



# INFOGRAPHIC

## KHẢO SÁT ĐẶC TÍNH CỦA PHỤ PHẨM DỨA VÀ THÔNG SỐ QUÁ TRÌNH CHIẾT XUẤT BROMELAIN BẰNG DUNG MÔI XANH

Tác giả:

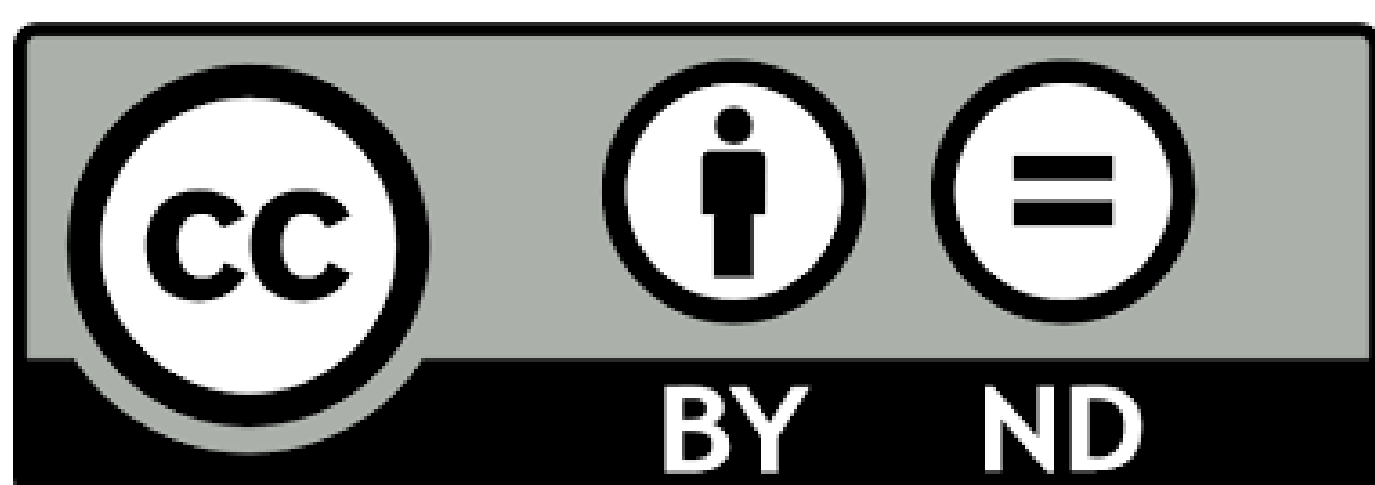
Lâm Việt Bình

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Năm xuất bản:

2026



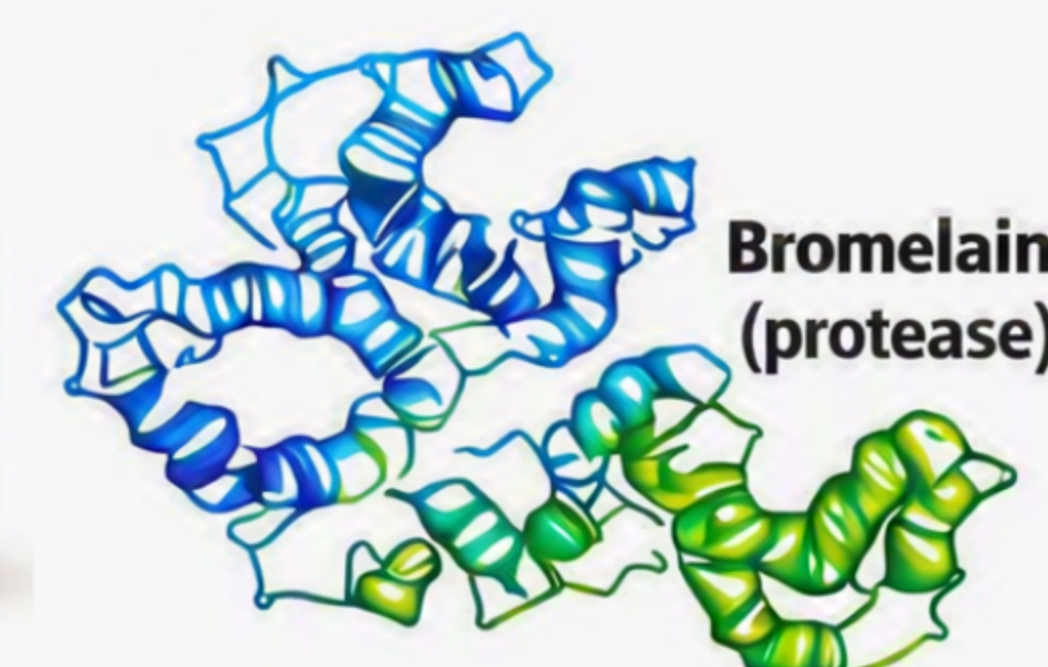
Khảo sát đặc tính của phụ phẩm dứa và thông số quá trình chiết xuất bromelain bằng dung môi xanh © 2026 bởi **Lâm Việt Bình** được cấp phép theo **CC BY-ND 4.0**.



