# 提升微藻破壁效果與萃取效率之策略

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## 摘要

微藻富有蛋白質與脂質，已被商業化培養並加工萃取製成保健食品或生質燃料。然而，由於微藻的細胞壁堅硬，難以有效的萃取其細胞質內的成分，因此為了提升萃取的效率，快速且低耗能的破壞細胞壁的方法持續被研究與改進。本次報告利用機械、化學及酵素的方法打破細胞壁，並利用反應曲面推算出最佳的操作參數。結合蝸牛酶與沙珠磨球並反應兩小時後，蛋白質、葉綠素及可溶性醣類萃取率分別提升 65.1%、34.7%及 20.2%。反應曲面圖在蛋白質萃取上並未找具有顯著差異的最佳條件 ($p>0.05$)；還原糖及葉綠素的最佳反應條件分別為酵素濃度 2%、1.125%；培養 1.25、2 小時及砂磨 8 分鐘。使用高壓均質機 (High-pressure homogenization, HPH)的破壁程度高於 pH12 溶液，脂質的萃取率關係於細胞破碎的程度，其線性關係 $R^2$=0.91，使用 HPH 的脂質萃取率高於 pH12 處理；蛋白質的萃取率主要受到蛋白質與細胞壁的鍵結破壞程度，使用 pH12 溶液有效的將鍵結水解，因此蛋白質萃取效果優於 HPH 處理。使用超音波 (Ultrasound, US) 與球磨破壁，脂質萃取量分別為 16.9%與 15.1%，葉綠素萃取量分別為 7.5 及 6.16mg/L，與未經任何處理之脂質萃取率 5.5% 及葉綠素萃取量 1.75 mg/L 相比，均顯著提高。綜上所述，單一或結合多種破壁技術皆能有效破壞微藻堅硬的細胞壁，釋放細胞質中的脂質，蛋白質與其餘功效成分，進而提高萃取率供後續產業應用。

# Strategies to Enhancing Microalgae Cell Wall Disruption and Extraction Efficiency

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## Outline

I. Introduction

II. Microalgae Cell wall Structure

III. Cell wall Disruption

IV. Cytoplasmic Extraction after Cell wall Disruption

V. Conclusion

## Abstract

Microalgae are rich in proteins and lipids, and have been commercially cultivated and processed into health supplements or biofuels. However, due to their rigid cell walls, it is difficult to efficiently extract intracellular components. Therefore, to enhance extraction efficiency, rapid and energy-saving cell wall disruption methods have been continuously studied and improved. In this study, mechanical, chemical, and enzymatic approaches were applied to disrupt the cell walls, and the optimal operating parameters were predicted using response surface methodology. Combining snailase with sand milling and incubation for two hours, the extraction yields of protein, chlorophyll, and soluble carbohydrates increased by 65.1%, 34.7%, and 20.2%, respectively. The response surface plots did not identify statistically significant optimal conditions for protein extraction ($p > 0.05$), while the optimal parameters for reducing sugar and chlorophyll extraction were enzyme concentrations of 2% and 1.125%, incubation times of 1.25 and 2 hours, and sand milling duration of 8 minutes. High-pressure homogenization (HPH) achieved higher disruption efficiency than pH 12 solution. Lipid extraction yield was strongly correlated with the degree of cell disruption ($R^2 = 0.91$), with HPH outperforming pH 12 treatment. In contrast, protein extraction yield was mainly influenced by the extent of bond cleavage between proteins and cell wall components. Alkaline treatment at pH 12 effectively hydrolyzed these linkages, resulting in better protein extraction efficiency than HPH. Using ultrasound (US) and ball milling, lipid extraction yields reached 16.9% and 15.1%, while chlorophyll extraction yields were 7.5 and 6.16 mg/L, respectively. Compared to untreated samples (lipid yield 5.5% and chlorophyll 1.75 mg/L), these methods significantly enhanced extraction efficiency. In summary, both individual and combined cell wall disruption techniques effectively break the rigid microalgal cell wall, releasing

intracellular lipids, proteins, and other bioactive compounds, thereby improving extraction yields for subsequent industrial applications.

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