm Chemical Reagent Co., Ltd.)

1.3 Instrument and equipment

A Chinese herbal medicine grinder (FW177, Tianjin Teste Instrument Co., LTD.), electronic balance (MP6001, Shanghai Sun-Yu Hengping Scientific Instrument Co., LTD.), digital display constant-temperature water bath (HH-6, Shanghai Pudong Logistics Optical Instrument Factory), rotary evaporation instrument (Shanghai Yarong Biochemical Instrument Factory), digital display blast drying box (GZX-9070 MBE, Shanghai Bosun Industrial Co., LTD. Medical Equipment factory), pH meter (FE28, METTLER Toledo Instrument Co., LTD.), ultraviolet spectrophotometer (756PC, Shanghai Sun-Yu Hengping Scientific Instrument Co., LTD.), and high-speed refrigerated centrifuge (MuLtifuge XIR, Thermo Fisher Technology Co., LTD.)were used.

2.Method

2.1 Preparation of polysaccharides from *Rosa roxburghii* Fruit Residue

2.1.1 Pretreatment of *Rosa roxburghii* fruit residue

The *Rosa roxburghii fruit residue* was crushed through a No. 4 sieve (65 mesh), appropriate amount of *Rosa roxburghii fruit residue* was taken, and 80% ethanol was added at a ratio of solid to liquid of 1:12g/ml, and reflux extraction was carried out in an 80 ℃ water bath 4 times each time for 2 h. In this way, the insoluble impurities, some pigments, and macromolecular impurities, fat and wax in the *Rosa roxburghii* fruit residue were removed, and the samples of the *Rosa roxburghii* fruit residue were obtained after extraction and filtration in a drying oven at 55 ℃ and stored for later use.

2.1.2 Extraction of *Rosa roxburghii* polysaccharide

The extraction of polysaccharides from *Rosa roxburghii* fruit residue was performed by water extraction and alcohol precipitation [17] with the assistance of ultrasonication [18]. After

pretreatment, a sample of *Rosa roxburghii* fruit residue was taken, and appropriate amount of deionized water was added to the ultrasonic machine for ultrasonic treatment, followed by centrifugation, pumping and filtration, and the filtrate was used for backup. The extraction of filtrate residue was repeated again to improve the extraction rate. The filtrate was combined twice, the filtrate volume was concentrated by rotary evaporation, and the polysaccharide precipitation was carried out by adding four times the volume of anhydrous ethanol, and the impurities were removed by washing with anhydrous ethanol twice. The extracted precipitate was freeze-dried to obtain the RrP. The yield of *Rosa roxburghii* crude polysaccharide was calculated according to the following formula:

A＝B/C×100%

Where A is the yield rate of *Rosa roxburghii* crude polysaccharide, B is the mass of *Rosa roxburghii* crude polysaccharide, and M is the sample mass.

2.1.3 Determination of polysaccharide content in *Rosa roxburghii*

The content polysaccharide was determined via the phenol-sulfuric acid method [19] with distilled water as the blank control and glucose as the standard substance. The absorbance was measured at 490 nm via an ultraviolet spectrophotometer. The standard curve Y=0.5245X+0.1465(R^2= 0.999) was drawn with glucose concentration as the horizontal coordinate and the absorbance as the vertical coordinate. Fig. 2-1-3. The formula for calculating the polysaccharide content of Roxburgh pear is as follows:

$$Y = \frac{B(g) \times C(g)}{D(g)} \times 100\%$$

Where Y represents the content of *Rosa roxburghii* polysaccharide, B represents the mass of *Rosa roxburghii* crude polysaccharide, C represents the mass of *Rosa roxburghii* polysaccharide in the mixture solution, and D represents the mass of the pretreated sample.

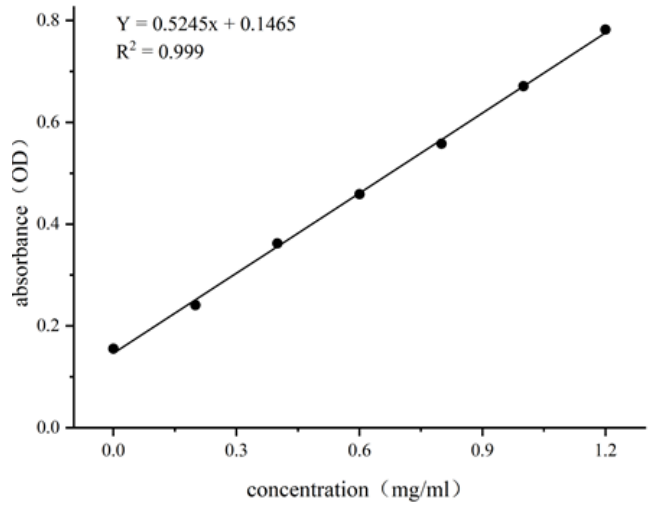

Figure 2-1-3 Glucose standard curves

2.1.4 Single factor experimental design for extraction and decolorization of *Rosa roxburghii* polysaccharide

By changing the four conditions of ultrasonic time, temperature, solid-liquid ratio, and power, the optimal conditions of these four factors can be determined. The

experimental condition were as follows: ultrasonic times of 5, 15, 30, 45, and 60 min, the ultrasonic temperatures of 50, 60, 70, 80, and 90 , solid–liquid ratios of 15, 30, 45, and 60 ml/g, and the ultrasonic powers of 50, 100, 150, 200, and 240 W. The other three factors were combined, and investigate the influence of another factor on the preparation yield of *Rosa roxburghii* polysaccharide was investigated. To determine the optimal time and dosage for polyamide decolorization, the decolorization effects at different times and dosages were compared to

determine the best decolorization conditions. The experimental conditions were as follows: the time was set at 1, 2, 3, 4, and 5 h, and the PA dosage was set at 0.25, 0.50, 0.75, and 1.0 g.

2.2 Preparation of soluble dietary fiber

The methods used to extract soluble dietary fiber from *Rosa roxburghii* fruit residue include various methods such as physical-assisted extraction, chemical extraction, and biological extraction [20-21]. Chemical methods has significant advantages such as high extraction efficiency, good purity, mature technology, and good cost-effectiveness. Chemical reagents can be used to efficiently separate dietary fiber, remove impurities, and achieve large-scale stable production at low cost. In this work, a chemical method is used to extract soluble dietary fiber, and the process was as follows: an appropriate amount of *Rosa roxburghii* crude residue was collected, add Na_2SO_3 was added, the mixture was heated, stirred in a water bath, and then filtered for decolorization. A certain concentration of hydrochloric acid solution was added to the decolorized crude residue, which was stirred in a water bath, and then filtered to obtain the acidolysis filtrate. The acidolysis filtrate was reacted with sodium hydroxide, and then ethanol was added. After standing, decarboxylation and alcohol precipitation occur to form dietary fiber precipitates. Finally, the soluble dietary fiber product is obtained through suction filtration and drying.

$$P = S/Z \times 100\%$$

Where P is the extraction rate of soluble dietary fiber from *Rosa roxburghii*, S is the mass of soluble dietary fiber from *Rosa roxburghii*, and Z is the mass of *Rosa roxburghii* fruit residue.

2.2.1 Single Factor Experimental Design for the Preparation of Soluble Dietary Fibers

By changing the amount of Na_2SO_3, the solid-liquid ratio of dilute hydrochloric acid, the pH, the water bath temperature, and the water bath time, the optimal conditions for can be determined. The experimental conditions were as follows: the sodium sulfite concentration were 0, 0.5, 1.0, 1.5, and 2.0 %, the solid-liquid ratios of the dilute hydrochloric acid solutions were 1:6, 1:8, 1:10, 1:12, and 1:14 g/mL, the pH values of the dilute hydrochloric acid solutions were 1.0, 1.5, 2.0, 2.5, and 3.0, the water bath temperatures were 70, 75, 80, 85, and 90 ℃, and the water bath time is 30, 45, 60, 75, and 90 (min). The other four factors were fixed and influence of another factor on the preparation yield of soluble dietary fiber was investigated.

2.2.2 Orthogonal Experimental Design for the Preparation of Soluble Dietary Fibers

To optimize the extraction conditions of soluble dietary fiber from *Rosa roxburghii* fruit pomace, an L9(4^3) orthogonal experimental design was further conducted on the basis of single-factor experiments, as shown in Table 1. Taking the extraction rate of soluble dietary fiber from *Rosa roxburghii* as the evaluation index, the influence of different combinations of condition on the extraction rate of soluble dietary fiber from *Rosa roxburghii* was observed to determine the most suitable extraction conditions.

Table 1 Orthogonal experimental factor level table

EXPNO	A Temp.(℃)	B pH	C Time(min)	D Solid-Liquid Ratio(g/mL)
1	75	1.2	30	1:8
2	80	1.4	45	1:10
3	85	1.6	60	1:12

2.3 Preparation of Microcrystalline Cellulose

At present, the commonly used methods for preparing microcrystalline cellulose include physical methods (such as extrusion), enzymatic methods, chemical methods (such as organic solvents, ionic liquids, and acid-base hydrolysis) and group methods (such as irradiation-enzymatic hydrolysis). Chemical methods have the advantages of low cost, short time and relatively mature preparation processes [22-25], and have been widely used in related research and practice. The acid-base hydrolysis method adopted in this paper was used to extract microcrystalline cellulose. The specific operations are as follows: *Rosa roxburghii* fruit residue is used as the raw material, and NaOH solution is first used to pretreat it, which can effectively remove some impurities in the residue, such as hemicellulose

and lignin, and create favorable conditions for subsequent extraction. Then, HCl solution was was subsequently used to further treat the NaOH-pretreated *Rosa roxburghii* fruit residue, and through the synergistic action of acid and base, the cellulose in the residue was hydrolyzed, and then the microcrystalline cellulose was subsequently prepared.

