REPORT

A SPECTROSCOPY STUDY OF REPEATEDLY HEATED PALM COOKING OIL USING AN OPEN PATH OPTICAL METHOD TO MEASURE THE CONCENTRATION OF FREE FATTY ACID

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Alhamdulillah.

This journey would not have been possible without
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ABSTRAK

Minyak kelapa sawit merupakan sejenis minyak sayuran yang boleh dimakan yang diperoleh dari buah dan benih kelapa sawit. Minyak sawit biasanya berwarna kemerahan kerana mengandungi isi beta karotena atau sebatian organik yang tinggi. Minyak kelapa sawit juga mempunyai asid lemak bebas di dalam minyak dan akan menghasilkan kesan yang buruk jika penggunaan minyak masak secara berulang kali. Ia disebabkan pemanasan minyak secara berulang kali, maka peningkatan pada asid lemak bebas akan meningkat dan berlakunya perubahan pada molekul di dalam minyak masak. Pemanasan ini juga memberi kesan dari segi fizikal seperti perubahan warna menjadi gelap, menjadi lebih pekat dan menghasilkan bau yang kurang menyenangkan. Kajian ini mempunyai tiga objektif utama iaitu menganalisis spektrum penyerapan minyak masak sawit yang telah dimasak berulang kali, untuk mengetahui jumlah Asid Lemak Bebas (FFA) dalam minyak masak sawit apabila dipanaskan untuk tempoh masa yang berbeza dan untuk menganalisis faktor lain yang boleh mempengaruhi spektrum penyerapan minyak masak. Objektif ini dianalisis dengan menggunakan kaedah optik dengan hanya mengunakan pantulan cahaya. Kaedah ini merupakan salah satu kaedah yang digunakan untuk mendapat ketepatan dalam pengukuran asid lemak dengan menggunakan peranti spektrometer. Hasil daripada kajian ini adalah untuk memperkenalan kaedah optik bagi menguji kualiti minyak masak yang digunakan secara berulang kali dan ia juga parameter yang boleh mengesan kualiti minyak masak bagi keselamatan pengguna menggunakan minyak masak dalam masakan. Konklusinya, kaedah ini dapat membantu masyarat untuk ketahui kualiti akan minyak masak yang digunakan untuk mengelak akan penyakit yang berbahaya seperti cancer, obesiti, sakit jantung dan kolestrol. ini adalah satu alternatif yang mudah dan harus diperkenalan untuk masyarakat ketahui akan bahayanya minyak yang digunakan secara berulang kali.

ABSTRACT

Palm oil is a vegetable oil that is extracted from the fruits and seeds of the oil palm tree. Since it includes a significant amount of beta carotene or organic compounds, palm oil is usually reddish in colour. Palm oil contains free fatty acids, which can have negative consequences if used repeatedly. Since the heated temperature differs from that of the original cooking oil, the amount of free fatty acids in the cooking oil increases, causing a shift in the molecules. The colour darkens, the concentration increases, and an unpleasant stench is produced as a result of the heating. The goal of this study to analyse the absorbance spectrum of palm cooking oil that has been cooked repeatedly, to figure out the amount of Free Fatty Acid (FFA) in used palm cooking oil when heated for different periods of time and to analyse other factors that can affect the absorption spectrum of the palm cooking oil. Optical methods that merely used light reflection to analyse this objective. Using a spectrometer apparatus, this method is one of the methods for obtaining accuracy in fatty acid measurement. The results of this analysis led to the development of an optical method for testing the quality of cooking oil that is used frequently, as well as a parameter that can detect the quality of cooking oil for the safety of consumers use cooking oil. Eventually, this method can assist the community in determining the quality of cooking oil used in order to prevent diseases such as cancer, obesity, heart disease, and cholesterol. This is a simple alternative that should be used to educate the people about the dangers of oil that is used repeatedly.

