

Feature Review

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Metabolic Engineering of Bt for Enhanced Production of Insecticidal Proteins

Wenfei Zhang ✉

College of Life Sciences, Hainan Normal University, Haikou, 570206, Hainan, China

✉ Corresponding email: wenfei2007@163.comBt Research, 2024, Vol.15, No.4 doi: [10.5376/bt.2024.15.0020](https://doi.org/10.5376/bt.2024.15.0020)

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Abstract *Bacillus thuringiensis* (Bt) is a key bacterial strain used for producing bioinsecticides, with its insecticidal proteins being widely applied in agricultural pest control. However, traditional Bt production faces challenges such as low protein yield and high production costs. To address these issues, this study explores strategies to enhance Bt metabolic pathways through metabolic engineering, aiming to increase protein production. The research covers Bt's primary and secondary metabolic pathways, their relationship with protein synthesis, and case studies of enhanced protein production achieved through genetic modification and metabolic flux optimization. This study aims to provide feasible improvements for the commercial production and application of Bt products in agriculture by offering theoretical insights into the metabolic engineering of Bt.

Keywords *Bacillus thuringiensis*; Insecticidal proteins; Metabolic engineering; Genetic modification; Agricultural application

1 Introduction

Bacillus thuringiensis (Bt) is a Gram-positive, spore-forming bacterium widely used in biological pest control due to its ability to produce insecticidal Cry proteins. These proteins are highly toxic to various insect orders, including Lepidoptera, Coleoptera, and Diptera, making Bt a crucial tool in agricultural pest management (Akhtar et al., 2021). Bt's insecticidal properties have been successfully applied in sprayable biopesticides and transgenic crops, providing an environmentally friendly alternative to chemical pesticides (Li et al., 2022; Yamamoto et al., 2022). Moreover, Bt's effectiveness against pests such as mosquitoes, which are vectors of disease, further underscores its importance in integrated pest management (Nair et al., 2020; Akhtar et al., 2021).

In modern agriculture, Bt insecticidal proteins play a vital role in crop protection. They are widely used in transgenic crops like cotton and corn, significantly reducing the use of chemical pesticides and boosting crop yields (Li et al., 2020; Yamamoto et al., 2022). The specificity of Bt proteins, which target only harmful insects while being safe for humans and other non-target organisms, makes them an ideal choice for sustainable agriculture (Chen et al., 2021; Singh et al., 2021). However, the emergence of insect resistance to certain Bt proteins necessitates ongoing research to design and develop new insecticidal proteins with enhanced efficacy and broader insecticidal spectra (Chen et al., 2021; Yamamoto et al., 2022).

This study focuses on the latest advancements in metabolic engineering to enhance the production of Bt insecticidal proteins. It analyzes and discusses various strategies to improve Bt protein yield and efficacy, including genetic modifications, co-expression systems, and the environmental impact of engineered Bt strains. Through these analyses, this study aims to provide a theoretical foundation for the future development of Bt insecticidal proteins and to promote the advancement of more effective and sustainable pest management solutions.

2 Overview of Bt and Insecticidal Proteins

2.1 Bt strains and their characteristics

Bacillus thuringiensis (Bt) is a Gram-positive, spore-forming bacterium widely recognized for its ability to produce insecticidal proteins during the sporulation phase of its growth cycle. These proteins, primarily Cry, Vip, and Cyt, are highly specific to certain insect orders, making Bt a valuable tool in pest management (Bravo et al.,