

Online Supplementary Material

Supplementary Methods

The different degradation methods of *Porphyra haitanensis* sulfated polysaccharide (PHSP)

Ultrasonic method (US): A major factor ultrasonic treatment is ultrasonic power in fragmentation, whereas temperature and ultrasonic time are minor factors. PHSP solution was treated with different ultrasonic power (240, 320, 400, 480, 600, 700, 800, 900 and 1000 W) for 1 h, every ultrasonic for 2 seconds, interval pause for 2 seconds. And then different degradation time was set as 0, 10, 30, 45, 60, 120, 180 min under 600 W ultrasonic power. The DPHSP precipitates were obtained by adding 5 times volume of ethanol to the treated solution after different ultrasonic power and treatment time, respectively. The DPHSP products were obtained after centrifugation and redissolution.

High temperature and pressure method (HP): PHSP solution was placed in a pressure cooker and treated with different pressure parameters (0 MPa, 0.05 MPa (110 °C), 0.15 MPa (121 °C), 0.16 MPa (127 °C)) for 2 h. Then the pressure parameters of 0.16 MPa (127 °C) were selected to degrade PHSP with different degradation time (0, 0.5, 1.0, 2.0, 2.5, 3.0, 4.0, 5.0 h). The DPHSP precipitates were obtained by adding 5 times volume of ethanol to the treated solution after different pressure and treatment time, respectively.

H₂O₂: PHSP solution was treated with different concentrations of H₂O₂ (5, 10, 20 mM) and different time (0, 30, 60, 90, 120 min) by orthogonal design. The DPHSP

precipitates were obtained by adding 5 times volume of ethanol to the treated solution, respectively.

Vitamin C method (VC): PHSP solution was treated with different concentrations of VC (10, 20, 30, 40, 50 mM) and different time (0.1, 0.5, 1.0, 2.0, 3.0 h) by orthogonal design. VC was removed by ethanol precipitation with 5 times of volume. The DPHSP product was obtained after redissolution and freeze-drying.

In this study, the optimal power of ultrasonic degradation of PHSP was 600 W and the optimal time was 60 min. The optimal temperature and time of HP concentration was 127 °C and 5 h. The degradation conditions of H₂O₂ were 20 mM and 120 min. The optimal concentration of PHSP degradation by VC was 30 mM, and the optimal time was 30 min. These four methods were combined in pairs to treatment PHSP under the optimum conditions:

US-HP: PHSP solution was degraded by 600 W ultrasound for 60 min and then treated at 0.16 MPa (127 °C) for 5 h.

US-H₂O₂: PHSP solution was treated with H₂O₂ (final concentration: 20 mM) for 2 h after being degraded by 600 W ultrasound for 60 min.

US-VC: PHSP solution was treated with VC (final concentration: 30 mM) for 30 min after being degraded by 600 W ultrasound for 60 min.

HP-H₂O₂: PHSP solution was degraded at 0.16 MPa (127 °C) for 5 h, and then treated with H₂O₂ (final concentration: 20 mM) for 2 h.

HP-VC: PHSP solution was degraded at 0.16 MPa (127 °C) for 5 h, and then treated with VC (final concentration: 30 mM) for 30 min

VC-H₂O₂: PHSP solution was treated with VC (final concentration: 30 mM) for 30 min and H₂O₂ (final concentration: 20 mM) for 2 h, respectively.