Effect of Pressurized Fluid Assisted by Ultrasound Processing on Hydrolysis of Shrimp Shell

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1. Introduction

Sustainability has become a critical challenge due to environmental concerns together with the growing global population. Currently, million tons of shrimp is produced worldwide, and this amount is expected to reach 7.3 million tons by 2025. From this amount, during the shrimp processing, about 50-60% is byproducts (shells and heads)[1]. Therefore, shrimp shells are a good source of biopolymers such as proteins (42%) and chitin (17%). Conventional methods such as alkali and acid extraction have been widely studied for valorization of these byproducts. These methods are time-consuming and result in low efficiency. Subcritical water processing has shown to be a promising and eco-friendly technology to recover valuable compounds from byproducts[2]. Also, the use of ultrasound with other processes has shown reduction in time and energy associated with the processes. The main objective of this study was to determine the effect of SCW assisted by ultrasound at different powers, and optimum conditions of temperature and time to hydrolyze protein from shrimp shell.

2. Materials and Methods

Shrimp shells were kindly provided by Marisquería Diego restaurant (Mexico City, Mexico). The materials used in this study including sodium tetraborate, o-phthadialdehyde, methanol, sodium dodecyl sulfate, β-mercaptoethanol, sodium hydroxide, folin reagent, sodium potassium tartrate, sodium carbonate and copper sulfate pentahydrate were acquired from Sigma Aldrich (Oakville, ON, Canada).

Shrimp shells were pretreated using a 10-mm ultrasound probe at 20 kHz (Model FS-1200N, Shanghai Sonxi Ultrasonic Instrument Co., Shanghai, ZJ, China) with nominal powers of 600 and 1200 W for 5 min. Then, the hydrolysis of shrimp shell was carried out using a semi-continuous subcritical water apparatus, earlier described in the study by Ciftci & Saldaña[3], at a pressure of 50 bar, flow rate of 5 mL/min and temperatures of 180, 220, and 260°C for 10, 20, 40 and 60 min. The alkali extraction was conducted following the method described by Ahing & Wid[4]. Total protein and amino acid contents in the hydrolysates were analyzed by the Lowry's method and the OPA method, respectively.

3. Results and discussion

The amounts of total protein obtained from shrimp shell using alkali, SCW, and ultrasound at powers of 600 and 1200 W are shown in Fig. 1. The use of only ultrasound and SCW resulted in lower protein content in comparison to the alkali treatment.

Using SCW treatment assisted by ultrasound resulted in better hydrolysis of shrimp shell. According to Fig. 2, the hydrolysate with the highest amount of total protein was obtained with SCW assisted by ultrasound at power of 1200 W for 5 min, and then hydrolysing at subcritical condition using water at 180°C and 50 bar for 60 min. Ultrasound pre-treatments at 600 and 1200 W increased the yield from 34.2 mg/g shrimp shell (only SCW treatment) to 74.06 and 99.01 mg/g shrimp shell, respectively. Also, ultrasound+SCW treatments resulted in the highest yield at lower temperature in comparison to the yield of SCW treatment at 260°C without pre-treatment. This is because ultrasonic waves produce cavitation. Cavitation produces shear stress that induces the breakage of nitrogen bonds and other molecular/intramolecular bonds,

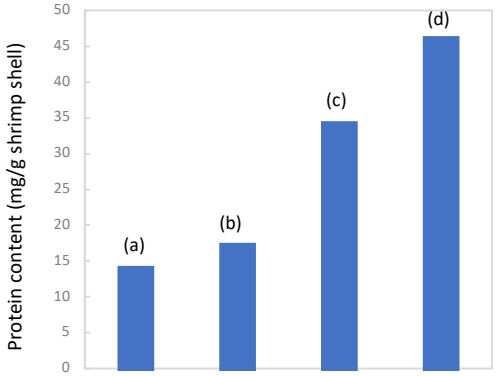

Figure 1. Total protein content of hydrolysates obtained by: (a) ultrasound (600 W, 5 min), (b) ultrasound (1200 W, 5 min), (c) SCW (260°C, 60 min) and (d) alkali treatments (2880 min).

depolymerizing the protein-chitin matrix in shrimp shell[5]. This favours the leaching of proteins and the hydrolysis process.