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LIST OF SYMBOLS

λ	Wavelength
A	Absorptivity
C	Concentration
ε	Molar absorptivity
l	Path length
I_o	Including light intensity
I_T	Transmitting light intensity
N	Concentration in molecules / cm^3 unit

LIST OF ABBREVIATIONS

FFA	Free Fatty Acid
PC	Personal Computer
TAG	Triacylglycerol
UV	Ultraviolet
IR	Infrared
VIS	Visible
USB	Universal Serial Bus

LIST OF EQUATIONS

$A=\varepsilon c l$

$A=\log_{10} (I_o/I_T)$

$\sigma = (\log_{10} (I_o/I_T) * 2.303) / (N*b)$

CHAPTER 1

INTRODUCTION

1.1 Background Project

Palm oil is a vegetable oil that comes from the *mesocarp* of the oil palm fruit. It is often used as cooking oil since it is affordable and has good oxidative stability when used for frying. When oil is used in food frying on a regular basis, it degrades chemically. This results in the creation of a molecule known as Free Fatty Acids (FFA), which is harmful to the human body. Oil degrades chemically when used in food frying on a frequent basis. As a result, a molecule known as Free Fatty Acids (FFA) is formed, which is damaging to the human body. Several studies have been conducted to determine the level of Free Fatty Acid (FFA). However, use a different type of frying oil. A few studies on palm cooking oil have been published, although they use diverse methods such as gas chromatography, reflection methods, and other types of detectors. To investigate the level of Free Fatty Acid (FFA) in palm cooking oil, a spectroscopic investigation employing an open route method is proposed in this project.

The incident beam travels through the sample (palm frying oil) before being detected by the spectrometer in the open path method. The optical spectrum of a few sets of new and heated palm cooking oil will be examined and analysed. Cooking oil that has been heated repeatedly is likely to have a distinct spectrum depending on how long it has been heated. As a result, it can be used to determine the amount of Free Fatty Acid (FFA). The findings of these foundational investigations could be used to construct an optical sensor device to test the safety of palm frying oil in the future. As a result, it can benefit our society by improving Malaysian food security measures.

1.2 Problem Statement

People are now aware that using cooking oil on a regular basis is dangerous. However, the majority of them are unaware of how far cooking oil can be reused. This is because, while previously used cooking oil may still appear to be in good condition, the concentration has changed, making it unsafe to consume. The absorption spectrum of heated palm cooking oil will look different if the chemical content has changed. This is due the amount of Free Fatty Acid (FFA) in palm cooking oil increases when heated to high temperatures(Deshmukh, 2019). Other factors can also have an impact on the spectrum of palm cooking oil such as foam in the oil. When deep-frying food at high temperatures, the oil undergoes a hydrolysis process that converts the frying oil to glycerol.

The oxidation process is another issue with heated cooking oil. The frying oil will undergo oxidation, resulting in unstable lipid species that can form secondary products, altering the absorption spectrum(Goswami, Bora, & Rathore, 2016). Despite the fact that many studies have been conducted to determine the concentration of Free Fatty Acid (FFA) in used cooking oil, the studies reported on different types of oil such as castor, canola, vegetable, sun flower, corn, coconut, and so on(Yalcin, Toker, & Dogan, 2012). There have also been information on the concentration and effects of Free Fatty Acid (FFA) in palm cooking oil. They are, however, using a different method of measurement, such as the reflection method, which has its own drawbacks, such as very high stray light. Some are employing alternative measurement techniques, such as gas chromatography, which has a relatively slow response time.

There is also a report that employs a different detector, such as a photodiode. Despite the fact that photodiodes are relatively inexpensive, they can only cover a very narrow range of wavelengths. Previous research studies have found numerous drawbacks and a lack of information regarding heated palm cooking oil. As a result, it must be addressed. The absorption spectrum of heated palm cooking oil must be examined, as well as the amount of Free Fatty Acid (FFA) in the heated palm cooking oil. Other factors that may influence the spectrum of palm cooking oil must also be investigated.

1.3 Objectives

The purpose of this study is to use the open path optical method to detect the concentration of fatty acids in repeatedly heated cooking oil. The project's goals are listed below:

1. To analyse the absorbance spectrum of palm cooking oil that has been cooked repeatedly.
2. To figure out the amount of Free Fatty Acid (FFA) in used palm cooking oil when heated for different periods of time.
3. To analyse other factors that can affect the absorption spectrum of the palm cooking oil.