From natural resources to  
valuable food products

## INVESTIGATION OF THE CHARACTERISTICS OF PINEAPPLE BY-PRODUCTS AND PARAMETERS OF THE BROMELAIN EXTRACTION PROCESS USING A EUTECTIC SOLVENT

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### INTRODUCTION

In recent years, the utilization of pineapple by-products to extract bromelain has become an important research direction. It both enhances economic value and reduces environmental impact. Vietnam produces more than 500 thousand tons of pineapple annually, concentrated in Tien Giang, Kien Giang, Hau Giang, and Ninh Binh. Processing generates large amounts of by-products such as peel, core, crown, and stem. These by-products contain valuable bioactive compounds, especially bromelain – a highly active protease [1]. Pineapple by-products are a cheap and abundant source for bromelain recovery. This provides a sustainable enzyme supply for food, pharmaceutical, and medical industries. At the same time, it supports a circular economy with zero waste [2]. Domestic studies have tested membrane filtration and spray drying. Results showed recovery efficiency above 49% and enzyme activity around 1542 U/g [3]. Globally, the trend of using green solvents (NADES) is gaining attention. Chiarelli et al. (2024) demonstrated that combining green solvents with assisted technologies increases yield by 25%. It also reduces extraction time from 12 hours to 90 minutes and lowers production costs [4]. Colletti et al. (2021) confirmed sustainable methods retain over 80% enzyme activity [5].

### Research Objectives

**General objective:** This study aims to investigate the characteristics of pineapple by-products and evaluate the parameters of the bromelain extraction process using green solvents.

**Specific objectives:**

- Determine the physicochemical properties of each type of by-product.
- Identify the suitable by-product type and solvent for the extraction process.
- Determine the optimal NADES concentration for the extraction process.
- Determine the optimal ultrasonic intensity for the extraction process.
- Determine the optimal sonication time for the extraction process.

### Materials and Methods

#### Materials



Figure 1 D-Glucose (Source: hoachatthanghiem.org)

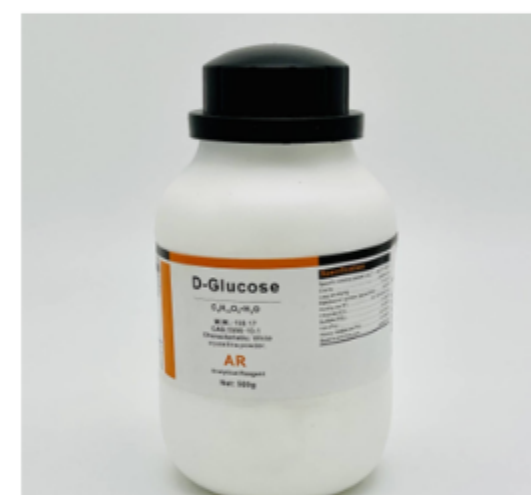


Figure 2 Vietnamese Queen Pineapple



Figure 3 Betaine monohydrate (Source: sigmaaldrich.com)