2.3.1 Alkali pretreatment of *Rosa roxburghii* fruit residue

The *Rosa roxburghii* fruit residue was crushed through a No. 4 sieve (65 mesh), and the *Rosa roxburghii* fruit residue powder was removed. A NaOH solution with a mass fraction of 9% was added at a liquid-to-material ratio of 20:1 ml/g, mixed well, and heated in a water bath at 85 ℃ for 2 hours. After cooling to room temperature, the mixture was filtered and washed with distilled water to neutral, dried, weighed, and crushed.

2.3.2 Preparation of Microcrystalline Cellulose by Acid Treatment

After alkali pretreatment, the *Rosa roxburghii* fruit residue powder was added to 9% hydrochloric acid solution at a liquid-to-material ratio of 20:1 ml/g, heated in a water bath at 90 ℃ for 2 h, removed and cooled to room temperature. After suction filtration, the mixture was washed with distilled water to a neutral pH, after which an appropriate amount of 7.5% hydrogen peroxide solution was added. The pH was adjusted to approximately 10, the mixture was heated in a water bath at 90 ℃ for 30 min, removed, cooled to room temperature, suction filtered, washed to neutral, dried, crushed, and passed through a 200-mesh sieve to obtain microcrystalline cellulose from *Rosa roxburghii* fruit residue. The yield of alkali pretreatment products and the yield of microcrystalline cellulose prepared by acid treatment were calculated via the following formula.

$$W = A / M \times 100\ \%$$

Where W is the yield of alkali pretreatment products, A is the quality of alkali pretreatment products, and M is the quality of *Rosa roxburghii* fruit residue. In acid hydrolysis, W is the yield of microcrystalline cellulose from *Rosa roxburghii* fruit residue, A is the quality of microcrystalline cellulose from *Rosa roxburghii* fruit residue, and M is the quality of the alkali-pretreated product.

2.3.3 Single Factor Experimental Design of Microcrystalline Cellulose Preparation

Single-factor experiments involving alkali pretreatment and acid hydrolysis were carried out on the basis of microcrystalline cellulose prepared previously. Alkali pretreatment and acid hydrolysis were carried out under different conditions, such as different liquid–solid ratios, NaOH solution concentrations, hydrochloric acid solution concentrations, hydrolysis times and hydrolysis temperatures.

The hydrolysis conditions for alkali pretreatment were as follows: the ratio of liquid to material was 10:1, 15:1, 20:1, 25:1, 30:1 (ml/g); the concentration of NaOH solution was 3%, 5%, 7%, 9%, and 11% (mass fraction); the hydrolysis temperatures were 50, 60, 70, 80, and 90 ℃; and the hydrolysis times were 1, 1.5, 2, 2, 5, and 3 h, respectively. The other three factors were fixed to investigate the effect of another factor on the yield of microcrystalline cellulose. After hydrolysis, the alkali pretreatment products were obtained by filtration, washing and drying.

The acid hydrolysis conditions were set as follows: the ratios of liquid to material were 10:1, 15:1, 20:1, 25:1, 30:1, and 35:1 (ml/g); the concentrations of hydrochloric acid were 3%, 5%, 7%, 9%, and 11% (mass fraction); the hydrolysis temperatures were 60, 70, 80, 90, and 100 ℃; and the hydrolysis times were 1, 1.5, 2, 2.5, and 3 h, respectively. The other three factors were fixed to investigate the effect of another factor on the yield of microcrystalline cellulose. After hydrolysis, microcrystalline cellulose products were obtained by filtration, washing to neutral, bleaching, filtration, washing to neutral, drying, crushing and sieving..

2.3.4 Orthogonal Experimental Design for the Preparation of Microcrystalline Cellulose

On the basis of single-factor experiments, the influence of each factor on the yield of microcrystalline cellulose was analyzed, and the L16(4 ^ 5) orthogonal experimental design was carried out at a reasonable level, as shown in Table 2 and Table 3. According to the data obtained, SPSS software was used to analyze the data to observe whether there was a significant difference between the different treatment groups, and then the best process parameters were obtained.

Table 2 Levels of factors in the orthogonal alkali pretreatment experiments

Level	A Conc. of NaOH (wt%)	B Solid-Liquid Ratio (mL/g)	C Hydrolysis Time (h)	D Hydrolysis Temp. (℃)
1	3	10:1	1	50
2	5	15:1	1.5	60
3	7	20:1	2	70
4	9	25:1	2.5	80
5	11	30:1	3	90

Table 3 Level table of orthogonal experimental factors for acid pretreatment

Level	A Conc. of HCl (wt%)	B Solid-Liquid Ratio (mL/g)	C Hydrolysis Time (h)	D Hydrolysis Temp. (℃)
1	3	10:1	1	60
2	5	15:1	1.5	70
3	7	20:1	2	80
4	9	25:1	2.5	90
5	11	30:1	3	100

2.4 Total extraction process of polysaccharides, microcrystalline cellulose and soluble dietary fiber from *Rosa roxburghii* Fruit Residue

Fifty grams of *Rosa roxburghii* fruit residue was collected, and the above three active ingredients were extracted under the best conditions. The process was as follows:

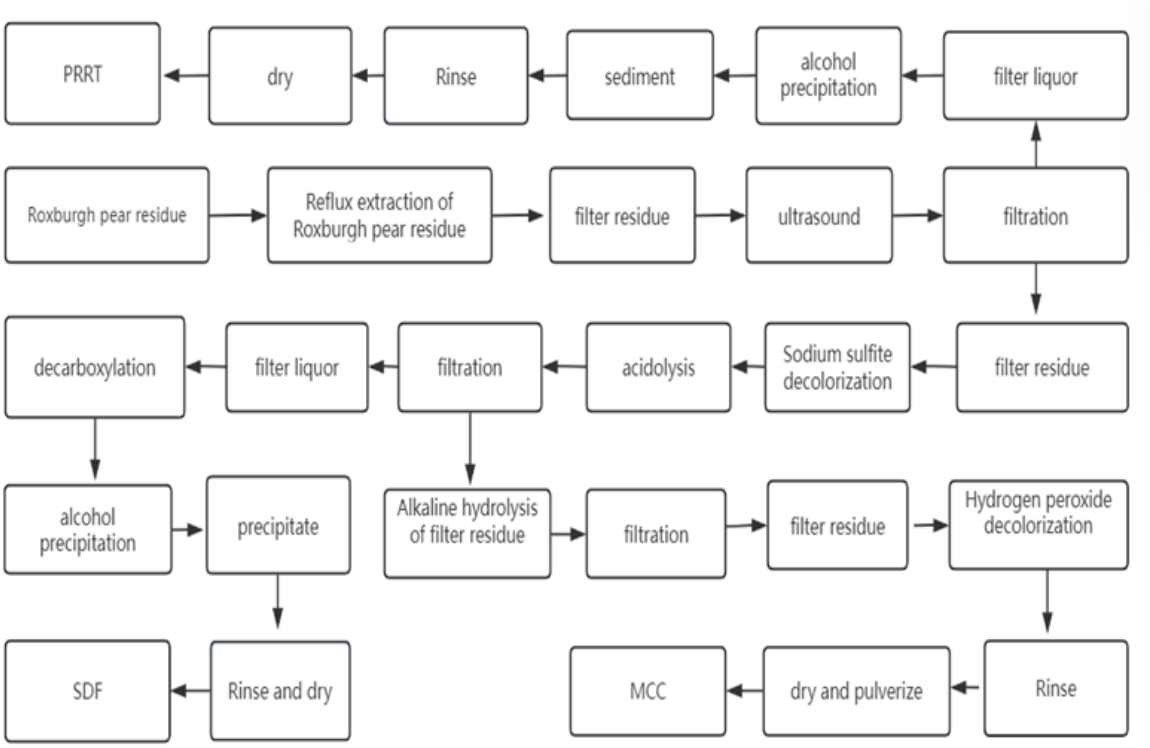

Figure 0-1General flowchart of the extraction of three active ingredients from *Rosa roxburghii* fruit residue

3. Results and analysis

3.1 Results and analysis of single-factor experiments for the preparation of *Rosa roxburghii* polysaccharide

3.1.1 Influence of ultrasonication time on the yield of *Rosa roxburghii* polysaccharide

Under the conditions of a liquid-to-material ratio of 45 mL/g, an extraction temperature of 80 ℃, and a power of 150 W, the effects of different ultrasonication times on the extraction efficiency of *Rosa roxburghii* polysaccharides are shown in Fig. 3-1-1 (a). Fig. 3-1-1 (a) shows that within the range of 5 - 60 min of extraction time, as the extraction time increased, the extraction rate of *Rosa roxburghii* polysaccharide first increased but then decreased. The extraction rate of *Rosa roxburghii* polysaccharide reached its peak when the ultrasonication time was 45 min.

