Chapter 1
Introduction

In this chapter, the background of this study will be elaborated, highlighting the issues and presenting the solution that led to the start of this study. With the proposed solution, the objectives of this study are outlined, followed by the hypothesis to visualize the expected outcome of this study.

1.1. Background

Food waste and loss are issues that are currently faced globally, where food waste streams generated from agri-food processing pose a significant environmental risk (Yoha & Moses, 2023). Approximately 20% of the total 14 MMT (Million Metric Tons) of waste generated annually comes from the production, distribution, and retail of food and beverages (Sarker et al., 2024). The growing issue pressures the food industries to find sustainable solutions to manage and minimize food waste. One approach is to properly utilize food waste as it contains valuable compounds, including proteins, lipids, starch, micronutrients, bioactive compounds, and dietary fibers. Incorporation of food waste or by-products into other food products as raw materials or additives could benefit the food industry and the environment while addressing nutritional concerns (Torres-León et al., 2018).

Like most countries, Thailand has significant potential for food waste utilization, as food waste can be generated from various by-products, including banana peels, rice bran, and hemp seed milk residue. Thailand produces 1.2 million tonnes of bananas per year, ranking the country 6th in the world for banana production. This leads to a huge amount of banana peels being wasted through its production in Thailand (Duangkham & Thuadaij, 2023). Additionally, Thailand is also ranked 6th as the largest producer of rice, and most cultivation areas in Thailand are for rice production (Jaibumrung et al., 2023). The process of rice milling can produce by-products such as rice bran, which constitutes 8%-10 % of the rice grain (Wisetkomolmat et al., 2022). Rice bran is often extracted for its oil for usage, while the rest is often discarded, contributing to food waste in Thailand. Other than that, hempseed

is an emerging cultivar that has high potential for its nutritional value and health benefits (Karus & Vogt, 2004). Its milk processing leaves a residue that is often wasted and unexplored for its potential. These three by-products have valuable potential as they contain a high amount of dietary fiber that can be utilized instead of being wasted. Additionally, bringing each by-product together provides other nutrients (protein, bioactives, minerals, vitamins, carbohydrates) that complimentary nutritional benefits, making a nutrient-dense combination (Karlson et al., 2012; Vu et al., 2019; Šeremet et al., 2020; Devi et al., 2021).

Dietary fiber has been a part of the human diet for centuries due to its known health benefits (Fuller et al., 2018). It has been demonstrated to reduce the risk of obesity, diabetes, intestinal disease, and cancer (He et al., 2022). From its functional perspective, dietary fiber can delay gastric emptying to create a sense of fullness, manage intestinal disorders, and help with constipation (Ciudad Mulero et al., 2019). Due to its numerous benefits, consumers have been demanding healthy foods, preferably containing dietary fiber (Li & Komarek, 2017). With such growing demands, the valorization of food waste with high fiber into food products can address environmental problems while meeting the consumer demands for healthier food. This valorization can be done using various technologies, one of them being through 3D food printing technology.

3D food printing (3DFP) is an innovative food manufacturing technology in the food industry that is highlighted for its personalized manufacturing. 3DFP offers exceptional adaptability and customization, expanding its potential to promote sustainability by reducing food waste, improving portion control, and encouraging eco-friendly practices (Sohel et al., 2025). Moreover, 3DFP demonstrated the ability of personalized nutrition to meet consumer needs and preferences (Sun et al., 2015). Through its adaptability, 3DFP can reduce food waste by printing food products using low-value food that will otherwise be discarded (Prakash et al., 2019). Studies have been performed on 3D printing using food waste such as grape pomace, broken wheat, and okara to be incorporated

into common snacks like cookies (Jagadiwaran et al., 2021; Lee et al., 2021). Moreover, 3D printing can develop a complex internal structure of the cookies, providing novel textures and controlled baking time compared to conventional cookies (Varghese et al., 2020). This evidence suggests that the incorporation of unfamiliar ingredients like food waste into familiar snacks such as cookies can be done through 3D printing while providing other benefits that conventional cookies do not.

Therefore, the issue of food waste in Thailand, particularly the banana peels, rice bran, and hemp seed milk residue, can be addressed through valorization into 3D-printed cookies. This approach not only improves sustainability but also increases the fiber content of the cookies, tackling both environmental and nutritional concerns.

1.2. Objective

The study aims to develop an optimal formulation of 3D-printed fiber cookies utilizing food waste in Thailand, including banana peels, rice bran, and hemp seed milk residue. Another objective is to investigate the difference between conventional cookies and 3D printed cookies by comparing their physicochemical properties (color, spread ratio, texture, moisture, and crude fiber analysis) and sensorial evaluation. In addition, acceptance of 3D food printing will be assessed through the hedonic scale and FTNS to Khon Kaen University students.

1.3. Hypothesis

Study 1: Overall, develop an optimal formulation of 3D printed fiber cookies utilizing food waste in Thailand, including banana peels, rice bran, and hemp seed milk residue.

Null hypothesis (h_0) : The variation of concentration between the banana peels, rice bran, and hemp seed milk residue does not significantly affect the most optimum physical properties

Alternative Hypothesis (h_1) : The variation of concentration between the banana peels, rice bran, and hemp seed milk residue does significantly affect the most optimum physical properties

Study 2: Investigating the difference between conventional cookies and 3D printing cookies through its physicochemical properties (color, spread ratio, texture, moisture, and crude fiber analysis) and sensorial evaluation.

Null hypothesis (h_0) : There is no significant difference in the physicochemical properties and sensorial attributes between conventional cookies and 3D printed cookies

Alternative Hypothesis (h_1) : There is a significant difference in the physicochemical properties and sensorial attributes between conventional cookies and 3D printed cookies

Study 3: Assessing the acceptance of Thailand Khon Kaen University students towards 3D printed fiber cookies through a hedonic scale and FTNS (Food Technology Neophobia Scale)

Null hypothesis (h_0) : The 3D-printed fiber cookies are not accepted by students at Khon Kaen University, based on the Hedonic scale and FTNS

Alternative Hypothesis (h_1) : The 3D-printed fiber cookies are accepted by students at Khon Kaen University, based on the Hedonic scale and FTNS.