#### Research methodology

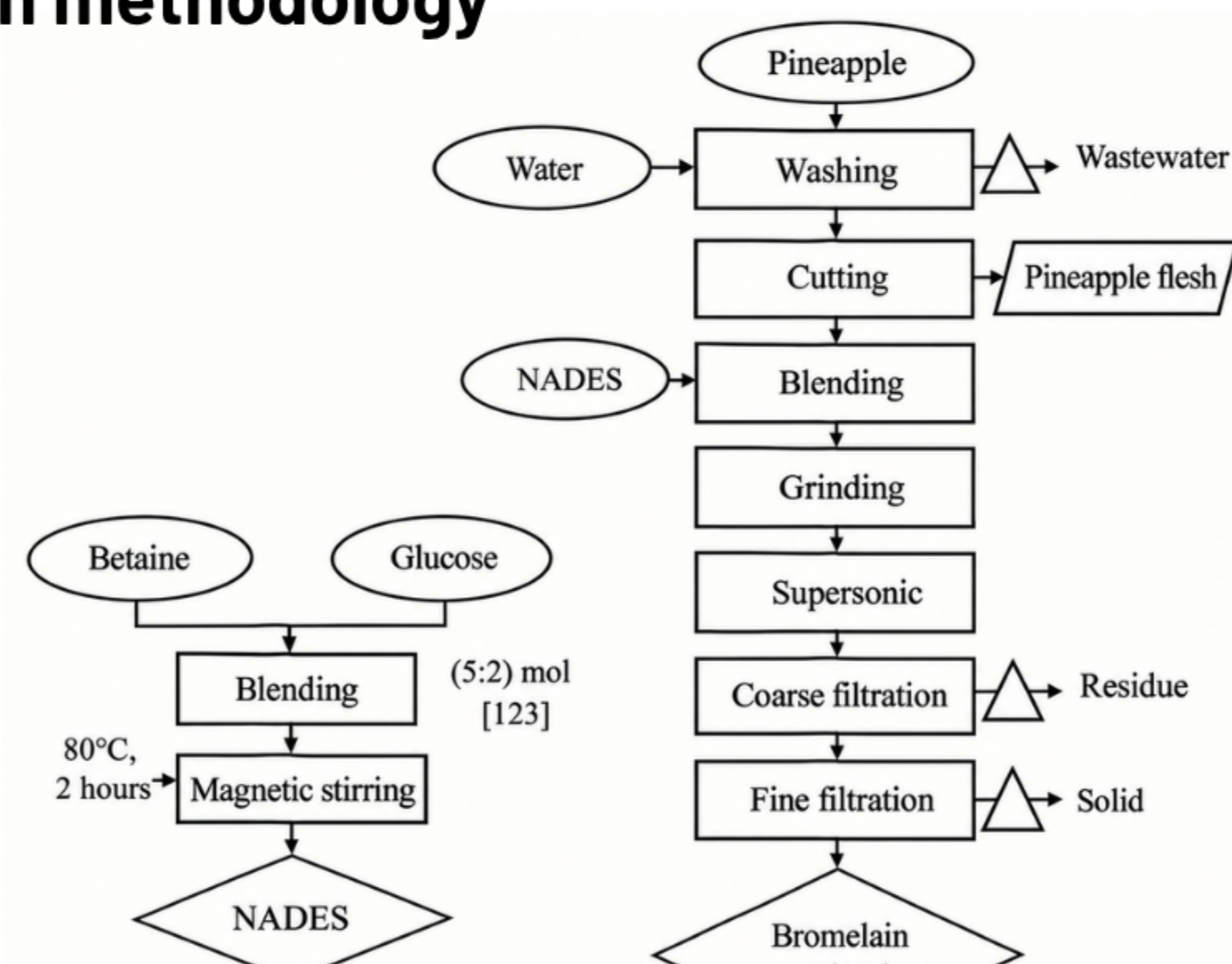


Fig. 1. Procedure for preparing NADES Fig. 2. Procedure for extracting bromelain

- Investigation of the physicochemical characteristics of pineapple by-products
- Investigation of the effect of different solvents on the quality of extracts from each type of by-product
- Investigation of the effect of NADES concentrations on extract quality (NADES concentration (%)(30, 40, 50, 60, 70, 80))
- Investigation of the effect of ultrasonic intensity on extract quality (Ultrasonic intensity % (20, 30, 40, 50, 60))
- Investigation of the effect of ultrasonication time on extract quality (Ultrasound duration (2, 4, 6, 8, 10) minutes)

#### References:

- [1] T. X. Nguyen, T. M. Le, Y. H. P. Duong, P. K. Le, and V. T. Tran, "Production of bromelain enzyme from pineapple waste by membrane process," Chem. Eng. Trans., vol. 106, pp. 943-948, 2023.
- [2] S. Banerjee, A. Arora, R. Vijayaraghavan, and A. F. Patti, "Extraction and crosslinking of bromelain aggregates for improved stability and reusability from pineapple processing waste," Int. J. Biol. Macromol., vol. 158, pp. 318-326, 2020.
- [3] D. T. M. Linh, N. T. Q. Mai, D. T. H. Tuyen, and N. T. N. Phuong, "Khảo sát quá trình tạo chế phẩm bromelain dạng bột từ phụ phẩm dứa," Tạp chí Khoa học và Công nghệ Thực phẩm, vol. 12, no. 1, 2017.
- [4] P. G. Chiarelli, B. Martinez, T. Nakamura, and K. Mis Solval, "Enhancing Bromelain Recovery from Pineapple By-Products: A Sustainable Approach for Value Addition and Waste Reduction," Foods, vol. 13, no. 4, p. 589, 2024.
- [5] A. Colletti, S. Li, M. Marengo, S. Adinolfi, and G. Cravotto, "Recent advances and insights into bromelain processing, pharmacokinetics and therapeutic uses," Applied Sciences, vol. 11, no. 18, p. 8428, 2021.
- [6] R. Kauschal, B. Kaur, P. S. Panesar, A. K. Anal, and S. Chu-Ky, "Valorization of pineapple rind for bromelain extraction using microwave assisted technique: optimization, purification, and structural characterization," J. Food Sci. Technol., vol. 61, no. 3, pp. 551-562, 2024.

### RESULTS

Table 1.1 Physicochemical characteristics of pineapple by-products

| Sample | Moisture content (%)    | TSS (°Brix)            | pH                     | By-product proportion (%) |
|--------|-------------------------|------------------------|------------------------|---------------------------|
| Stem   | 89,40±2,49 <sup>a</sup> | 1,81±0,09 <sup>d</sup> | 5,72±0,28 <sup>a</sup> | 3,52±0,71 <sup>c</sup>    |
| Crown  | 85,21±1,52 <sup>a</sup> | 2,50±0,10 <sup>c</sup> | 4,94±0,22 <sup>b</sup> | 10,59±1,99 <sup>b</sup>   |
| Peel   | 85,35±2,56 <sup>a</sup> | 3,73±0,21 <sup>b</sup> | 4,78±0,17 <sup>b</sup> | 31,95±2,84 <sup>a</sup>   |
| Core   | 88,20±2,22 <sup>a</sup> | 4,88±0,23 <sup>a</sup> | 4,55±0,21 <sup>b</sup> | 6,00±0,73 <sup>b</sup>    |



Stem



Crown



Peel



Core

Figure 1.1 Visual representation of by-products from Queen pineapples.