3.1.2 The Influence of ultrasonic temperature on the yield of *Rosa roxburghii* polysaccharide

Under the conditions of a liquid-to-material ratio of 45 mL/g, an extraction time of 45 min, and a power of 150 W, the effects of different extraction temperatures on the extraction efficiency of *Rosa roxburghii* polysaccharides are shown in Fig. 3-1-1 (b). As shown in Fig. 3-1-1 (b), within the temperature range of 50 - 80 ℃, with increasing extraction temperature, the extraction rate of *Rosa roxburghii* polysaccharide first increased but then decreased. The extraction rate of *Rosa roxburghii* polysaccharide reached its maximum when the extraction temperature was 70 ℃.

3.1.3 The Influence of ultrasonic power on the yield of *Rosa roxburghii* polysaccharide

Under the conditions of an extraction time of 45 min, a temperature of 70 ℃, and a liquid-to-material ratio of 45 mL/g, the influence of different ultrasonic powers on the extraction efficiency of *Rosa roxburghii* polysaccharide is shown in Fig. 3-1-1 (c). Figs. 3-1-1 (c) show that when the ultrasonic power varies from 50-200 W, with increasing ultrasonic power, the extraction rate of *Rosa roxburghii* polysaccharide first increases but then decreases. The extraction rate of *Rosa roxburghii* polysaccharide reached its maximum when the ultrasonic power was 200 W.

3.1.4 Influence of the ultrasonic liquid-to-material ratio on the yield of *Rosa roxburghii* polysaccharide

Under the conditions of an extraction time of 45 min, an extraction temperature of 70 ℃, and a power of 150 W, the effects of different liquid-to-material ratios on the extraction efficiency of *Rosa roxburghii* polysaccharides are shown in Fig. 3-1-1 (d). Fig. 3-1-1 (d) shows that when the liquid-to-material ratio varies from 15:1 to 60:1, with increasing liquid-to-material ratio, the extraction rate of *Rosa roxburghii* polysaccharide first increases but then decreases. The extraction rate of *Rosa roxburghii* polysaccharide reached its maximum when the liquid-to-material ratio was 45:1.

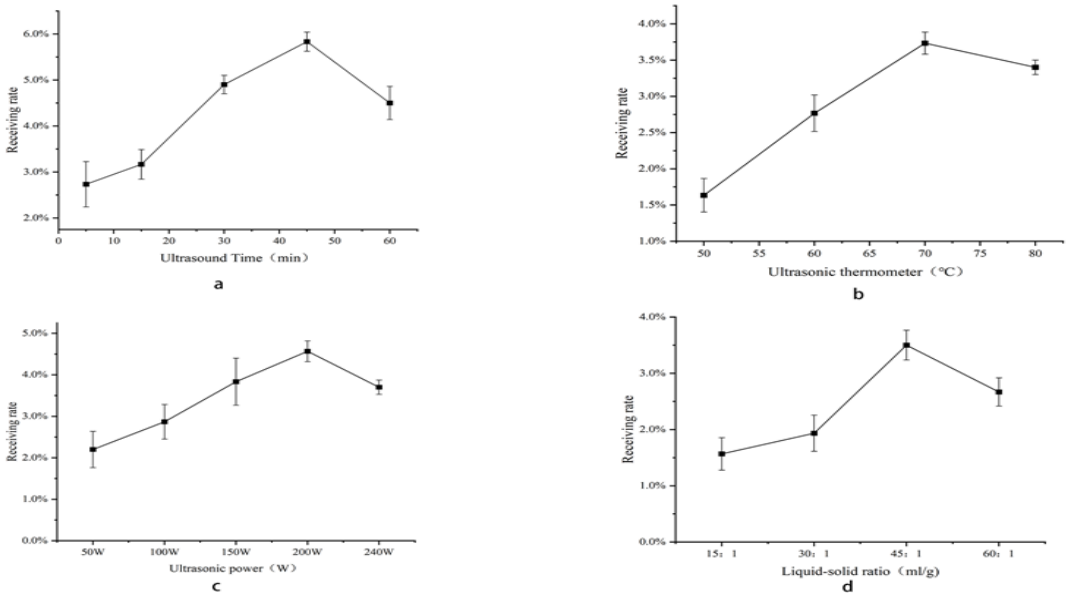

Figure 0-1Influence of different factors on the polysaccharide yield of *Rosa roxburghii*

Note: (a represents the influence of ultrasonic time on the yield of *Rosa roxburghii* polysaccharide, b represents the influence of ultrasonic temperature on the yield of *Rosa roxburghii* polysaccharide, c represents the influence of ultrasonic power on the yield of *Rosa roxburghii* polysaccharide,d represents the influence of the liquid-solid ratio on the yield of *Rosa roxburghii* polysaccharide.)

3.1.5 Decolorization Rate

3.1.5.1 Effect of the Polyamide Treatment Time on the Decolorization Rate

The fixed polyamide was 0.25 g, and the effect of treatment time on the decolorization rate of polysaccharides is shown in Fig. 3-1-2 (a). Fig. 3-1-2 (a) shows that when the decolorization rate of polysaccharides was in the range of 1~4 h, the decolorization rate of polysaccharides first increased and then decreased with increasing time and peaked at 4 h.

3.1.5.2 Effect of the Polyamide Dosage on the Decolorization Rate

The fixed decolorization time was 4 h, and the effect of the PA dosage on the decolorization rate of polysaccharides is shown in Fig. 3-1-2 (b). Fig. 3-1-2 (b) shows that when the decolorization rate of polysaccharides is in the range of 0.25~1 g, the decolorization rate of polysaccharides first increases and then decreases with increasing PA dosage, reaching a peak at 0.5 g.

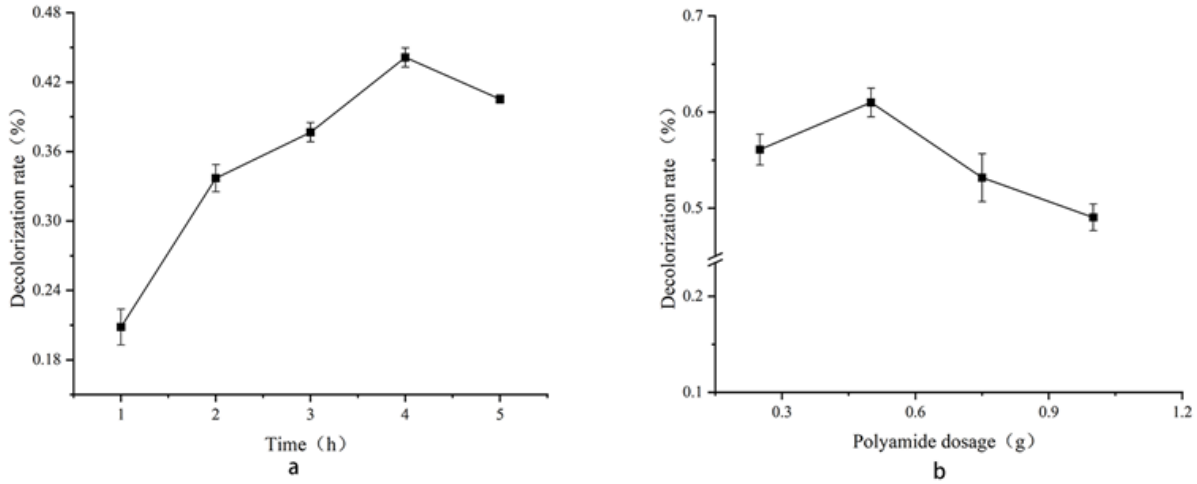

Figure 3.1-2 Changes in the decolorization rate of *Rosa roxburghii* polysaccharides caused by different factors

Note: (an indicates the relationship between the decolorization rate of the polyamide and time, b indicates the relationship between the decolorization rate of the polyamide and the dosage)

3.2 Results and Analysis of Single Factor Experiments for the Preparation of Soluble Dietary Fibers

3.2.1 Influence of different amounts of added sodium sulfite on the extraction rate of *Rosa roxburghii* soluble dietary fibers

Under the conditions of a solid–liquid ratio of 10:1 (mL/g), a dilute hydrochloric acid solution (pH = 1.0), and an 80 ℃ water bath for 60 min, the effect of the addition of sodium sulfite on the extraction rate of soluble dietary fiber from *Rosa roxburghii Tratt* was observed, as shown in Fig. 3-2 (a). Fig. 3-2 (a) shows that the extraction rate of soluble dietary fiber first increased but then decreased with increasing sodium sulfite mass fraction and reached the highest value at 1.0%. Above this ratio, the extraction rate decreased, especially at 1.5%, which may be due to the excessive rupture of cells caused by the high concentration of sodium sulfite; thus, the material is lost during cleaning, so the addition of excessive sodium sulfite is not appropriate.

3.2.2 Influence of Different Solid–Liquid Ratios on the Extraction Rate of *Rosa roxburghii* Soluble Dietary Fiber

Under the conditions of 1.0% anhydrous sodium

sulfite, dilute hydrochloric acid solution (pH = 1.0), and 80 ℃ water bath heating for 60 min, the effect of the solid–liquid ratio on the extraction rate of soluble dietary fiber from *Rosa roxburghii Tratt* was observed, as shown in Fig. 3-2 (b). Fig. 3-2 (b) shows that the extraction rate of soluble dietary fiber first increased but then decreased with increasing solid–liquid ratio and reached the highest value when the solid–liquid ratio was 1:10. Above this ratio, the extraction rate decreased, especially when the ratio of material to liquid was 1:12, and the extraction rate decreased significantly. The reason may be that the ratio of material to liquid is too high, which leads to the solution being too thick and difficult to filter. Some of the solution is not filtered out to cause loss, and the ratio of material to liquid should not be too large. Therefore, ratios of 1:8, 1:10 and 1:12 were selected as the ratios of material to liquid for the orthogonal experiments.

