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Exploiting starch and cellulose biodegradation for microbial polyhydroxyalkanoate (PHA) production

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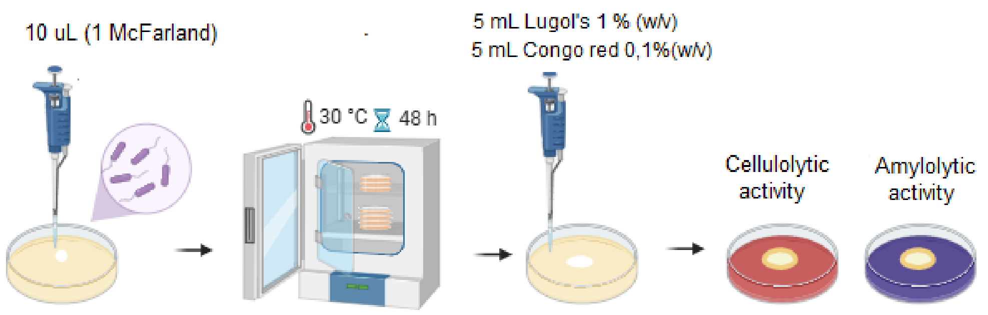
INTRODUCTION

In Colombia, annual plastic consumption reaches nearly 1.2 million tons, resulting in a significant impact on the environment and public health, as most of this waste ends up in landfills that pollute mangroves, rivers, and seas. To address the problems associated with non-biodegradable and non-renewable plastics, alternative materials such as biodegradable and non-toxic polymers have been promoted, among which polyhydroxyalkanoates (PHA) stand out. These microbially derived biopolymers are biocompatible, can be produced from various renewable carbon sources, and are suitable for both single-use plastics and biomedical applications, making them consistent with circular economy principles (Jin et al., 2023) (Gautam et al., 2024).

This study aimed to evaluate PHA production by ***Bacillus thuringiensis*** (C01) using starch and carboxymethylcellulose (CMC) as carbon sources, and to optimize the process through a central composite design with response surface methodology.