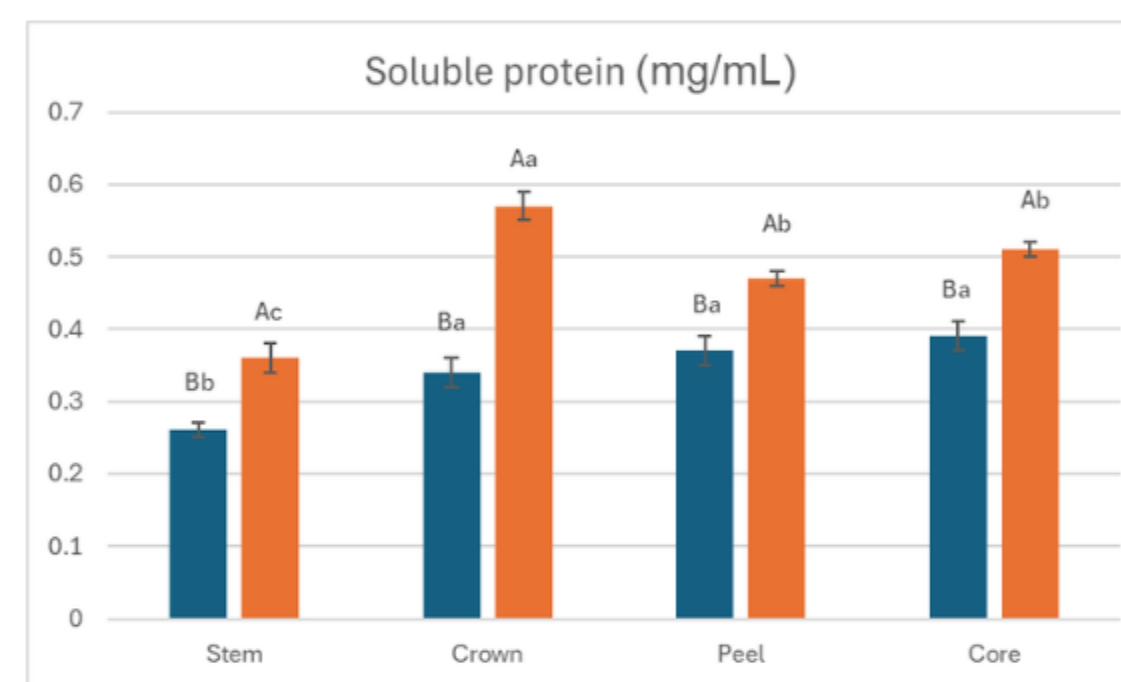


Figure 2.1 Soluble proteins in various solvents

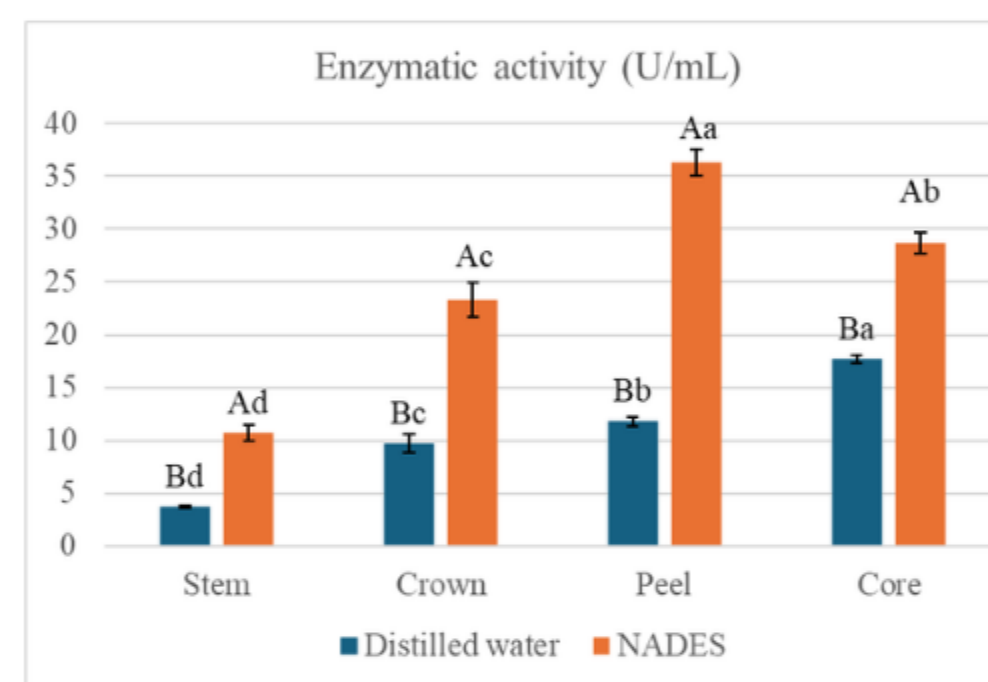


Figure 2.2 Enzyme activity with various solvents