3.2.3 Influence of Different pH Values on the Extraction Yield of Soluble Dietary Fibers from *Rosa roxburghii*

Under the conditions of 1.0% anhydrous sodium sulfite, a 1:10 (g/mL) solid–liquid ratio, and 80 ℃ water bath heating for 60 min, the effect of pH on the extraction rate of soluble dietary fiber from *Rosa roxburghii Tratt* was observed, as shown in Fig. 3-2 (c). Fig. 3-2 (c) shows that within the set pH range, the extraction rate tended to increase first and then decrease with decreasing acidity. At pH = 1.0 ~ 1.5, the reaction between the residue and the solution was slightly slower, which may have been caused by the high pH, which destroyed the chemical structure of some soluble dietary fiber. When the pH was 1.5, the extraction rate of soluble dietary fiber from *Rosa roxburghii* peaked. With the continuous decrease in pH, the reaction between the residue and the solution was not sufficient, and the extraction rate of soluble dietary fiber from *Rosa roxburghii* decreased significantly. The pH range should be reduced.

Figure 3-2 (c) shows that the pH range of soluble dietary fiber extracted from *Rosa roxburghii Tratt* by acid extraction was pH = 1.0 ~ 2.0, and a smaller experimental gradient was set in this pH range for the second experiment. Fig. 3-2 (d) shows that the extraction rate of soluble dietary fiber first increased but then decreased, reaching a maximum at pH = 1.4, and then the extraction rate of soluble dietary fiber from *Rosa roxburghii Tratt* decreased. The optimum pH for extracting soluble dietary fiber from *Rosa roxburghii Tratt* was pH = 1.4, and pH values of 1.2, 1.4, and 1.6 were selected as the pH values for the orthogonal experiments.

3.2.4 Influence of Different pH Values on the Extraction Rate of *Rosa roxburghii* Soluble Dietary Fibers

Under the conditions of 1.0% anhydrous sodium sulfite, a 1:10 (g/mL) solid–liquid ratio, a dilute hydrochloric acid solution (pH = 1.0), and water bath heating for 60 min, the effect of the water bath temperature on the extraction rate of soluble dietary fiber from *Rosa roxburghii Tratt* was observed, as shown in Fig. 3-2 (e). Fig. 3-2 (e) shows that with increasing water bath temperature, molecular thermal motion promoted the dissolution of soluble dietary fiber from *Rosa roxburghii Tratt*, and the extraction rate of soluble dietary fiber from *Rosa roxburghii Tratt* increased. When the water bath temperature reached 80 ℃, the extraction effect was the best. With the continuous increase in the water bath temperature, some soluble dietary fiber is hydrolyzed and lost because of the inability to withstand high temperatures, resulting in a decrease in the extraction rate. The optimum water bath temperature of soluble dietary fiber in *Rosa roxburghii Tratt* is 80 ℃, and 75 ℃, 80 ℃ and 85 ℃ are selected as the water bath temperatures for the orthogonal experiments.

3.2.5 Influence of Different Water-Bath Durations on the Extraction Rate of *Rosa roxburghii* Soluble Dietary Fiber

Under the conditions of 1.0% anhydrous sodium sulfite, a 1:10 (g/mL) solid–liquid ratio, a dilute hydrochloric acid solution (pH = 1.0), and an 80 ℃ water bath, the effects of the water bath temperature and time on the extraction rate of soluble dietary fiber from *Rosa roxburghii Tratt* were observed, as shown in Fig. 3-2 (f). Fig. 3-2 (f) shows that with increasing water bath time, the extraction rate of soluble dietary fiber from *Rosa roxburghii* reached a maximum at 45 min, after which the extraction rate slowly decreased. The reason may be that the soaking time of the residue is too long. The hydrolysis of soluble dietary fiber from *Rosa roxburghii* in solution led to incomplete alcohol precipitation, and thus, the extraction rate decreased. The optimum water

bath time for the soluble dietary fiber of *Rosa roxburghii* was 45 min, and water bath durations of 30 min, 45 min and 60 min for the orthogonal experiments were selected.

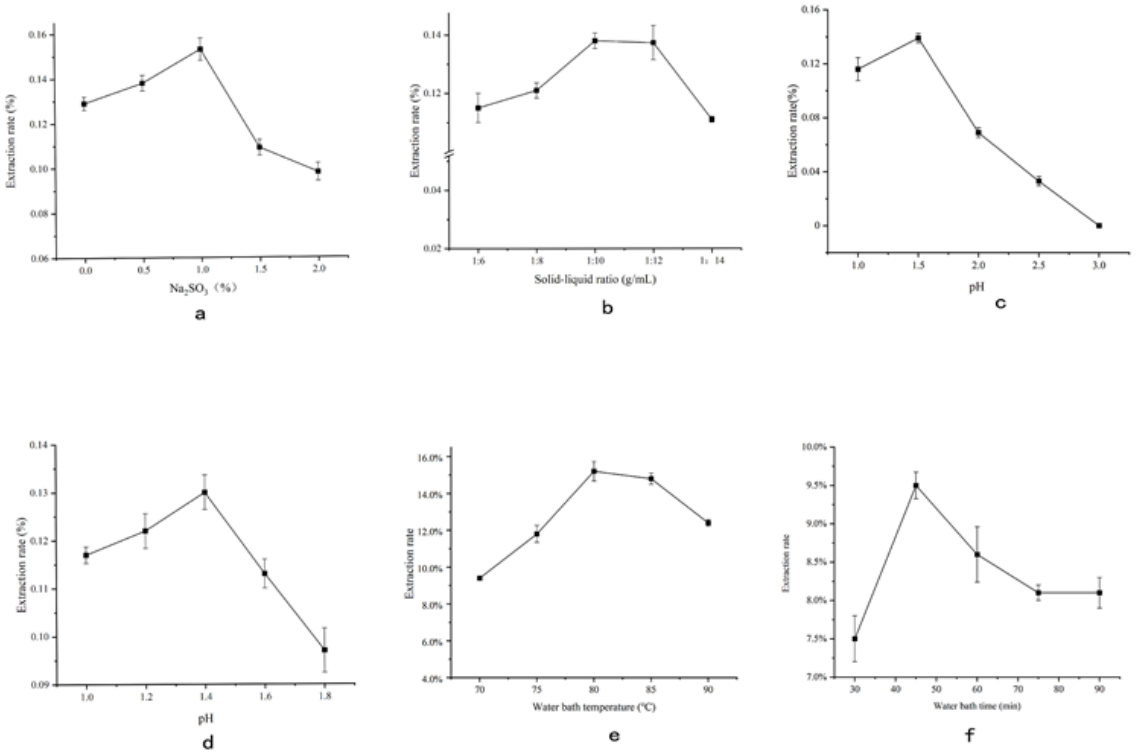

Figure 0-2Influence of different factors on the extraction rate of soluble dietary fiber from *Rosa roxburghii*

Note: (a represents the effect of the addition of sodium sulfite on the extraction rate of soluble dietary fiber from *Rosa roxburghii Tratt*; b represents the effect of the solid–liquid ratio on the extraction rate of soluble dietary fiber from *Rosa roxburghii Tratt*; c represents the effect of pH on the extraction rate of soluble dietary fiber from *Rosa roxburghii Tratt*; d represents the effect of pH on the extraction rate of soluble dietary fiber from *Rosa roxburghii Tratt* after narrowing the pH range; e represents the effect of the water bath temperature on the extraction rate of soluble dietary fiber from *Rosa roxburghii Tratt*; f represents the effect of the water bath time on the extraction rate of soluble dietary fiber from *Rosa roxburghii Tratt*.)

3.2.6 Analysis of Orthogonal Experimental Results for the Preparation of Soluble Dietary Fibers

The analysis of the orthogonal experimental results in Table 4 revealed that the order of the factors affecting the extraction rate of soluble dietary fiber from *Rosa roxburghii Tratt* was A > C > D > B, that is, temperature > time > solid–liquid ratio > pH. The optimal combination for extracting soluble dietary fiber from *Rosa roxburghii Tratt* via acid extraction is A3B1C3D2; that is, the optimal temperature is 85 ℃, the pH is 1.2, the optimal duration is 60 min, and the solid–liquid ratio is 1:10 (g/mL). According to the optimal process combination obtained via orthogonal experiments, three verification experiments were carried out, and the average value was taken. The results revealed that the extraction rate of soluble dietary fiber from *Rosa roxburghii Tratt* was 1.48% when this process was combined.

