Chapter 1

Introduction

1.1 Background

Thailand is one of the world's leading producers of bananas, with the Kluai Hom Thong variety (Musa acuminata, AAA group) being highly abundant (Suthiluk et al., 2021). Green bananas, particularly unripe ones, are rich in resistant starch (RS), a type of dietary fiber that provides multiple health benefits (Zhang et al., 2023). Resistant starch is not digested in the small intestine but reaches the colon, where it serves as a substrate for beneficial gut bacteria, making it an essential prebiotic component (Hasan et al., 2019). Studies have shown that the RS (Resistance Starch) content in unripe bananas can range from 50% to 70% of the total starch content, depending on the variety and maturation stage (Chong et al., 2019). This makes green banana powder an ideal ingredient for functional food applications aimed at improving digestive health and metabolic function (Neolaka et al., 2021).

Unripe green bananas are widely used for their high RS content, which gradually decreases as the fruit ripens and converts to simpler sugars (Zheng et al., 2023). This high RS concentration provides numerous benefits, including improved gut health, enhanced insulin sensitivity, and better weight management (Bachari et al., 2024). Additionally, resistant starch fermentation in the colon leads to the production of short-chain fatty acids (SCFAs), such as butyrate, acetate, and propionate, which contribute to maintaining intestinal health, reducing inflammation, and regulating blood glucose levels (Zaman et al., 2021).

Green banana powder, derived from either peeled or unpeeled bananas, serves as a valuable prebiotic ingredient (Shini et al., 2024). Peeled green banana powder contains a higher concentration of resistant starch due to the removal of the fibrous peel, making it more effective in promoting gut microbiota fermentation (Zhang et al., 2021). However, unpeeled green banana powder retains

higher amounts of dietary fiber, antioxidants, and bioactive compounds, which provide additional health benefits, such as improved gut motility and enhanced antioxidant activity (Singh et al., 2020). The differences between these two forms of banana powder make them suitable for different functional food applications based on their nutritional properties.

While banana pulp is commonly consumed, recent studies have shown that the peel, often considered waste, contains significantly higher levels of phenolic compounds, including flavonoids and tannins, which contribute to its strong antibacterial properties (Sulaiman et al., 2011; Akinmoladun et al., 2022). In contrast, the edible pulp has relatively lower antimicrobial activity due to its lower concentration of these bioactive substances (Akinmoladun et al., 2022). Extracts from unripe banana peel have demonstrated inhibitory effects against several pathogenic bacteria such as *Escherichia coli*, *Staphylococcus aureus*, and *Pseudomonas aeruginosa* (Ilyas et al., 2022; Sulaiman et al., 2011). Furthermore, the incorporation of banana peel powder into food products has been found to enhance microbial safety and extend shelf life, suggesting its potential as a natural preservative (Choudhary et al., 2022).

To further enhance the functional properties of green banana powder, incorporating probiotics is a promising strategy (Gibson et al., 2017). Probiotics are beneficial microorganisms that support gut health by balancing the intestinal microbiota, improving digestion, and strengthening the immune system (Markowiak & Śliżewska, 2017). Among the various probiotic strains, *Bacillus coagulans* stands out due to its adaptability and resilience in harsh environments (Cao et al., 2020). Unlike other probiotics such as Lactobacillus and Bifidobacterium, Bacillus coagulans is a spore-forming bacterium capable of withstanding extreme conditions, including heat, acid, and desiccation (McFarland et al., 2018). This makes it an excellent candidate for inclusion in dried food products, such as synbiotic green banana powder.

The use of *Bacillus coagulans* spores instead of live bacterial cells is particularly advantageous for the production of powdered functional foods (Kim et al., 2021). Spores are highly resistant to

environmental stressors, ensuring better stability and longevity of the probiotic during storage and transportation (Adipour et al., 2019). This enhances the viability and effectiveness of the probiotic upon ingestion, as the spores can germinate and colonize the gut when exposed to favorable conditions in the gastrointestinal tract (Zhou et al., 2020). The sporulation process in Bacillus coagulans is triggered by stressful conditions, such as nutrient depletion, heat exposure, and acidic environments, making it a robust probiotic for industrial applications (Dijksterhuis, 2019). *Bacillus coagulans* exhibits optimal growth within a temperature range of 35°C to 50°C, with studies indicating that incubation at 45°C can enhance cell density and growth rates compared to lower temperatures, such as 35°C (Li et al., 2018; Wang et al., 2020).

The primary aim of this study is to develop a synbiotic product by combining green banana powder, rich in resistant starch, with Bacillus coagulans spores to create a functional beverage powder (Kuo et al., 2021). This formulation leverages the prebiotic benefits of green banana powder and the probiotic advantages of Bacillus coagulans spores to promote gut health, metabolic regulation, and overall well-being (Helander et al., 2023). By optimizing the combination of these two components, this research seeks to enhance the stability, functionality, and health benefits of synbiotic banana powder, making it a viable option for promoting digestive and metabolic health in functional food applications.

1.2 Objective

The objectives of this research are to determine whether peeled or unpeeled green banana powder is more suitable for supporting the growth and stability of the probiotic *Bacillus coagulans*, considering differences in resistant starch and dietary fiber content. Additionally, the research seeks to identify the optimal temperature for maximizing *Bacillus coagulans* spore production yield, ensuring enhanced viability, stability, and functionality in synbiotic formulations. By optimizing these factors, this research aims to improve the effectiveness of synbiotic banana powder for functional food applications, promoting better gut health and metabolic benefits.

1.3 Hypothesis

To explore the key factors influencing the viability and functionality of *Bacillus coagulans* in synbiotic formulations, two hypotheses were formulated. The first focuses on the impact of banana powder type, while the second examines the role of incubation temperature on spore production efficiency.

1.3.1 Unpeeled and Peeled Banana Powder

H0 (Null Hypothesis): There is no significant difference in the suitability of unpeeled and peeled banana powders for the growth of *Bacillus coagulans*.

H1 (Alternative Hypothesis): There is a significant difference in the suitability of unpeeled and peeled banana powders for the growth of *Bacillus coagulans*.

1.3.2 Optimal Temperature for Sporulation

H0 (Null Hypothesis): There is no significant difference in the spore production yield of *Bacillus coagulans* at different temperatures.

H1 (Alternative Hypothesis): There is a significant difference in the spore production yield of *Bacillus coagulans* at different temperatures.