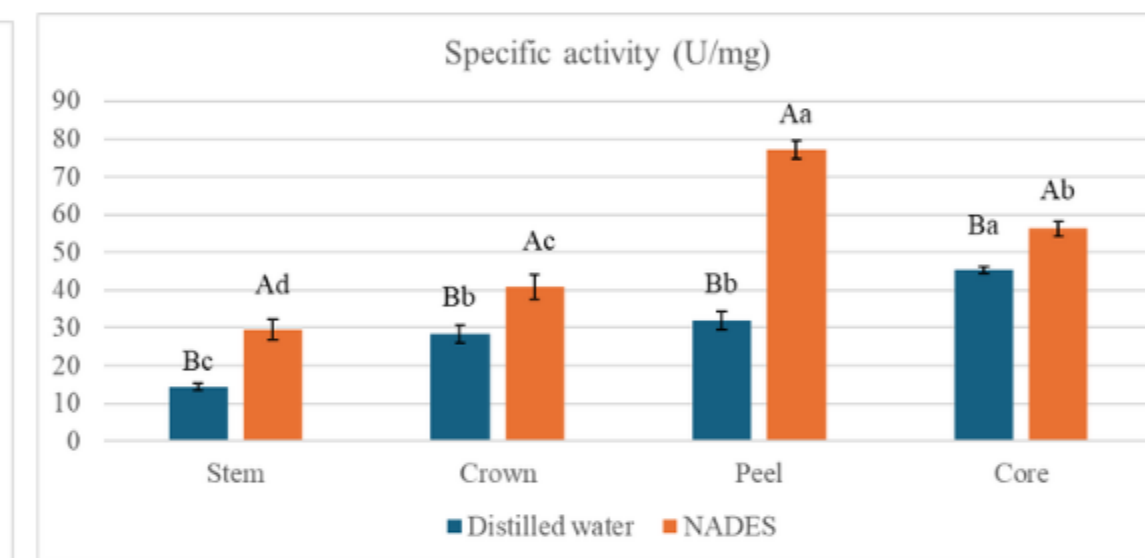


Figure 2.3 Specific activity of the solvents

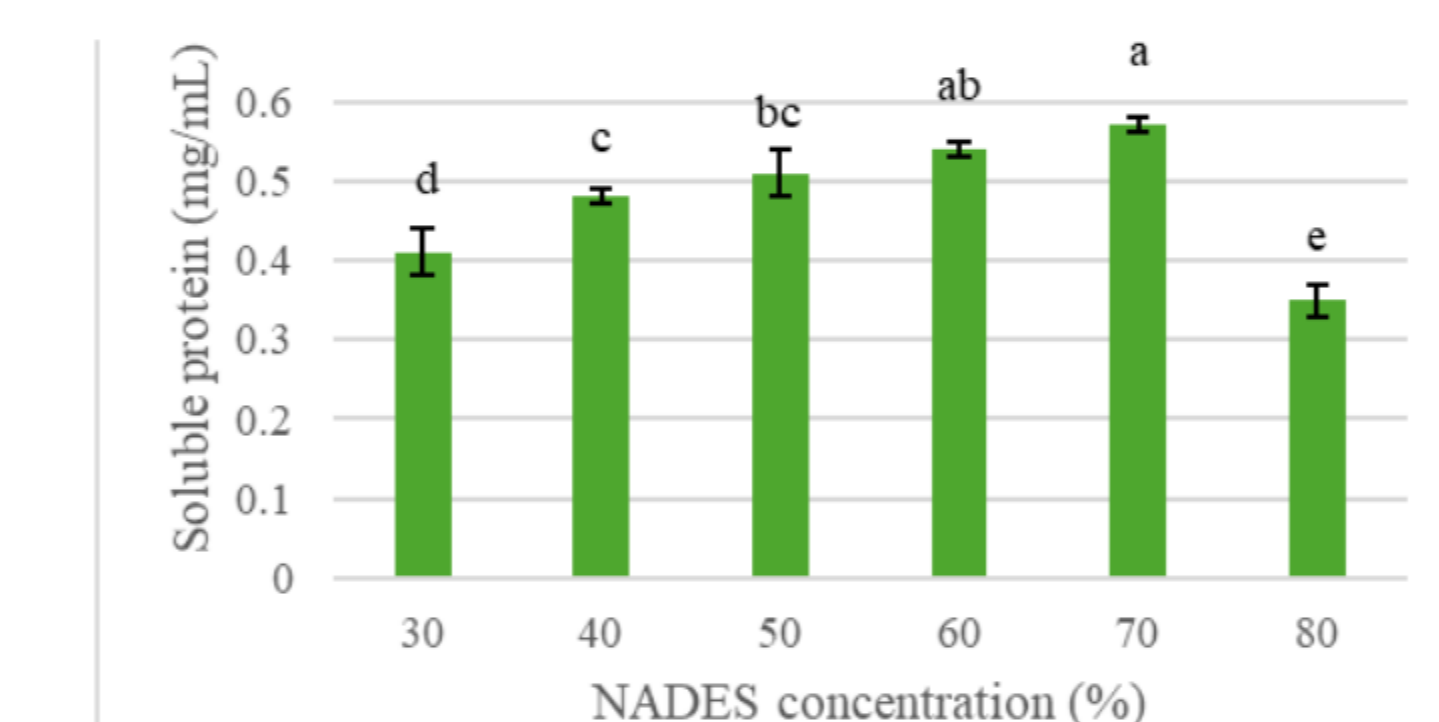


Figure 3.1 Soluble protein at various NADES concentrations.