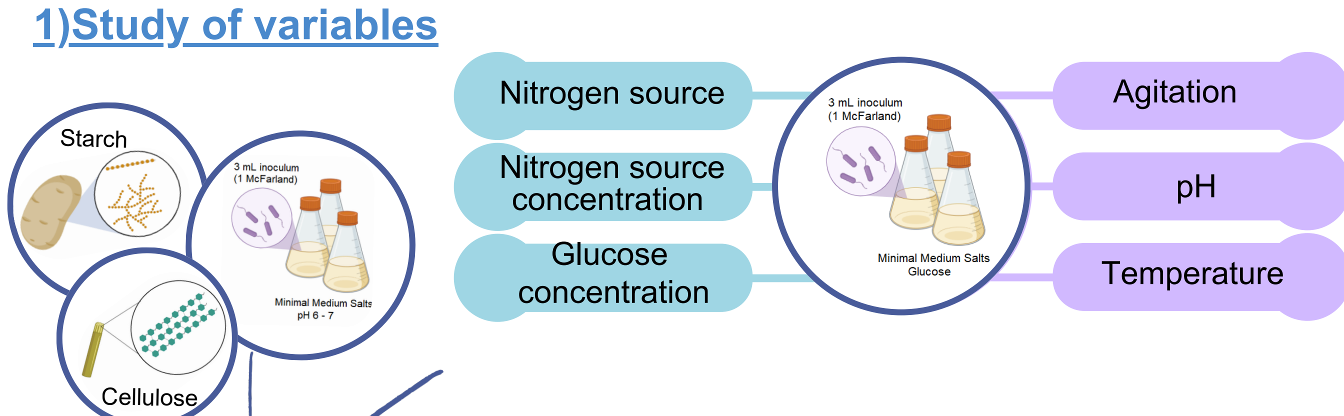
METHODOLOGY

PHASE 1: EVALUATION OF AMYLOLYTIC AND CELLULOLYTIC ACTIVITY

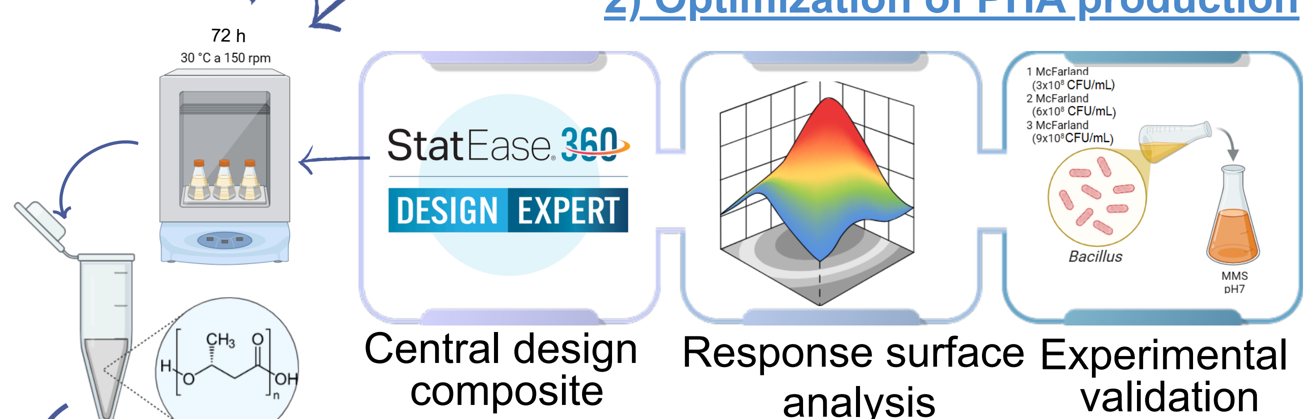


PHASE 2: STUDY OF GROWTH VARIABLES IN FERMENTATION WITH GLUCOSE, STARCH, AND CMC FOR PHA PRODUCTION

1)Study of variables



2) Optimization of PHA production



PHASE 3: CHARACTERIZATION OF PHA

- Fourier transform infrared spectroscopy (FTIR)
- Thermogravimetry (TGA)
- Differential scanning calorimetry (DSC)
- MALDI-TOF/TOF MS

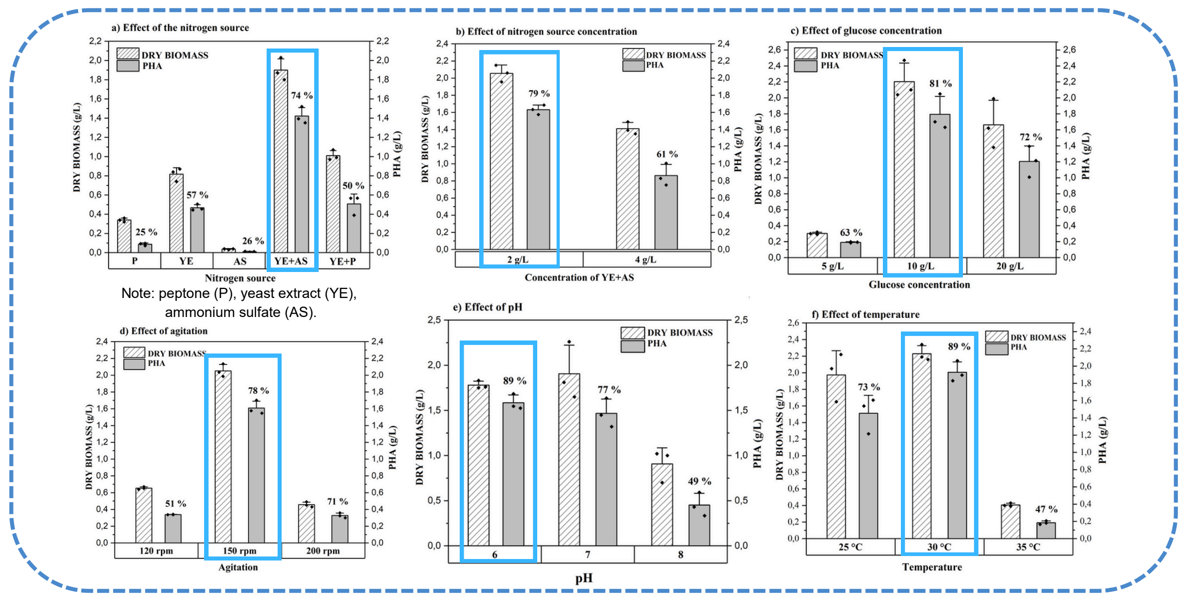
RESULTS & DISCUSSION

AMYLOLYTIC AND CELLULOLYTIC ACTIVITY

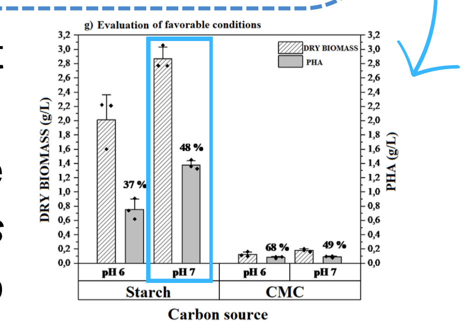
Starch hydrolysis

CMC hydrolysis

PHA PRODUCTION



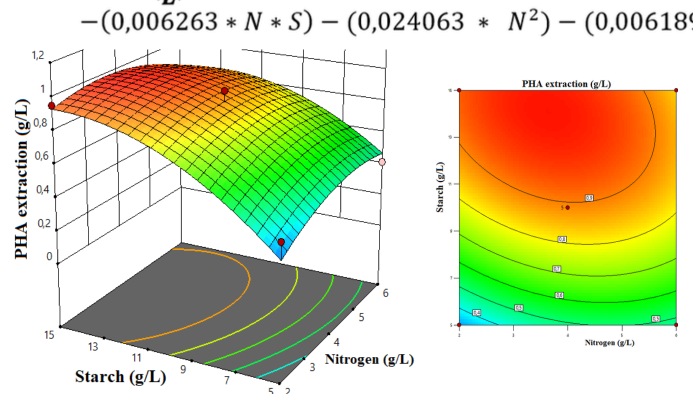
Metabolic efficiency in PHA production at pH 7 is related to enzyme activity. Shamala et al. (2012) reported that the activity of α-amylase produced by *Bacillus sp.* improves at neutral pH compared to acidic pH.



