Chapter 1

Introduction

1.1 Background

The global demand for functional beverages has surged, with the market projected to reach a total of 466.5 billion U.S. dollars by 2034, driven by consumers seeking health-promoting alternatives (More, 2025). Herbal and fruit-based teas are prized for their high concentrations of phytochemicals, particularly antioxidants such as flavonoids and phenolic acids, which neutralize free radicals and support immune function (Chang et al., 2019). Limeberry (*Triphasia trifolia*), a tropical shrub in the family Rutaceae, represents a largely underexplored fruit. Native to Southeast Asia and underutilized globally, it produces small, crimson fruits with a distinct citrus aroma, alongside aromatic leaves (Wilson, 2024). Phytochemical studies have confirmed the presence of flavonoid glucosides such as naringin, hesperidin, and rutin, phenolic acids, and coumarins throughout its fruit, peels, and leaves (Herdiana et al., 2024; Herdiana et al., 2025). The fruit ethanol extract showed a notable 22.5% extraction yield containing polyphenolic flavonoids and tannins (Herdiana et al., 2025). Traditionally used across Southeast Asia to treat respiratory, inflammatory, and digestive ailments, limeberry still remains commercially underutilized (Md-Othman et al., 2016). The fruit is rarely consumed fresh due to its intensely bitter and astringent flavor from high naringin concentrations in the peel, which makes it unpalatable (Ye et al., 2022). These flavonoids are beneficial, providing anti-inflammatory, and free-radical scavenging effects without toxicity at typical levels, but their bitterness limits their appeal (Marinho et al., 2024).

The plant is currently processed primarily into essential oils for perfumery, leaving its water-soluble bioactives largely underexplored as functional food ingredients. Converting limeberry fruit and peels into a ready-to-drink (RTD) tea beverage is a scientifically and commercially justified approach. Tea production via hot water infusion efficiently solubilizes water-soluble phytochemicals, such as phenolic acids, flavonoid glycosides, and minerals from the plant matrix into a bioavailable liquid medium without organic solvents, making it scalable for RTD applications (Choi et al., 2025). However, brewing temperature is a critical variable. Research by Cheng et al. (2023) on hot water extraction across 25–100°C has demonstrated that extraction efficiency increases with temperature, with the highest antioxidant yield at 100°C; however, degradation of heat-sensitive bioactives occurs beyond 120 minutes of extraction, and total phenolic content peaks at only 100°C in conventional brewing. Excessive heat accelerates oxidative decomposition of phenolic acids through dehydrogenation reactions, reducing antioxidant activity, while also promoting the over-extraction of condensed tannins that intensify astringency (Antony & Farid, 2022). Conversely, temperatures that are too low fail to fully solubilize the flavonoid glycosides bound within limeberry's peel matrix. Studies by Yu et al. (2024) on citrus-related plant materials have identified 90°C for 30 minutes as a balanced extraction condition that optimizes polyphenol yield while limiting thermal breakdown, yet no study has been conducted for limeberry RTD tea, which means the optimal temperature and infusion time for limeberry tea remain undefined.

A further challenge in developing a palatable limeberry RTD tea is mitigating its naringin-driven bitterness and tannin-driven astringency, both of which substantially limit consumer acceptability. Sweeteners remain the most direct strategy for bitterness masking in functional beverages (Ramsey et al., 2025). Among commonly used sweeteners, sucrose, honey, and Glucose syrup differ markedly in composition, sweetness profile, glycemic impact, and interaction with polyphenols. Sucrose provides a clean, familiar sweetness but carries a high glycemic load (Andersen et al., 2023). Honey is a complex mixture of fructose, glucose, organic acids and bioactive phenolics, and can contribute to antioxidant activity (Pandiselvam et al., 2023). Glucose syrup, derived from starch hydrolysis, offers mild, neutral sweetness and high solubility (Simpson et al., 2022).

Through the given conditions, the underutilization of limeberry's bioactive potential, undefined optimal brewing parameters, and unresolved sweetener selection. Therefore, this study aims to develop a healthy, palatable, and commercially viable limeberry RTD tea. By systematically testing brewing temperatures and sweetener types, this study seeks to determine conditions that maximize antioxidant content while achieving consumer-acceptable sensory characteristics.

1.2 Objective

The objective of this study is to investigate the effect of brewing temperature on antioxidant activity, and to develop an RTD product of the limeberry fruit tea using three types of sweeteners at two concentrations, while monitoring their physicochemical properties. Additionally, this study also aims to evaluate the effect of the sweeteners on consumer preferences.

1.3 Hypothesis

1.3.1 Brewing Temperature

H_0: Different Brewing temperatures do not significantly affect the antioxidant activity and total phenolic content of the limeberry fruit tea.

H_1: Different Brewing temperatures significantly affect the antioxidant activity and total phenolic content of the limeberry fruit tea.

1.3.2 Effect of Types and Concentration of the Sweeteners

H_0: The types and concentrations of the sweetener do not significantly affect the physicochemical properties of the RTD limeberry tea.

H_1: The types and concentrations of the sweetener significantly affect the physicochemical properties of the RTD limeberry tea.

1.3.3 Sensory Acceptance

H_0: Different types and concentrations of sweeteners do not significantly affect consumers' preferences toward the limeberry fruit tea.

H_1: Different types and concentrations of sweeteners significantly affect consumers' preferences toward the limeberry fruit tea.