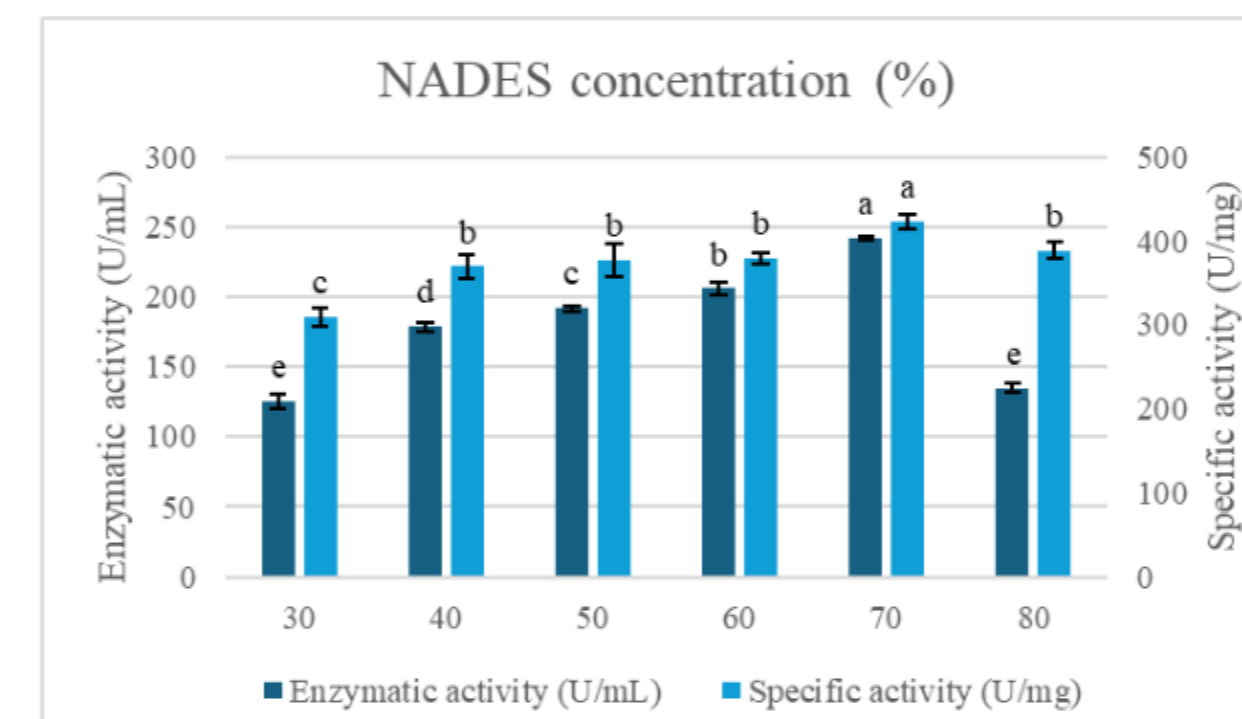


Figure 3.2 Enzymatic activity and specific activity at various NADES concentrations.

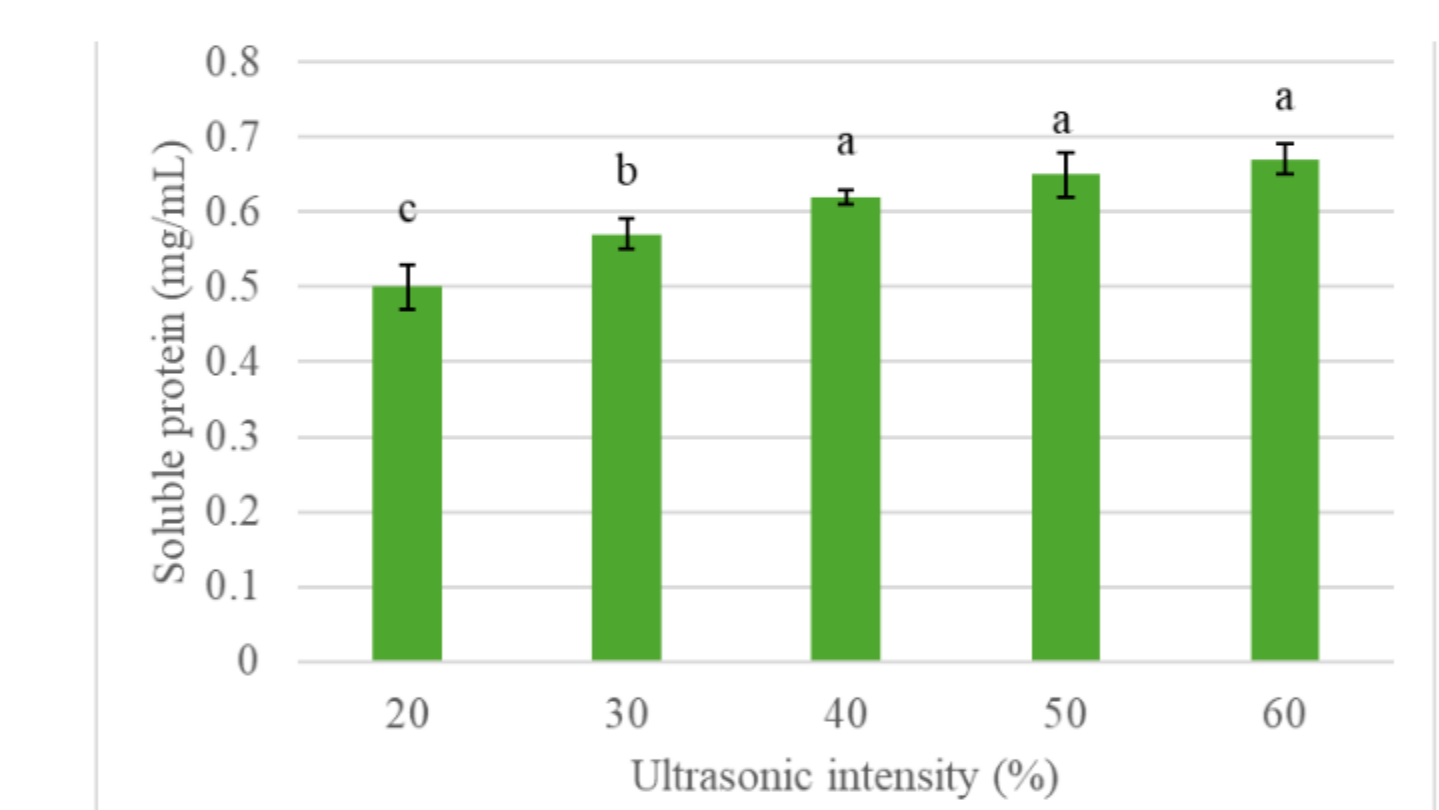


Figure 4.1 Soluble protein at various ultrasonic intensities.

