Chapter 1

Introduction

1.1 Background

Brownies were first introduced in the United States in 1897 and gained massive popularity due to their rich flavor, firm texture, and also very appetising aroma (Mardiana et al., 2021). Classic brownies were typically made by combining several ingredients including flour, cocoa powder, eggs, butter, and most importantly, sugar. According to Dana and Sonia (2024), sugar not only enhanced the sweetness of baked goods, but it also played a crucial role in preserving their moisture content by retaining water, thereby preventing the final product from drying out. White sugar is a common kitchen ingredient, consisting of purely natural crystalline sucrose which mainly functions as a sweetening agent and due to its carbohydrate chain, sugar also can act as an energy source for the human body (Zaitoun et al., 2018). Sucrose is a disaccharides, consisting of 1 glucose and 1 fructose molecule which can be easily digested with the help of sucrase-isomaltase or shortly sucrase enzyme in the small intestine (McWhorter et al., 2021). The rapid digestion leads to a rapid absorption process which rapidly increases the consumer blood sugar, classifying it as a medium GI food product.

Glycemic index (GI) is a measurement of how quickly blood glucose levels rose after consuming carbohydrate-containing foods (Moini, 2019). According to research by Atkinson et al. (2021) , high-GI foods products are defined as those with a GI value ≥70, medium-GI foods are those with a GI from 56 to 69, and low-GI foods are those with a GI value ≤55. These classifications are important to ensure the safety after consuming the food product as consumption of high-GI food product by diabetic people may lead to serious consequences. Under normal conditions, when blood sugar levels increased following the intake of high-GI foods, the human body naturally released insulin to restore the glucose homeostasis condition. However, in individuals with diabetes, this regulatory process was impaired which leads to hyperglycemia and an elevated risk of cardiovascular diseases (Galicia-Garcia et al., 2020; Ilachos et al., 2020). Therefore, diabetic patients require alternative sweeteners with a

low GI value to safely consume sweet products. But unfortunately, the existing low-GI sweeteners had several consumption limitations due to various reasons. Several low-GI sweeteners such as d-tagatose, d-allulose, or d-sorbose were very rare due to their very limited sources in nature, making them unavailable for large numbers of people (Moss et al., 2024). Furthermore, several low-GI sweeteners such as xylitol or stevia have distinct sensorial attributes which may not be preferable by some groups of people as xylitol has a cooling effect with mint taste while stevia exhibits bitter aftertaste (Santos et al., 2014). Therefore, another alternative sweetener needs to be researched in order to develop an alternative low-GI sweetener that can be consumed widely and one of the promising alternatives is sap from Palmyra tree.

Palm sap is a natural juice that derived from the Palmyra palm tree (*Borassus flabellifer* L.), containing high sucrose content, comprising approximately 13–19% of its total weight and was harvested from the Palmyra tree's inflorescence (Naknaen & Meenune, 2016). However, fresh palm sap had a very limited shelf life due to lactic acid accumulation caused by containing lactic acid bacteria (LAB) which metabolizes sucrose into lactic acid, negatively affecting the sap's characteristics (Naknean et al., 2010). To extend shelf life, traditional methods such as boiling were commonly conducted by the local sugar farmer to eliminate the contaminating bacteria. However, thermal processing can significantly alter the sap's natural properties as it triggers the Maillard reaction which transforms it into a brown sugar syrup or commonly referred as brown sugar (Naknaen & Meenune, 2016).

According to research by Sarkar et al. (2023), spray drying appeared to be the most promising method as it can significantly reduce the water activity and moisture content of the sap while preserving its natural compounds. Spray drying is a very popular drying method where it converts liquid substances into dried powders, thereby improving storage stability and transportation efficiency while retaining nutritional value (Fang & Bhandari, 2012). However, this process required a carrier agent to encapsulate food components and protect volatile compounds from heat exposure during the drying process.

This research utilizes common carrier agents such as maltodextrin and gum arabic with addition of inulin, a carrier agent that is well-known for its superior encapsulation properties (Etzbach et al., 2020). Combining different carrier agents was essential to compensate for the limitations of each and enhance encapsulation efficiency. Research by Cid-Ortega and Guerrero-Beltrán (2020) shows that combining gum arabic and maltodextrin to spray-dry *Roselle* (*Hibiscus sabdariffa*) extract improved antioxidant compound retention. The same study also showed that higher concentrations of carrier agents can significantly increase the powder production yield percentage. However, in terms of antioxidant encapsulation, higher concentrations of carrier agents led to reduced levels of total monomeric anthocyanins, total phenolic compounds, and antioxidant activity in the final powder. Therefore, determining the appropriate concentration of carrier agents was crucial prior to the spray-drying process.

1.2 Objective

- Evaluate the impact of different carrier agents type and concentrations towards the powdered palm sap physicochemical properties.
- To investigate the effect of palm sap powder as a functional, low-GI sweetener for developing low-GI food products, particularly by examining its effect on the brownie's physical, GI value, antioxidant, and sensorial properties.

1.3 Hypothesis

This research comprised two main sections, the first section focused on investigating the most effective carrier agent concentration for producing powdered palm sap. It was hypothesized that different carrier agent type and concentration would significantly influence the physicochemical properties of the resulting powder. The second section investigated the effects of substituting conventional sweeteners with powdered palm sap in development of low-GI brownies. It was hypothesized that this substitution would significantly affect the physicochemical and sensorial properties of the low-GI brownies.