1.4 Scope Project

The scope of this project is as follows:

1. Analyze the spectrum of palm cooking oil, especially the concentration of Free Fatty Acid (FFA) in the UV/VIS spectrum.

2. The heating time of palm cooking oil is limited to 10 hours, with the intervals of one hour.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

The purpose of this chapter is to highlight the literature review of previous case studies that have been done related to this project. Literature review is written in order to achieve deeper understanding of the project. Besides that, by having a deep understanding on the topic at hand, it could also act as an initial starting point of this project to make a better invention for humankind.

2.2 The Effect of Repeatedly Cooking Oils

This palm oil is a necessary ingredient in cooking, whether frying, baking, sautéing, or marinating(Ganesan, Sukalingam, & Xu, 2019). However, many consumers use this oil repeatedly in order to save money, particularly in businesses such as roadside stalls, hotels, and restaurants in order to save money and reap excessive profits without being aware of the harm to the customers. Palm oil is extracted from the ripe palm fruit's mesocarp (Elaeis guineensis). Palm oil has a unique fatty acid (FA) and triacilglycerol (TAG) profile, making it suitable for a variety of food applications(Mba, Dumont, & Ngadi, 2015). When consumers use this palm oil repeatedly, it will undergo physical changes such as colour darkening, viscosity, and odour, which is also known as oxidation(Ganesan et al., 2019).

Oil oxidation happens when a sequence of undesired chemical reactions involving oxygen occur, degrading the quality of the oil and potentially changing the fatty acid composition of the oil. Free Fatty Acid (FFA) levels increase when palm oil is used repeatedly. The high Free Fatty Acid (FFA) content of palm oil can have a negative impact on human health, causing cancer, coronary heart disease, and lowering of bad cholesterol cause the condition(Perumalla Venkata & Subramanyam, 2016). It will also have an effect on the quality of palm oil if the oil is heated repeatedly. Moreover, advanced technology can assist in resolving the problems that plague the community regarding the dangers of cooking oil that is heated repeatedly, and this dangerous disease will strike regardless of age(Di Pietro, Mannu, & Mele, 2020).

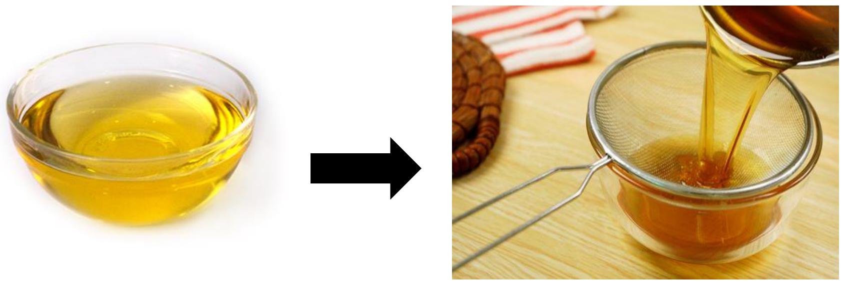

Figure 1: Cooking oil's physical changes

2.3 Spectroscopy

Spectroscopy is a technique and measurement of the electromagnetic radiation spectrum produced by materials that interact with or emit it. It is an investigation into the interaction of radiation and matter as a function of wavelength (λ)(Foundation, 2009). Traditionally, spectroscopy was defined as the use of visible light dispersed according to wavelengths, such as by a prism. Later, the concept was widened to include any sample that can be measured as a function of wavelength or frequency.

Besides that, spectrometry is a spectroscopic technique for determining the concentration or amount of a specific species. In such cases, the instrument used to make such measurements is a spectrometer or spectrograph. Spectroscopy or spectrometry is often used in physical and analytical chemistry for the identification of substances through the spectrum emitted from or absorbed. In physical and analytical chemistry, spectroscopy or spectrometry is frequently used to identify substances by the spectrum emitted or absorbed (Foundation, 2009).

