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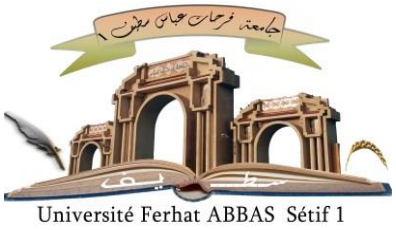
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ملخص

تناول هذه الأطروحة التثمين البيوتكنولوجي للمخلفات الزراعية والصناعية بوصفها مصادر كربونية مستدامة لإنتاج الإنزيمات الميكروبية، من خلال بناء مصفوفة مقارنة بين عوامل حيوية وركائز متنوعة. فقد تم تقييم كفاءة ثلاث سلالات بكتيرية (*Bacillus subtilis*، *Bacillus amyloliquefaciens*، و*Bacillus atrophaeus*) في إنتاج إنزيم ألفا-أميلاز خارج الخلية، بالتوازي مع دراسة تحفيز إنتاج إنزيم السيليلاز بواسطة فطر *Aspergillus niger* على ركائز تشمل قشور البطاطس، ونخالة القمح، وتبن القمح. ولتفكيك المصفوفة اللجنوسليلوزية للتبن، تم تطبيق معالجات كيميائية أولية باستخدام هيدروكسيد الصوديوم (NaOH) ، تلتها عمليات تخمير في الوسطين الصلب والمغمور. وتمت تحليل مستخلصات الإنزيم الخام كمياً باستخدام طريقة حمض ثنائي نيتروساليسيليك (DNS) ونمذجة منحنيات المعايرة عبر الانحدار الطيفي لتحديد تراكيز السكريات المختزلة. أظهرت النتائج أن تغيير السلالة البكتيرية لا يؤثر جوهرياً في التعبير عن إنزيم الأميلاز، بينما تنظم الخصائص البنيوية للركائز آليات تحفيز إنزيم السيليلاز مع تجاوز الكبت التقويضي بالكربون. ختاماً، يقدم البحث إطاراً متكاملاً لعمليات الفصل اللاحقة مع دراسة جدوى فنية واقتصادية لتوسيع نطاق المفاعلات الحيوية، مما يؤسس لنموذج (Biorefinery) فعال يحول النفايات المحلية إلى منتجات حيوية ذات قيمة صناعية عالية.

الكلمات المفتاحية :المخلفات الزراعية الصناعية، سلالات *Bacillus*، ألفا-أميلاز، السيليلاز، *Aspergillus niger*، التحفيز الإنزيمي، التثمين البيوتكنولوجي.

Abstract

This thesis investigates the valorization of agro-industrial by-products as sustainable carbon sources for microbial enzyme production, focusing on a comparative matrix of biocatalysts and substrates. Specifically, the study screened three *Bacillus* strains (*B. subtilis*, *B. amyloliquefaciens*, and *Bacillus atrophaeus*) for extracellular alpha-amylase efficiency, while simultaneously evaluating cellulase induction profiles of Aspergillus niger grown on potato peel waste, wheat bran, and wheat straw. Following sodium hydroxide NaOH pretreatment of the lignocellulosic biomass, solid-state and submerged fermentation protocols were utilized, with crude enzyme yields quantified through dinitrosalicylic acid (DNS) colorimetric assays and rigorous spectrophotometric regression modeling. Experimental results demonstrate how bacterial strain selection modulates amylase expression and how the structural complexity of raw biomass regulates cellulase induction while bypassing carbon catabolite repression; ultimately, this research integrates a conceptual framework for downstream purification with a techno-economic feasibility analysis to establish a viable, closed-loop biorefinery model for converting abundant local waste into high-value industrial biocatalysts.

Keywords : Agro-industrial waste, *Bacillus* strains, Alpha-amylase, Cellulase substrates, *Aspergillus niger*, Enzyme induction.

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GENERAL INTRODUCTION

General Introduction

Enzymes play a critical role in industrial bioprocesses due to their capability to catalyze chemical reactions with high efficiency and specificity under mild operating conditions. Within the food, beverage, and pharmaceutical sectors, the integration of enzymatic processes significantly lowers energy consumption and avoids the use of harsh chemical reagents (Kirk et al., 2002). Over time, their application has shifted from being a specialized laboratory tool to a core component in large-scale manufacturing systems. recently, the industrial market relies heavily on these biological catalysts to make manufacturing workflows eco-friendlier and more cost-effective.

The majority of commercial enzymes are sourced from microorganisms such as bacteria and fungi. These organisms are highly favored because they grow rapidly, adapt well to diverse environmental conditions, and can be physiologically or genetically engineered to produce high levels of extracellular enzymes. However, the primary economic obstacle in industrial fermentation remains the high cost of the growth media. Utilizing expensive, refined sugars as carbon sources renders large-scale production unsustainable. Consequently, industrial biotechnology is increasingly turning to low-cost, abundant agricultural by-products to minimize production costs (Singh et al., 2016).

Among the various industrial enzymes, amylases and cellulases are of paramount importance due to their capacity to degrade abundant natural biopolymers. Amylases catalyze the hydrolysis of starch into simpler sugars, such as maltose and glucose, which is essential for baking dough conditioning, brewing, and bioethanol production (Gupta et al., 2003). Cellulases, on the other hand, break down cellulose. This biodegradation process is highly complex because cellulose is crystalline in nature and tightly locked inside a plant cell wall matrix containing hemicellulose and lignin. This recalcitrant structure requires a coordinated mixture of different enzymes working sequentially to fully hydrolyze the material into glucose (Bhat, 2000).

To optimize production economics, agricultural residues such as potato peels, wheat bran, and wheat straw can serve as alternative fermentation substrates. The filamentous fungus Aspergillus niger is widely utilized in solid-state fermentation (SSF) systems featuring these materials. Its hyphae physically penetrate the solid matrix, enabling the localized secretion of a robust cocktail of extracellular enzymes (Raimbault, 1998; Schuster et al., 2002; Pandey, 2003). In parallel, *Bacillus* species are highly efficient producers of extracellular amylases, secreting

these enzymes directly into liquid media during submerged fermentation (SmF), which simplifies subsequent downstream recovery and purification (Schallmey et al., 2004).

This study evaluates the use of local agro-industrial residues, such as potato peels and wheat waste, as sustainable and low-cost alternatives to expensive commercial media for the production of two key industrial enzymes: alpha-amylase and cellulase. By substituting refined chemicals with these complex agricultural substrates, the research aims to establish an economically viable, closed-loop biochemical process. It specifically investigates alpha-amylase production by *Bacillus* strains via SMF and cellulase production by *Aspergillus niger* through SSF , with the ultimate goal of identifying the most efficient microbe-substrate combinations.