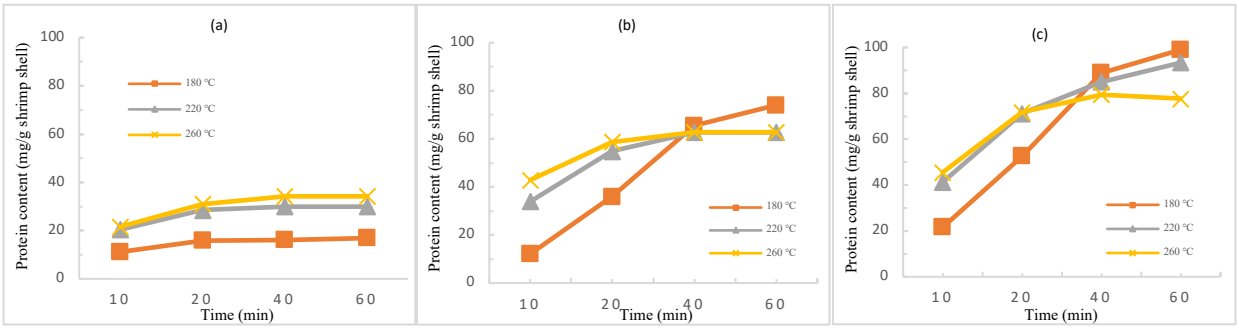

Figure 2. Effect of temperature and time on total protein content of shrimp shell hydrolysates obtained by: (a) only SCW, (b) ultrasound (600 W, 5 min)+SCW, and (c) ultrasound (1200 W, 5 min)+SCW treatments at 50 bar.

The hydrolysis of protein with SCW water was due to the increase in the dissociation constant of water and concentration of hydronium and hydroxide ions at high temperatures (180-260°C). The increase of hydronium and hydroxide ions could break down proteins into amino acids. The highest amino acid content of 67.54 mg/g shrimp shell was achieved by ultrasound (1200 W, 5 min) followed by SCW (260°C, 60 min) treatment (Fig. 3). This value is consistent with the yield of 70 mg amino acid/g shrimp shell reached using water at a temperature of 250°C at its corresponding saturated vapor pressure for 60 min[6].

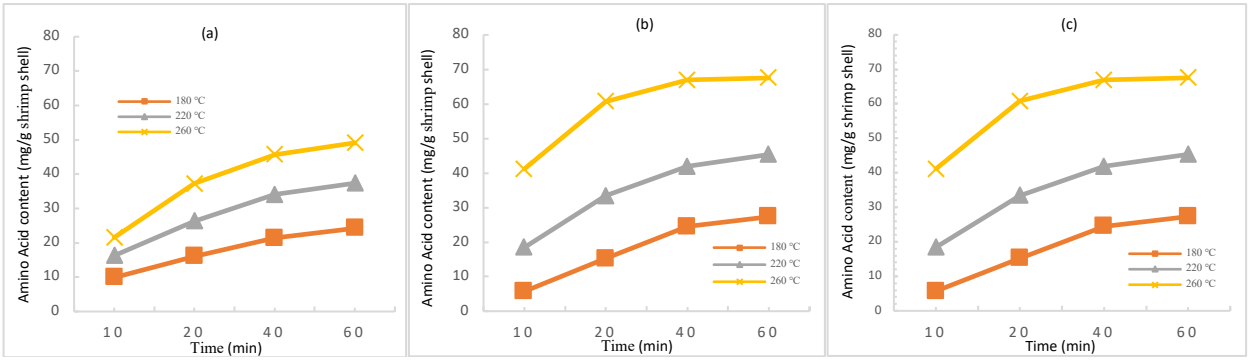

Figure 3. Effect of temperature and time on amino acid content of shrimp shell hydrolysates obtained by: (a) only SCW, (b) ultrasound (600 W, 5 min)+SCW, and (c) ultrasound (1200 W, 5 min)+SCW treatments at 50 bar.

4. Conclusions

The use of SCW assisted by ultrasound has great potential to be used for hydrolysis reactions. The process has greatly benefited from the use of ultrasound since it enhanced protein hydrolysis. However, at temperatures of 180 and 220°C, SCW resulted in comparable amino acid yields with SCW assisted by ultrasound. While at 260°C, SCW assisted by ultrasound (600 W, 5min) resulted in much higher amino acid yield than SCW.

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References

1. Nirmal, N.P., Santivarangkna, C., Rajput, M.S. & Benjakul, S. *Trends Food Sci Technol*, 2020, 1, 20-35.
2. Saldaña, M.D.A., Valdivieso-Ramirez, C.S. *J. Supercrit Fluids*, 2015, 96, 228-244.
3. Ciftci, D., Saldaña, M.D.A. *Bioresour. Technol*, 2015, 194: 75-82.
4. Ahing, F. A., Wid, N. *Trans Sci Technol*, 2016, *3*(1-2), 227-237.
5. Vallejo-Domínguez, D., Rubio-Rosas, E., Aguila-Almanza, E., Hernández-Cocoletzi, H., Ramos-Cassellis, M. E., Luna-Guevara, M. L., ... & Show, P. L. *Ultrason Sonochem*, 2021, *72*, 105417.
6. Quitain, A.T., Faisal, M., Kang, K., Daimon, H. & Fujie, K. *J. Hazard. Mater,* 2002, *93*, 209-220