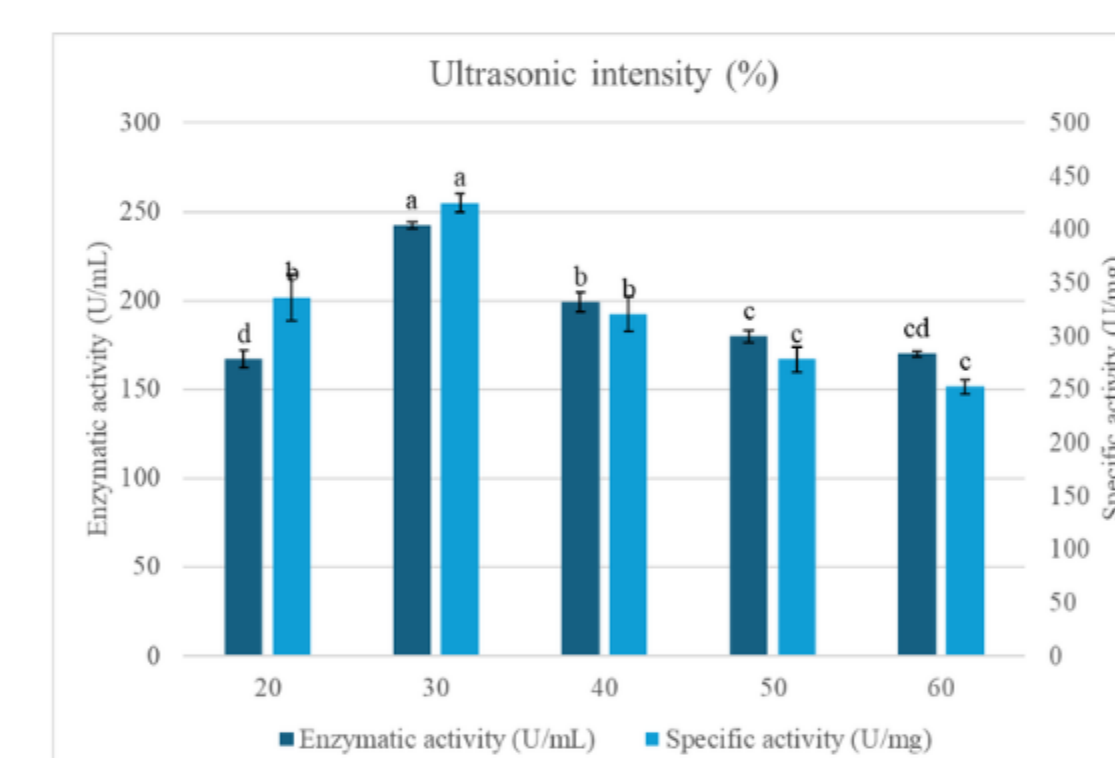


Figure 4.2 Enzymatic activity and specific activity at various ultrasonic intensities.

