CHAPTER 1

INTRODUCTION

This chapter discusses the introduction and the problem statement, which contributes to the idea and development of this research, objectives, and scopes of the study.

1.1 Introduction

This research aims to analyse milk based on light propagation and random lasing using experimental and theoretical methods. The light propagation in milk is studied through the observation of absorbance, transmission, reflectance and fluorescence spectra. This study is important to analyse optical properties of milk based on milk fat content and fermentation. Various types of milk used for this research, such as fresh milk, skimmed milk, soy milk, almond milk, and oat milk. Meanwhile, different milk conditions, such as newly opened milk and fermented milk from different days of storage, were compared to study milk quality. Both experimental setup and theoretical analysis are designed to obtain the optimum research output. This research also aims to model random laser to study the effect of fat content on random laser properties.

The dairy industry is one of the important industries in food and beverages sectors. People around the world consume milk and dairy products to sustain a healthy and nutritious diet as part of their daily life (Kubicová et al., 2019). The production of dairy product increases substantially from 482 million tons in 1982 to 831 million tons in 2017 (Bórawski et al., 2020). Therefore, it is crucial for the consumers to know not only the milk contents but also the milk quality to prevent food poisoning and to have a healthy diet. Hence, the spectrometry method can be used to assess milk

properties.Through spectrometry experiments, the optical properties of milk in terms of absorbance, transmission, and reflectance can be observed and analysed (Aernouts et al., 2011).

The whole research is divided into three parts. Each parts has its own objective and scope of study to emphasize the research results accordingly. The first part of the research focuses on analysing the milk fat from spectral absorbance and transmittance peak measured using various spectrometry experiments. The Monte Carlo algorithm is applied to distinguish the milk fat between skimmed and whole milk. Important scattering factors such as internal coefficient, anisotropic parameters, and forward power are being analysed.

The second part of the research analyses the light propagation in milk after being kept in the room temperature for a few days, known as fermented milk. This study compares the fermented milk with the fresh milk by measuring the absorbance, transmission and reflectance spectra observed using VIS-NIR and NIR spectrometer. The output of Mie theory modeling based on Monte Carlo is correlated with the experimental method where particle size, absorption, and scattering efficiency are computed using Mie theory.

Finally, the third part involves study of light propagation theory in various types of milk, such as almond milk, fresh milk, and oat milk. The absorbance and fluorescence spectra are observed using VIS-NIR and NIR spectrometers. Besides that, random laser modeling based on light scattering in milk is also done using light propagation theory.

1.2 Problem Statements

Milk is a delicate fluid that can be easily spoiled during producing, processing, packaging and storage process as it is rich with nutrients (Lu et al., 2013). The consumers can suffer from food poisoning, diarrhoea, abdominal pain and other stomach diseases due to bacteria production in milk (Velázquez-Ordonez et al., 2019).

The healthy diet also can be affected with extra consumption fat, protein, and carbohydrates through milk (Lamarche et al., 2016). Furthermore, the adulteration of milk becomes a common scenario in dairy industry nowadays. In order to attract more consumers, the milk will be adulterated by adding water, sugar, flavors and neutralizers (Ojha et al., 2018) to fit consumer's preferences.

Study on milk quality is important to investigate the durability of the milk to be consumed to prevent any health issue whereas study on various types of milk is useful to understand the optical properties of various types of milk. Many studies have been done to investigate the milk quality and milk content such as developing the plastic optical fibre as a sensor for milk fat detection (Angrasari et al., 2019), developing a portable detector to detect the main compositions of milk (Yang et al., 2020), using an external cavity-quantum cascade laser spectrometry for milk protein analysis (Montemurro et al., 2019) and developing a method through liquid chromatography–high resolution mass spectrometry to determine the free fatty acids in milk (Kokotou et al., 2020). Gerber method was also used to determine fat content in dairy products but it involved the certain risk of handling concentrated sulfuric acid (Xiong et al., 2016). Light propagation had been used to study the quality of foods and beverages for years (Askoura et al., 2016). Many light propagation techniques such as fiber optics sensors (Gowri et al., 2019), ultrasound technique (Mohammadi et al., 2014) and spectrometry experiments (Choudhary et al., 2019a) had been

developed to study and monitor the quality of milk. However, the studies conducted are complex, intrusive and time consuming.

Thus, this research aims to develop techniques to investigate fat content in milk and differentiate milk quality from fermentation process based on light propagation theory. The study comprises of experimental and theoretical analysis for various types of milk which are valuable to be referred for future research. Experimental analysis comprises of spectrometry methods whereas the theoretical analysis comprises of Monte Carlo algorithm, scattering probability and light propagation theory. Through spectrometry experiments, we monitor the milk quality by observing the absorbance, transmission, and fluorescence of milk. Meanwhile, the theoretical studies are used to model a random laser based on various types of milk to study on milk contents using properties of random lasers such as emission intensity, linewidth, and lasing threshold. The techniques are simple and non-intrusive which may reduce the time consuming, cost and milk contamination.

1.3 Research Objectives

The main goal of this study is to analyse milk based on light propagation and random lasing using experimental and theoretical methods. The following objectives are applied to accomplish the research goal, which are:

I. To investigate and compare light propagation in milk using various spectrometers.
II. To analyse milk quality after fermentation using spectrometry technique.
III. To model random laser based on light propagation in various types of milk.

1.4 Research Scopes

This research analyses the light propagation in milk to study milk quality and milk contents. The studies comprise of experimental and theoretical analysis which are divided into three parts as discussed below:

Part 1

A. Simulating the light propagation in milk and distinguishing the optical properties, such as backscattered count and the loss count through Monte Carlo simulation in MATLAB.
B. Conducting the experiment of light propagation in milk using three types of spectrometers, which are:
    i. Ocean Optic Flame Near-Infrared (NIR) Spectrometer.
    ii. Varian 3100 Excalibur Series Fourier Transform Infra-Red (FTIR) Spectrometer.
    iii. Perkin Elmer Lambda, 750 UV/VIS/NIR Spectrometer and Varian 3100 Excalibur Series Fourier Transform Infra-Red (FTIR) Spectrometer.

Part 2

A. Simulation based on Mie intensities and the scattering angular efficiency using MATLAB software.
B. Experimenting with the light propagation of milk and fermented milk covers three intensity spectra of absorbance, transmission, and reflection. The spectrometers used in the experiments are:
    i. Ocean Optic Near-Infrared (NIR) spectrometer.
    ii. Ocean Optic Visible-Infrared (VIS-NIR) spectrometer.

Part 3

A. Conducting experiment comprises of light propagation of different types of milk based on absorbance, and fluorescence. The statistical analysis is done using principal component analysis (PCA) to summarize the information content in the large data. The spectrometers used in the experiments are:
    i. Ocean Optic Near-Infrared (NIR) spectrometer.
    ii. Ocean Optic Visible-Infrared (VIS-NIR) spectrometer.

B. Modeling a random laser for different types of milk based on light propagation theory using MATLAB software.