PHA production with starch and CMC under favorable conditions

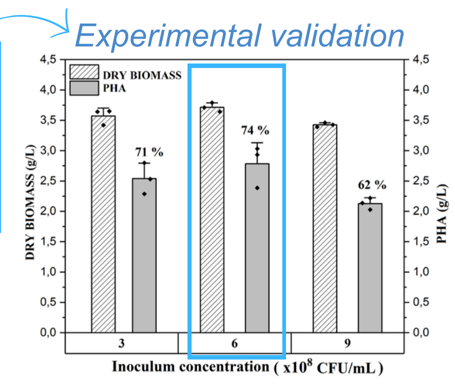
OPTIMIZATION

$$PHA\left(\frac{g}{L}\right) = -(0{,}888439) + (0{,}262760 * N) + (0{,}198049 * S) - (0{,}006263 * N * S) - (0{,}024063 * N^2) - (0{,}006189 * S^2)$$



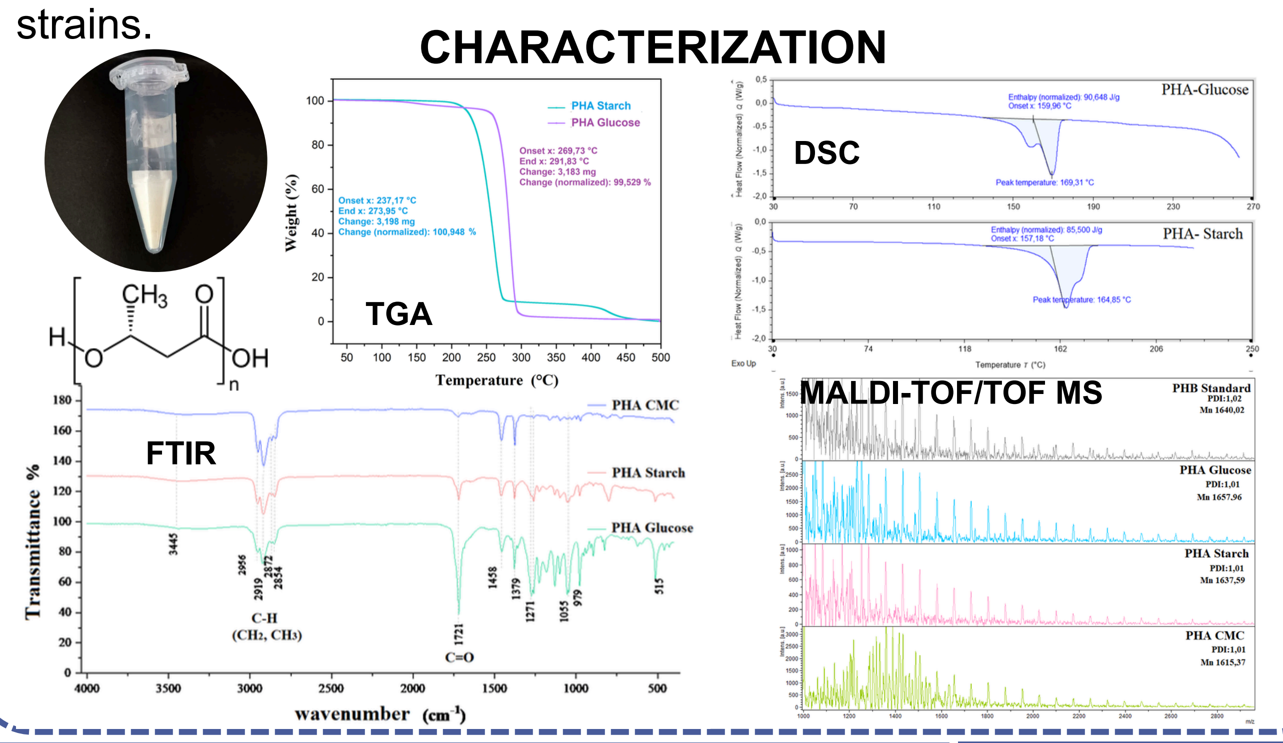
Starch: 14,168 g/L
YE+AS: 3,616 g/L

Experimental validation



The optimization resulted in a maximum production of 2.78 g/L of PHA, which was more efficient than that reported by Ibrahim et al. (2025), who used 40 g/L of starch in the optimization of PHA (2.17 g/L) with the *Bacillus australimaris.* Similarly, Basak et al. (2024) and Odeniyi & Adeola (2017) reported lower biopolymer production when using starch as a carbon source for *Bacillus* strains.

CHARACTERIZATION



CONCLUSION

The amylolytic activity of ***Bacillus thuringiensis*** highlights its potential for using starch-rich agroindustrial residues as substrates for sustainable poly(3-hydroxybutyrate) (PHB) production.

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REFERENCES