Table 4 Orthogonal experiment results and analysis table

number	A	B	C	D	extraction ratio(%)

1	1	1	1	1	0.38
2	1	2	3	2	0.52
3	1	3	2	3	0.45
4	2	1	3	3	0.51
5	2	2	2	1	0.39
6	2	3	1	2	0.43
7	3	1	2	2	1.45
8	3	2	1	3	1.01
9	3	3	3	1	1.40
K1	0.450	0.780	0.607	0.723	
K2	0.443	0.640	0.763	0.800	
K3	1.287	0.760	0.810	0.657	
R	0.844	0.140	0.203	0.143	

3.3 Results and Analysis of Single-Factor Experiments for the Preparation of Microcrystalline Cellulose

3.3.1 Influence of the NaOH Solution Concentration in the Alkali Pretreatment on the Yield of Microcrystalline Cellulose

Under the conditions of a fixed temperature of 85 ℃, a liquid–solid ratio of 20:1 (ml/g) and a time of 2 h, the effect of the NaOH solution concentration on the yield of microcrystalline cellulose is shown in Figure 3-3-1 (a). Figure 3-3-1 (a) shows that when the concentration of NaOH solution was 9%, the alkali pretreatment effect was the best. With increasing NaOH concentration, the yield of pretreated products decreased, indicating that lye destroyed the hemicellulose and lignin structure of R. roxburghii residue and improved its quality. However, when the concentration of NaOH exceeded 9%, the yield of the product increased, and the quality decreased, indicating that a high concentration of alkali solution contributed to the dissociation of the substrate but reduced the quality of the product.

3.3.2 Influence of the Liquid-to-Material Ratio during Alkali Pretreatment on the Yield of Microcrystalline Cellulose

Under the conditions of a fixed temperature of 85 ℃, a time of 2 h, and a mass fraction of NaOH solution of 3%, the influence of the liquid-to-material ratio on the yield of microcrystalline cellulose is shown in Figure 3 - 3 - 1 (b). Figure 3 - 3 - 1 (b) shows that when the liquid-to-material ratio is 10:1 ml/g, the yield of alkali pretreatment is the lowest, indicating the best impurity removal effect. In the experiment, a lower liquid-to-material ratio (5:1 ml/g) led to the failure of hydrolysis, as the alkali solution could not completely infiltrate the raw materials. Therefore, starting at 10:1 ml/g, the yield showed an unstable trend with the change in the liquid-to-material ratio. To save resources and protect the environment, no additional experimental groups were added. When the liquid-to-material ratio was 15:1 (mL/g), the extraction rate of microcrystalline cellulose reached a maximum.

3.3.3 Influence of hydrolysis time during alkali pretreatment on the yield of microcrystalline cellulose

Under the conditions of a fixed temperature of 85 ℃, a mass fraction of NaOH solution of 3% and a liquid-to-material ratio of 15:1 (ml/g), the influence of hydrolysis time on the yield of microcrystalline cellulose is shown in Figure 3-3-1 (c). Figures 3-3-1 (c) show that when the hydrolysis time was 1 h, the extraction rate of microcrystalline cellulose reached a maximum. At a hydrolysis time of 2 h, the yield of alkali pretreatment was the lowest, which was 45.5%. As the hydrolysis time increased, the amount of lignin and hemicellulose in the *Rosa roxburghii* fruit residue hydrolyzed by the alkali solution increased, resulting in a decrease in yield. After 2 h, the yield first increases but then decreases, possibly because other reactions occur between the alkali solution and the substrate.

3.3.4 Influence of the Hydrolysis Temperature during Alkali Pretreatment on the Yield of Microcrystalline Cellulose

The influence of hydrolysis temperature on the yield of microcrystalline cellulose with a NaOH

solution mass fraction of 3%, a liquid-to-material ratio of 15:1 (ml/g), and a duration of 1 h is shown in Figure 3-3-1 (d). Figures 3-3-1 (d) show that when the hydrolysis temperature was 50 ℃, the extraction rate of microcrystalline cellulose reached a maximum. At 90 ℃, the yield after alkali pretreatment of *Rosa roxburghii* fruit residue was the lowest, at 40%. The experimental results indicate that as the temperature increases, the yield of alkali pretreatment decreases. However, when the temperature exceeds 90 ℃, the yield begins to rise, possibly because of the reaction between the alkali solution and the components in the fruit residue.

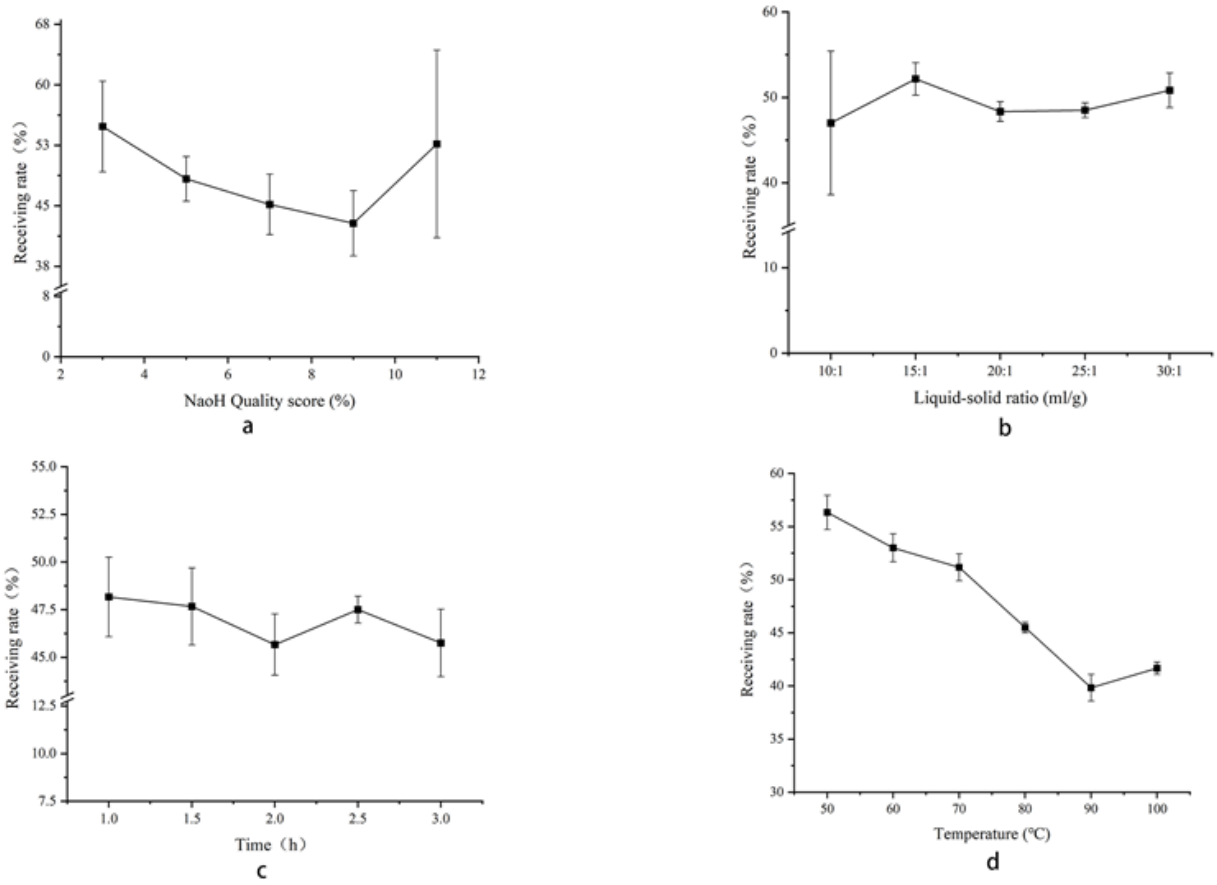

Figure 0-3Effects of different factors on the yield of alkali pretreatment products

Note: a represents the effect of hydrolysis temperature on the yield of alkali-pretreated products, b represents the effect of the liquid–solid ratio on the yield of alkali-pretreated products, c represents the effect of hydrolysis time on the yield of alkali-pretreated products, and d represents the effect of NaOH solution concentration on the yield of alkali-pretreated products)

3.3.5 Results and Analysis of Orthogonal Experiments for Alkali Pretreatment 。

3.3.5.1 Range Analysis

Table 5 Results of range analysis in the orthogonal experiment of alkali pretreatments

item	level	Conc. of NaOH (wt%)	Solid-Liquid Ratio (mL/g)	Hydrolysis Time (h)	Hydrolysis Temp. (℃)
K value	1	4.96	3.98	4	4.44
	2	4.65	3.84	3.95	4.3
	3	4.1	3.97	3.95	4.21
	4	3.08	4.01	3.86	3.5
	5	3.05	4.04	4.08	3.39

K Avg.	1	0.99	0.8	0.8	0.89
	2	0.93	0.77	0.79	0.86
	3	0.82	0.79	0.79	0.84
	4	0.62	0.8	0.77	0.7
	5	0.61	0.81	0.82	0.68
Optimum level		5	2	4	5
R		-0.38	-0.04	-0.04	-0.21
Number of Levels		5	5	5	5
Number of repetitions per level(r)		5	5	5	5

The results of the range analysis of alkali pretreatment are shown in Table 5. A comparison revealed that the order of the four factors was as follows: liquid-to-material ratio = hydrolysis time > hydrolysis temperature > NaOH solution concentration. Combined with the optimal level of each factor, the concentration of NaOH solution is optimal at the fifth level, that is, 11%, the liquid–solid ratio is optimal at the second level, that is, 1:15 g/ml, the hydrolysis time is optimal at the fourth level, that is, 2.5 h, and the hydrolysis temperature is optimal at the fifth level, that is, 90 ℃. The above analysis revealed that the optimal factors are the liquid–solid ratio and hydrolysis time; the optimal combination was a NaOH solution concentration of 11%, a liquid–solid ratio of 15:1 ml/g, a hydrolysis time of 2.5 h, and a hydrolysis temperature of 90 ℃