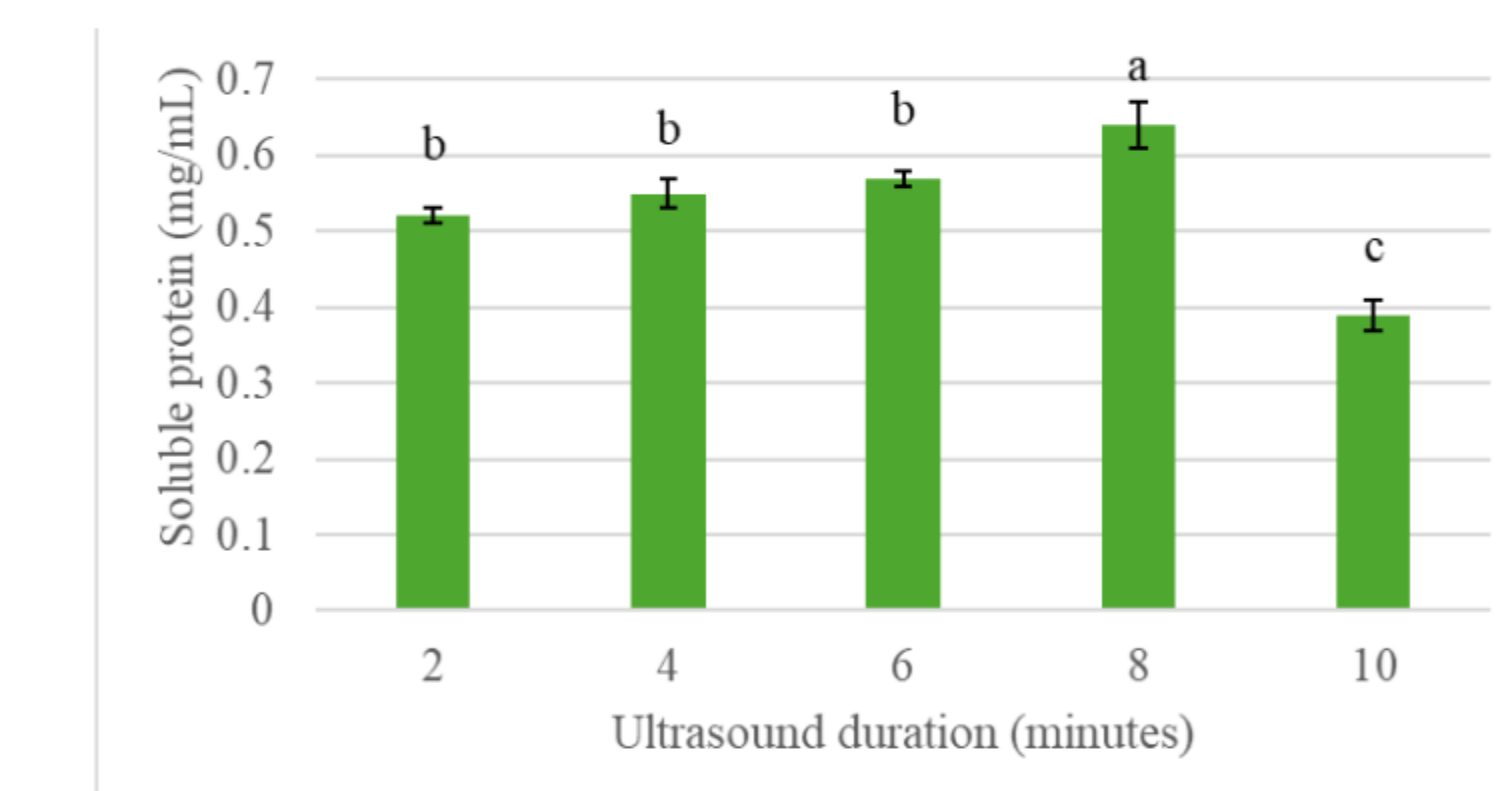


Figure 5.1 Soluble protein content at different sonication times.

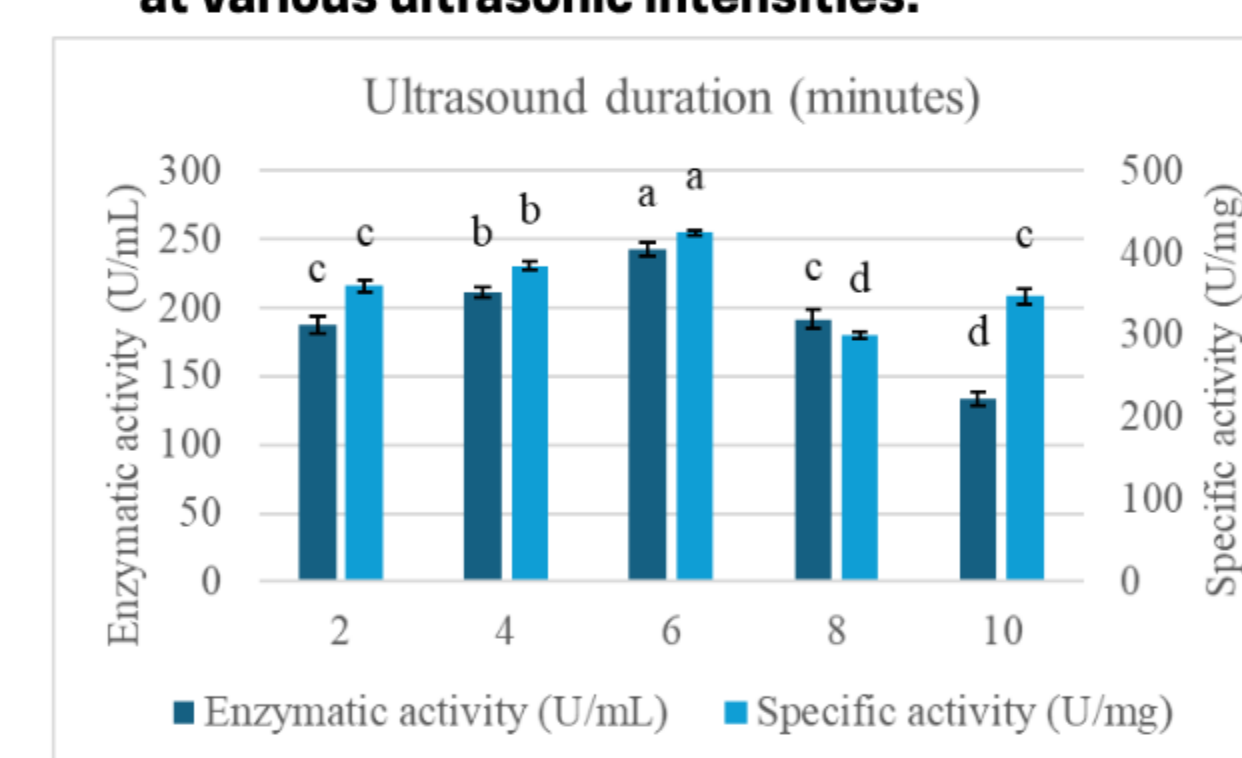


Figure 5.2 Enzymatic activity and specific activity at different sonication times.

### Conclusion

The results showed that moisture content did not differ significantly among the types of by-products ( $p < 0.05$ ). Total soluble solids (TSS) were recorded with differences between structural parts, in descending order: core > peel > crown > stem. The average pH index varied, with the stem having the highest mean pH (5.72); however, the differences among crown, peel, and core were not statistically significant ( $p > 0.05$ ). Among the by-products, pineapple peel accounted for the largest proportion at  $31.95 \pm 2.84$ . The solvent selected for subsequent experiments was NADES, with the highest specific activity of peel bromelain in NADES ( $77.12 \text{ U/mg}$ ), confirming the effectiveness of NADES in bromelain extraction. A NADES concentration of 70% (w/w) was optimal for bromelain extraction from Queen pineapple peel, yielding the highest values of soluble protein ( $0.57 \pm 0.01$ ), enzyme activity ( $241.83 \pm 1.53$ ), and specific activity ( $422.76 \pm 9.31$ ). The survey (Figures 3.4–3.7) demonstrated that an ultrasound intensity of 30% and a duration of 6 minutes were most suitable for the extraction process, with both enzymatic activity and specific activity reaching peak values. This confirms that controlling ultrasound intensity and duration is one of the key factors influencing the efficiency of bromelain extraction in NADES.