Chapter 1

Introduction

1.1 Background

One of the most significant and well-known of all the carotenoids is beta-carotene. It is a precursor to vitamin A and is mainly contained in carrots, spanish, mango, etc (Baliga et al., 2019). Beta-carotene acts not only as a strong antioxidant, but also scavenges of singlet oxygen (Padmanabhan et al., 2016). It is also commonly used as a natural colorant, as an orange-red pigment in non-alcoholic drinks which is not heated, cheese, etc (Rodriguez-Amaya, 2015; Bogacz-Radomska & Harasym, 2018)

Despite its numerous advantages, beta-carotene has drawbacks that limit its use in the food industry. Beta-carotene is a lipophilic molecule with high hydrophobicity which is poorly soluble in water due to the amount of non-polar compounds (Martín Ortega & Segura Campos, 2021; Zeece, 2020). It also has a limited bioavailability and is sensitive to environmental factors (Maurya et al., 2021). When exposed to heat, oxygen, acidic pH, and UV light, it would undergo rapid degradation (Baek et al., 2020; Shao et al., 2017).

Encapsulation methods have been commonly used in the food industry because it makes it easier to incorporate and stabilize bioactive substances by encasing bioactive compounds in a carrier material. It improves stability and bioavailability (Rezagholizade-shirvan et al., 2024). As an example, beta-carotene has been encapsulated using materials such as WPI and food-grade nanofibers to improve its thermal, moisture, and oxidative stability (Drosou & Krokida, 2024; Drosou et al., 2022). However, some encapsulation techniques may have several drawbacks such as high processing cost for freeze-drying and the usage of high temperature for spray drying (Stratta et al., 2020; Morales & Ruiz, 2016)Cocrystallization is one of encapsulation techniques that is simple and affordable (López-Córdoba et al., 2016). It is a process where two or more distinct species coexist in a lattice as a result of intermolecular interactions between molecules (Bodiuzzaman & Pradeep, 2023). Cocrystals are commonly bound together by non-covalent forces such Van der Waals forces, π–π interactions, and hydrogen bonds. Hydrogen bonds are common and essential to the formation of cocrystals due to their strength and flexibility(Pantwalawalkar et al., 2025). While non-covalent bonds are weak enough to disintegrate when dissolved in water, those bonds are strong enough to stack molecules in a solid form lattice, giving the material the stability of crystals (Bashimam & El-Zein, 2022).

One of the most crucial steps in the development of co-crystals is choosing a co-former (Wang et al., 2021). Sweeteners can improve solubility and cover up some tastes, such bitterness, making it suitable as a co-former (Arafa et al., 2015). Furthermore, the abundance, affordability, and low reactivity with active ingredients, and their ability to readily form crystalline structures, are some of the main reasons for choosing sweeteners as a co-former (Luján-Torres et al., 2023). Sucrose is commonly used in cocrystallization because it provides a cost-effective method to the handling, protecting, and preserving of powdered active ingredients. When being turned to co-crystal, it would increase surface area and vacant space that creates a porous foundation for the active component to be added, which would be able to protect the active component from environmental factors like moisture and oxidation (Chezanoglou & Goula, 2021; Bofill et al., 2020). It mainly works by creating a space. Dextrose could also be used as a co-former because it is readily available and is a GRAS compound. As a co-former in a curcumin-dextrose co-crystal, it could increase the solubility of curcumin by up to 25 mg/ml of water compared to pure curcumin (Katherine et al., 2018). Xylitol, a sugar alcohol which has about one-third fewer calories than sucrose, was also proven to increase the solubility of felodipine (Dasgupta et al., 2017; Arafa et al., 2016). Erythritol, a low-calorie sweetener which is commonly used as a sweetener in candies and bakery products, also has a high solubility in water (Regnat et al., 2017; BeMiller, 2018).

Co-crystallization is an encapsulation technique that is more commonly utilized in the pharmaceutical industry (Arafa et al., 2016; Arbiol Enguita et al., 2025; Yu et al., 2022). However, there are still limited studies on the co-crystallization of beta carotene and the usage of different types of sweeteners as a co-former. Furthermore, beta carotene is highly sensitive to environmental factors such as heat, oxygen, and light. As an example, when fresh tomatoes were stored at 60°C and 100°C, beta carotene degradation went from 305.24mg /100 g to 58.02 mg/100 g and 12.96 mg/100 g (Demiray et al., 2013). Therefore, the purpose of this study is to compare the stability of beta carotene in the form of pure and co-crystal and the impact of different co-formers towards the stability of beta carotene.

1.2 Objective

This study has an objective to investigate and compare the stability of beta carotene in pure and co-crystal form in combination with several co-formers, specifically erythritol, sucrose, dextrose, and xylitol under various temperatures and pH. The half life of beta carotene and its co-crystal form will be calculated from the obtained data.

1.3 Hypothesis

The hypothesis of this experiment are:

1. H0 : Cocrystal form of beta carotene will not significantly affect temperature stability compared to pure beta carotene.

   H1 : Cocrystal form of beta carotene will significantly affect temperature stability compared to pure beta carotene.
2. H0 : Cocrystal form of beta carotene will not significantly affect pH stability compared to pure beta carotene.

   H1 : Cocrystal form of beta carotene will significantly affect pH stability compared to pure beta carotene.
3. H0 : Cocrystal form of beta carotene will not significantly affect the half-life compared to pure beta-carotene.

H1 : Cocrystal form of beta carotene will significantly affect the half-life compared to pure beta-carotene.

4. H0 : The types of co-former (erythritol, sucrose, dextrose, or xylitol) will not significantly affect the stability of beta-carotene under various conditions.

   H1 : The types of co-former (erythritol, sucrose, dextrose, or xylitol) will significantly affect the stability of beta-carotene under various conditions.