3.3.5.2 Analysis of Variance

Table 6 ANOVA results for the orthogonal alkali pretreatment experiments

Yield (% , Mean ± SD)	Conc. of NaOH (wt%)	Solid-Liquid Ratio (mL/g)	Hydrolysis Time (h)	Hydrolysis Temp. (℃)
0.57(n=1)	4.00± N/A	1.00±N/A	3.00±N/A	5.00±N/A
0.59(n=1)	5.00±N/A	4.00±N/A	3.00±N/A	2.00±N/A
0.6(n=3)	4.33±0.58	4.67±0.58	3.33±2.08	3.67±1.53
0.61(n=1)	5.00±N/A	3.00±N/A	1.00±N/A	4.00±N/A
0.62(n=1)	5.00±N/A	2.00±N/A	4.00±N/A	1.00±N/A
0.63(n=1)	5.00±N/A	1.00±N/A	2.00±N/A	3.00±N/A
0.64(n=1)	4.00±N/A	2.00±N/A	5.00±N/A	3.00±N/A
0.67(n=2)	3.50±0.71	2.50±0.71	1.50±0.71	3.00±2.83
0.69(n=1)	2.00±N/A	3.00±N/A	4.00±N/A	5.00±N/A
0.7(n=1)	3.00±N/A	5.00±N/A	2.00±N/A	4.00±N/A
0.77(n=1)	2.00±N/A	1.00±N/A	5.00±N/A	4.00±N/A
0.82(n=1)	1.00±N/A	2.00±N/A	3.00±N/A	4.00±N/A
0.86(n=1)	1.00±N/A	4.00±N/A	2.00±N/A	5.00±N/A
0.88(n=1)	3.00±N/A	3.00±N/A	3.00±N/A	3.00±N/A
0.9(n=1)	3.00±N/A	1.00±N/A	4.00±N/A	2.00±N/A
0.95(n=1)	3.00±N/A	4.00±N/A	5.00±N/A	1.00±N/A
1.01(n=1)	2.00±N/A	4.00±N/A	1.00±N/A	3.00±N/A
1.05(n=1)	1.00±N/A	5.00±N/A	4.00±N/A	3.00±N/A
1.09(n=2)	2.00±0.00	3.50±2.12	2.50±0.71	1.50±0.71
1.11(n=1)	1.00±N/A	1.00±N/A	1.00±N/A	1.00±N/A
1.12(n=1)	1.00±N/A	3.00±N/A	5.00±N/A	2.00±N/A
F	8.371	1.565	0.834	0.559
p	0.026*	0.359	0.658	0.829
Note：* p<0.05 ** p<0.01				

Through the analysis of variance in Table 6, it can be seen that in the study of the relationships between yield and NaOH solution concentration, the liquid-to-material ratio, hydrolysis time, and hydrolysis temperature, the p values corresponding to the liquid-to-material ratio, hydrolysis time, and hydrolysis temperature were all greater than 0.05, indicating that different yield samples were consistent in these three factors and that there was no significant difference. The concentration of NaOH solution ($F = 8.371$, $p = 0.026$) showed that the samples with different yields had significant differences in the concentration of NaOH solution, with a significance level of 0.05

3.3.6 Liquid-to-solid ratio of acid hydrolysis to prepare microcrystalline cellulose

Under the conditions of a fixed mass fraction of 5% hydrochloric acid solution, a temperature of 80 ℃ and a time of 1.5 h, the effect of the hydrochloric acid concentration on the extraction rate of microcrystalline cellulose is shown in Fig. 3-3-2 (a). Figure 3-3-2 (a) shows that the yield of microcrystalline cellulose first increased but then decreased with increasing liquid–solid ratio. When the liquid–solid ratio was 30:1 ml/g, the yield reached the highest value, and then the yield decreased sharply because of the degradation of microcrystalline cellulose caused by an excessive volume of hydrochloric acid. When the liquid–solid ratio was low, the hydrochloric acid solution could not fully soak the substrate, which limited the hydrolysis of cellulose. When the liquid–solid ratio is moderate, hydrogen ions are more likely to penetrate, promote the hydrolysis reaction, and increase the yield.

3.3.7 Hydrochloric acid concentration for the preparation of microcrystalline cellulose by acid hydrolysis

Under the fixed conditions of a liquid-to-material ratio of 20:1 (ml/g), a temperature of 80 ℃, and a time of 1.5 h, the influence of hydrochloric acid concentration on the extraction rate of microcrystalline cellulose is shown in Figure 3-3-2 (b). Figures 3-3-2 (b) show that at a hydrochloric acid concentration of 5%, the yield of microcrystalline cellulose is the highest, reaching 19%. In the range of 3% to 5% hydrochloric acid, the yield increases rapidly because the increase in hydrochloric acid concentration accelerates the hydrolysis reaction, destroys the amorphous region of cellulose in *Rosa roxburghii* fruit residue, and promotes the depolymerization of cellulose molecules. However, when the hydrochloric acid concentration exceeds 5%, the yield first decreases and then increases slowly, but the effect is not as good as that at a 5% hydrochloric acid concentration. Considering environmental protection and resource sustainability, no further experiments were carried out by increasing the hydrochloric acid concentration..

3.3.8 Hydrolysis time of preparation of microcrystalline cellulose by acid hydrolysis

Under the fixed conditions of a hydrochloric acid mass fraction of 5%, a temperature of 80 ℃, and a liquid-to-material ratio of 30:1 (ml/g), the influence of hydrolysis time on the extraction rate of microcrystalline cellulose is shown in Fig. 3-3-2 (c). Figs. 3-3-2 (c) show that within the range of 1-3.5 h of hydrolysis time, as the hydrolysis time increased, the extraction rate of microcrystalline cellulose first increased but then decreased. The extraction rate of microcrystalline cellulose reached its peak when the hydrolysis time was 2.5 h.

3.3.9 Hydrolysis temperature of microcrystalline cellulose prepared via acid hydrolysis

Under the fixed conditions of a hydrochloric acid mass fraction of 5%, a liquid-to-material ratio of 30:1 (ml/g), and a time of 2.5 h, the influence of hydrolysis temperature on the extraction rate of microcrystalline cellulose is shown in Fig. 3-3-2 (d). Figs. 3-3-2 (d) show that within the hydrolysis temperature range of 60 - 100 ℃, as the hydrolysis temperature increases, the extraction rate of microcrystalline cellulose first tends to increase, then decreases, then increases again, and then decreases again. The extraction rate of microcrystalline cellulose peaks when the hydrolysis temperature is 90 ℃. Subsequently, its yield begins to decline significantly. This is because high temperatures cause the molecular motion in the hydrolysis reaction system to become more active, the mass transfer effect to be significantly enhanced, and the reaction rate to accelerate. As a result, the decomposition of

cellulose is manifested more in the breaking of β-1,4-glucosidic bonds and the formation of small-molecule sugars, which significantly reduces the yield of microcrystalline cellulose.

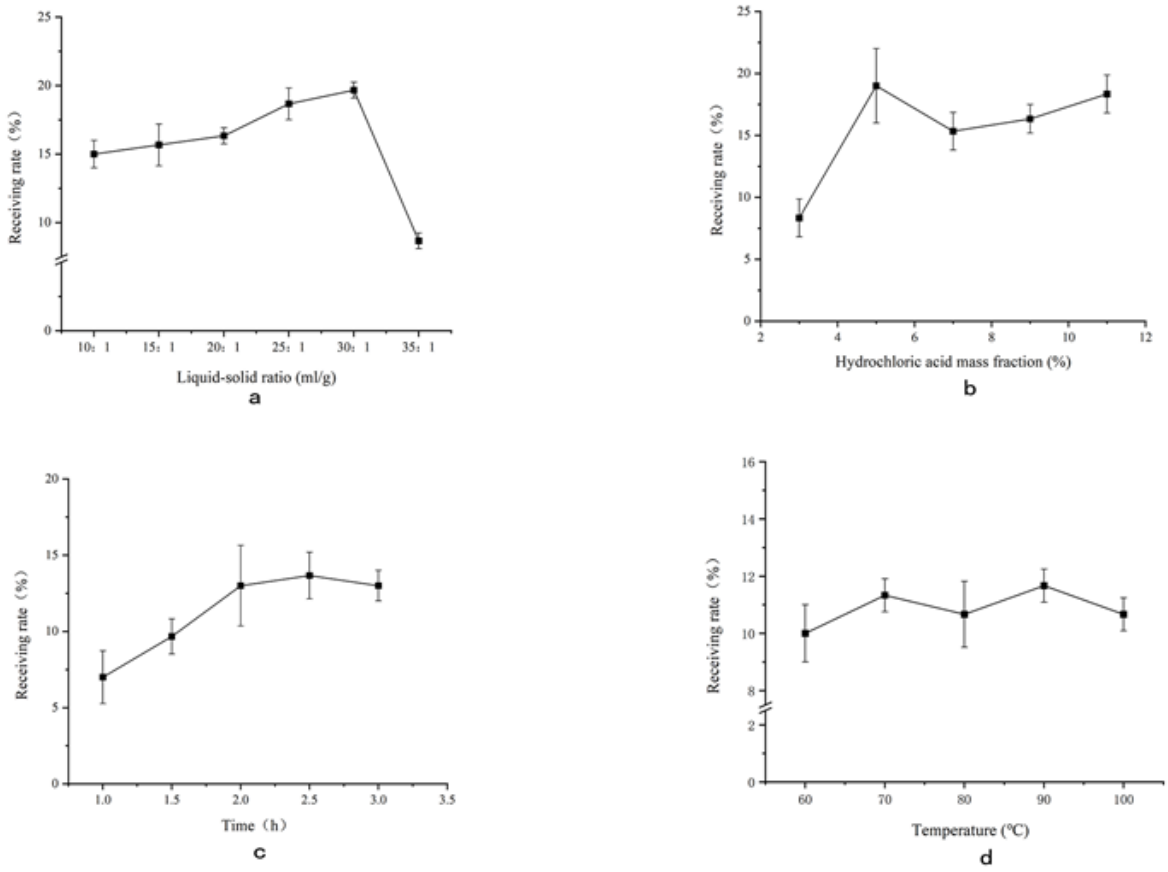

Figure 0-4Effects of different factors on the yield of microcrystalline cellulose prepared by acid hydrolysis

Note: a represents the effect of the liquid–solid ratio on the yield of microcrystalline cellulose products prepared via acid hydrolysis; b represents the effect of the hydrochloric acid concentration on the yield of microcrystalline cellulose products prepared via acid hydrolysis; c represents the effect of the hydrolysis time on the yield of microcrystalline cellulose products prepared via acid hydrolysis; d represents the effect of the hydrolysis temperature on the yield of microcrystalline cellulose products prepared via acid hydrolysis.

3.3.10 Results and Analysis of Orthogonal Experiments for the Preparation of Microcrystalline Cellulose by Acid Hydrolysis

3.3.10.1 Range analysis

Table 7 Results of orthogonal range analysis for acid hydrolysis preparation of microcrystalline cellulose

Item	level	Conc. of HCl (wt%)	Solid-Liquid Ratio (mL/g)	Hydrolysis Time (h)	Hydrolysis Temp. (℃)
K value	1	0.95	0.91	0.94	1.1
	2	1	0.98	0.98	1.08
	3	0.94	0.87	0.92	0.89
	4	0.92	0.97	0.94	0.85
	5	0.89	0.97	0.92	0.78
K Avg.	1	0.19	0.18	0.19	0.22
	2	0.2	0.2	0.2	0.22

	3	0.19	0.17	0.18	0.18
	4	0.18	0.19	0.19	0.17
	5	0.18	0.19	0.18	0.16
Optimum level		2	2	2	1
R		0.02	0.02	0.01	0.06
Number of Levels		5	5	5	5
Number of repetitions per lever (r)		5	5	5	5

The results of the range analysis of the orthogonal experiment for the preparation of microcrystalline cellulose by acid hydrolysis are shown in Table 7. By comparison, the superiority-inferiority ranking of the four factors is as follows: hydrolysis temperature > hydrochloric acid concentration = liquid-to-material ratio > hydrolysis time. Combined with the optimal level of each factor, the hydrochloric acid concentration is optimal at the second level, which is 5%; the liquid-to-material ratio is optimal at the second level, which is 15:1 ml/g; the hydrolysis time is optimal at the second level, which is 1.5 h; and the hydrolysis temperature is optimal at the first level, which is 60 ℃. On the basis of the abovementioned analysis, the optimal factor is the hydrolysis temperature, and the optimal combination is a hydrochloric acid concentration of 5%, a liquid-to-material ratio of 15:1 ml/g, a hydrolysis time of 1.5 h, and a hydrolysis temperature of 60 ℃

3.3.10.2 Analysis of Variance

Table 8 Results of orthogonal experimental variance analysis for the preparation of microcrystalline cellulose by acid hydrolysis

Yield %(Mean± SD)	Conc. of HCl (wt%)	Solid-Liquid Ratio (mL/g)	Hydrolysis Time (h)	Hydrolysis Temp. (℃)
0.12(n=1)	5.00±N/A	5.00±N/A	5.00±N/A	5.00±N/A
0.14(n=1)	4.00±N/A	4.00±N/A	4.00±N/A	4.00±N/A
0.15(n=3)	4.00±1.00	2.33±1.15	2.33±1.15	4.00±1.00
0.16(n=1)	3.00±N/A	2.00±N/A	1.00±N/A	5.00±N/A
0.17(n=2)	3.50±2.12	2.00±1.41	3.00±1.41	4.00±1.41
0.18(n=3)	2.00±1.73	2.67±1.15	3.33±1.53	4.00±1.00
0.19(n=4)	2.00±0.82	3.25±1.71	3.25±2.06	3.25±0.96
0.2(n=3)	1.67±1.15	2.33±2.31	3.00±1.73	2.00±1.00
0.21(n=1)	4.00±N/A	3.00±N/A	2.00±N/A	1.00±N/A
0.22(n=2)	3.50±2.12	4.50±0.71	3.00±0.00	1.50±0.71
0.23(n=2)	3.50±2.12	2.00±0.00	3.00±1.41	1.50±0.71
0.24(n=2)	3.50±0.71	4.50±0.71	3.00±2.83	1.50±0.71
F	1.034	0.948	0.37	3.642
p	0.471	0.53	0.947	0.015*
Note：* p<0.05 ** p<0.01				

Through the analysis of variance in Table 8, it can be seen that in the study of the relationships between yield and hydrochloric acid concentration, the liquid-to-material ratio, hydrolysis time, and hydrolysis temperature, the hydrochloric acid concentration, liquid-to-material ratio, hydrolysis time, and corresponding p values were all greater than 0.05, indicating that different yield samples were consistent and that there was no difference in these three factors. The hydrolysis temperature (F = 3.642, p = 0.015) revealed that samples with different yields had significant differences in hydrolysis temperature, with a value of 0.05.

3.4 Results and Analysis of the Preparation of Three Edible Components in *Rosa roxburghii* Crude Residue

According to the optimal experimental conditions for the three active ingredients explored above, extraction was carried out in accordance with the designed general process flow diagram (Figs. 2-4). From 50 g of *Rosa roxburghii* crude residue, 7.51 g of *Rosa roxburghii* polysaccharide, 18 g of microcrystalline cellulose, and 0.523 g of soluble dietary fiber were obtained, indicating a remarkable extraction effect. The total recovery of the three edible components was 14.95 g, with a recovery rate of 29.9%. During the extraction of *Rosa roxburghii* polysaccharide, after the pretreatment of 50 g of *Rosa roxburghii* crude residue, only approximately 30 g of *Rosa roxburghii* crude residue remained, indicating that the *Rosa roxburghii* residue contained approximately 40% impurities. These findings indicate that pretreatment with *Rosa roxburghii* polysaccharide reduces the polysaccharide yield. In this study, *Rosa roxburghii* fruit residue was prepared in the laboratory. If industrial fruit residue is used, the polysaccharide content would be relatively high, and the yield would increase accordingly. This study demonstrated that *Rosa roxburghii* fruit residue has great development and utilization value. However, in actual production, the processing and utilization of *Rosa roxburghii* are mostly limited to primary utilization, and the degree of secondary development and utilization is low. According to the general process flow we designed, the edible components in *Rosa roxburghii* crude residue can be efficiently extracted, maximizing the utilization of *Rosa roxburghii* crude residue and significantly reducing the discharge of solid waste.

Discussion

In this work, the crude residue of *Rosa roxburghii Tratt* is taken as the research object, and the extraction rates and influencing factors of *Rosa roxburghii Tratt* polysaccharide, microcrystalline cellulose and soluble dietary fiber in the crude residue of *Rosa roxburghii Tratt* are discussed to provide the necessary reference basis and technical support for solving the waste problem of *Rosa roxburghii Tratt* residue in the existing *Rosa roxburghii Tratt* industry. The results of this study revealed two main points: (1) Different extraction methods and extraction times had significant effects on the extraction rate of each component of the crude residue of *Rosa roxburghii Tratt*. The water extraction and alcohol precipitation methods were used to extract polysaccharides from *Rosa roxburghii Tratt*. Eighty percent ethanol was used as the extraction solvent, and the solid–liquid ratio was 1:45 (g/mL). The extraction rate was high, which was beneficial for the dissolution of polysaccharides, but the method was time-consuming and energy-consuming. However, with the help of ultrasonic-assisted extraction, this method can improve the extraction rate, save energy and reduce consumption, and it is easy to perform and scale up industrialization. When the ultrasonication time was 45 min, the ultrasonic temperature was 70 ℃, and the ultrasonic power was 200 W, the extraction rate of polysaccharides significantly improved, and polyamide decolorization was carried out (the decolorization conditions were 0.5 g of polyamide for 4 h). The ultrasonic cavitation effect not only accelerated the release of polysaccharides but also increased the contact area and penetration ability between the solvent and the raw material. The decolorization of the polyamide improved the purity of the polysaccharides. Microcrystalline cellulose extraction, NaOH solution pretreatment (11% concentration, solid–liquid ratio of 1:15 g/ml, 90 ℃, 2.5 h) and acid treatment (chloric acid concentration of 5%, liquid–material ratio of 15:1 ml/g, hydrolysis time of 1.5 h, and hydrolysis temperature of 60 ℃) have good effects and can remove lignin and hemicellulose, improve the purity and extraction rate, and meet industrial production requirements. For soluble dietary fiber extraction, the acid extraction method involves the addition of 1% sodium sulfite and a solid–liquid ratio of 1:10 (g/mL) to dilute hydrochloric acid solution to pH 1.2. At 85 ℃ for 1 h, the release of dietary fiber is excellent. The order of raw material pretreatment and component extraction affects the extraction effect. Drying and crushing the coarse residue of *Rosa roxburghii* increased the specific surface area and improved the extraction efficiency. The order of polysaccharide extraction first and then soluble dietary fiber and microcrystalline cellulose extraction from the residue was reasonable. The extraction of polysaccharides caused little damage to the structure of the raw materials, which was beneficial for subsequent extraction. Preextraction of microcrystalline cellulose may destroy the

structure of polysaccharides and dietary fiber and reduce the extraction rate. Optimizing these factors is expected to lead to the development of an efficient technical system for the comprehensive utilization of roxburgh rose coarse residue, reduce waste and increase the added value of the industry.

Conclusion

This study successfully optimized the extraction process of three edible components from the crude residue of *Rosa roxburghii Tratt*. Through single-factor experiments and process optimization, the optimum extraction conditions for the three edible components were determined. The roxburgh rose polysaccharide (RBP) obtained under optimal conditions and decolorized by polyamide has high purity, which provides a high-quality raw material for the research and development of functional foods and drugs. The microcrystalline cellulose (MCC) prepared via the optimized process can fully meet the needs of high-quality MCC in many industrial fields, such as food, medicine and cosmetics, and effectively increase the added value of *Rosa roxburghii* coarse residue. The extraction rate of soluble dietary fiber (SDF) was improved by optimizing the extraction process. SDF has potential application value in improving intestinal function and reducing blood glucose and blood lipid levels and has opened a new path for the innovative research and development of healthy foods.

This study not only improves the comprehensive utilization technology system of *Rosa roxburghii* coarse residue but also provides solid technical support for the development of resource-saving and environmentally friendly industries. In the future, scaling up the extraction process and conducting feasibility studies of industrial production can be considered to promote the in-depth development of the *Rosa roxburghii* industry and increase the economic and social benefits. Moreover, the structure–activity relationships of these three edible components can be further explored, and their innovative applications in more fields can be actively explored.

None of the authors have any conflicts of interest to declare

Practical application: Our research focused on extracting three edible components from *Rosa roxburghii Tratt* residue, innovatively developing a set of highly efficient extraction process flows. This process not only improves the utilization rate of *Rosa roxburghii Tratt* resources but also opens new avenues for the development of food raw materials, which is highly important for reducing food industry waste and increasing economic benefits.

Research Funding Statement for the Process of extracting three edible components from Rosa roxburghii fruit residue

This research was generously funded by the Guizhou Provincial Science and Technology Plan Project (Qiankehe Jichu - ZK [2024] Yiban 505) and Hubei Medicinal and Edible Fusion Research Co., Ltd. The funded project is titled "Process of extracting three edible components from Rosa roxburghii Fruit Residue". This funding has played a crucial role in the smooth progress of this research, covering multiple key aspects of the research process, including but not limited to the purchase of experimental equipment and the expenses for in - depth analysis and processing of scientific research data, ensuring the scientificity and reliability of the research results.

Here, we express our sincere gratitude to the Guizhou Provincial Science and Technology Plan Project (Qiankehe Jichu - ZK [2024] Yiban 505) and Hubei Medicinal and Edible Fusion Research Co., Ltd. Their high - level attention to and active support for scientific research innovation have created a favorable scientific research environment for our research team, inspiring us to continue to advance in the research on the extraction process of edible components from Rosa roxburghii Tratt pomace, striving to provide innovative technical solutions for the efficient utilization and development of food resources.

References

1. Ren, Q. P. (2003). Sanwang Fruit - *Rosa roxburghii Tratt*. China Fruit & Vegetable, (5), 39 - 40.
2. Chen, C. B. (2014). Expanding Guizhou's *Rosa roxburghii Tratt* Industry - Creating the Heaven - Bestowed "King of Vitamin C". Contemporary Guizhou, (21), 38-39.
3. Li, H. J., Wu, W. X., Guo, Z. Y., et al. (2023). Evaluation of the feeding value of *Rosa roxburghii* pomace for meat sheep. China Feed, (21), 184 - 188.

4. Hao, M. H., Zhang, F., Liu, X. X., Zhang, F., Wang, L. J., Xu, S. J., Zhang, J. H., Ji, H. L., & Xu, P. (2018). Qualitative and quantitative analysis of catechin and quercetin in flavonoids extracted from *Rosa roxburghii Tratt*. Tropical Journal of Pharmaceutical Research, 17(1), 71–76.
5. Yang, S., Tan, S. M., Chen, C., & Dai, X. T. (2022). Purification process and in vitro antioxidant study of *Rosa roxburghii* polyphenols. Food and Fermentation Sciences & Technology, (01), 7 - 14.
6. Wu, Y., Wei, A. J., Yang, K., Li, J. G., Dong, S. S., Liu, D. L., … Liu, S. Q. (2023). Intervention study of *Rosa roxburghii* polysaccharide extract on type II diabetes in mice. Guihaia, 43(11), 2120 - 2130.
7. Wei, J. M. (2022). Preparation and functionality research of *Rosa roxburghii* enzyme [Master's thesis, Guizhou University].
8. Liu, Y. Q., Sun, Y. L., Lu, M., & An, H. M. (2015). Components and contents of dietary fiber in *Rosa roxburghii* fruits. Acta Nutrimenta Sinica, 37(3), 303 - 305. doi:10.13325/j.cnki.acta.nutr.sin.2015.03.024.
9. Zhou, Y. J., & Fan, W. G. (2021). Evaluation of the nutrition, health-promoting components and utilization value of *Rosa roxburghii* pomace. Food and Fermentation Industries, 47(07), 217 - 224.
10. Liang, X. Y., Zhang, Y., & Ding, Z. H. (2018). Effect of *Rosa roxburghii* pomace with different particle sizes on blood lipid and tissue antioxidant activity in hyperlipidemic mice. Science and Technology of Food Industry, 39(16), 290 - 295.
11. Zhang, X., Li, L. L., Yang, J., Yang, X. S., Wang, Y., Wang, L., … Song, J. R. (2021). Study on the laxative function of dietary fiber from fermented *Rosa roxburghii* pomace. Food and Fermentation Sciences & Technology, (02), 30 - 34.
12. Niu, X. R., Yang, Y., Wu, W. X., et al. (2023). Effects of replacing alfalfa with *Rosa roxburghii* pomace on nutrient digestibility of diet and plasma biochemical indexes in goats. Acta Ecologae Animalis Domestici, 44(2), 56 - 60.
13. Chen, Q. H., Wei, J. M., Mu, X., et al. (2023). Optimization of the compound fermentation process of *Rosa roxburghii* pomace enzyme. China Condiment, 48(9), 122 - 130.
14. Tu, X. Y. (2019). Extraction of seed oil from *Rosa roxburghii* pomace and its application in vesicle preparation [Dissertation, Guizhou University].
15. Tu, W. C., & Hallett, J. P. (2019). Recent advances in the pretreatment of lignocellulosic biomass. Current Opinion in Green and Sustainable Chemistry, 20, 11 - 17.
16. Chen, Y. B., & Wang, S. N. (2020). Thoughts on the utilization ways of Liupanshui rose roxburghii fruit residue. Modern Horticulture, 43(12), 15 - 16.
17. Yan, X. Y., & Li, L. (2019). Extraction of coix seed polysaccharide by water extraction and alcohol precipitation method and its scavenging effect on hydroxyl radicals. Food Research and Development, 40(18), 1 - 5.
18. Zhu, J. X., Chen, Z. H., Li, G. J., Qiu, S. Y., Luo, Y., & Song, A. X. (2024). Study on ultrasonic-assisted extraction of polysaccharides from *Rosa roxburghii* pomace and their antioxidant activity. Journal of Food Safety and Quality, (12), 81 - 88.
19. Huang, Q. L., Lei, T., He, Z. X., Ning, N., Chen, X. Y., Lin, R. Z., & Dang, L. (2023). Determination of polysaccharide content in Xiaoke Pills by phenol-sulfuric acid method. Research of Integrated Traditional Chinese and Western Medicine, (05), 308 - 310, 327.
20. Zhang, Y., Li, X. X., Liu, F. S., & Ding, Z. H. (2015). Preparation and quality analysis of dietary fiber from *Rosa roxburghii* pomace by different processes. China Brewing, (02), 82 - 86.
21. Zhu, R. W., Tan, S., & Huang, L. (2023). Research progress on extraction, modification and biological activities of dietary fiber from *Rosa roxburghii* pomace. Journal of Food Safety and Quality, (14), 290 - 297.
22. Tu, W. C., & Hallett, J. P. (2019). Recent advances in the pretreatment of lignocellulosic biomass. Current Opinion in Green and Sustainable Chemistry, 20, 11 - 17.
23. Jahan, M. S., Saeed, A., He, Z., & Ni, Y. (2011). Jute as raw material for the preparation of microcrystalline cellulose. Cellulose, 18(2), 451 - 459.
24. Yan, J. Q., Ji, D. X., Yang, G. H., Luo, S. Y., Zhang, K., & Chen, J. C. (2021). Overview of preparation methods and application fields of microcrystalline cellulose. China Pulp & Paper Industry, (10), 8 - 13.

25. Lau, K. K., Jawaid, M., Ariffin, H., & Alothman, O. Y. (2017). Isolation and characterization of microcrystalline cellulose from roselle fibers. International Journal of Biological Macromolecules, 104, 931 - 940.