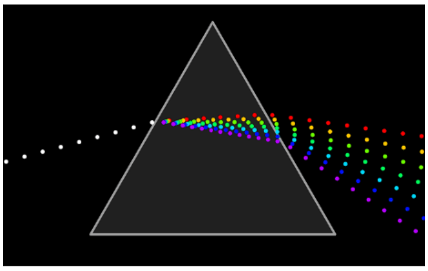

Figure 2: Animation of the dispersion of light as it travels through a triangular prism

2.4 Absorbance Spectroscopy

Absorbance spectroscopy is a method of molecular spectroscopy in which absorbance characteristics based on a material's wavelength are used to identify and calculate a specific substance. As the optical beam's attenuation increases, so does the solution's absorbance. The figure 3 below depicts a sample illuminated with electromagnetic rays of various wavelengths in the visible (VIS, i.e. various colours) and adjacent ranges of the spectrum, namely ultraviolet (UV) and a portion of the lower infrared region (near IR)(Caro & Claudia, 2017).

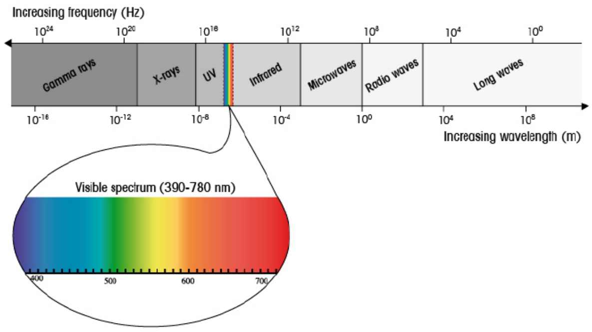

Figure 3: The visible spectrum (390 – 780 nm) represents only a small portion of the whole electromagnetic spectrum

Light is absorbed in different ways depending on the material. The UV spectrum of the sample is obtained by recording the residual light, i.e. the transmitted light, as a function of wavelength using an appropriate detector. As a result of each material's unique and specific relationship with its UV spectrum, each absorbs light in a different way. After that, the spectrum can be used to identify or quantify a substance.

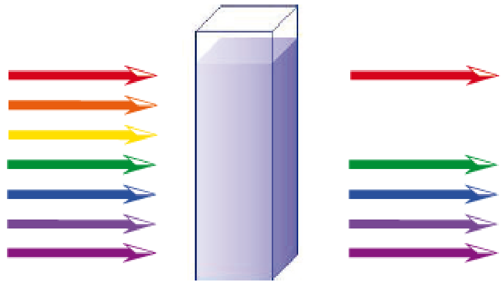

Figure 4: Light passing through a sample solution is partially absorbed by the components

Beer-Law Lambert's is used to measure or calculate specific molecular concentrations from absorption for UV spectroscopy. Beer Lambert's law relates light attenuation to the material through which the light travels(Grazia, Ciaccheri, Azelio, & Cimato, 2012). Beer-Law Lambert's is shown in figure 5:

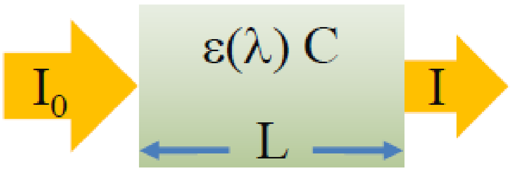

Figure 5: Beer-Law Lambert’s

2.5 Wavelength

The only balanced deuterium halogen source is the DH-2000-BAL. The DH-2000 uses a mix of deuterium and halogen lamps to measure and analyse a wide range of samples. All deuterium sources exhibit alpha lines, sharp spectrum characteristics concentrated on 655 nm, and balanced output in the 210-2500nm range. Free Fatty Acid in Palm Oil that has been cooked repeatedly can also be tested using light sources. In the range of 300-400nm, a peak of 364nm was observed to detect the absorption of Free Fatty Acid and tests should be conducted to determine the results obtained with various heating time samples(Azeman et al., 2015).

2.6 Conclusion

Palm oil is commonly used in many types of cooking, especially frying. As a result, the oil contains Free Fatty Acid due to the repeated heating. When palm oil is heated for an extended length of time, free fatty acid levels rise, posing a risks to human health. To summarise, Spectroscopy method is used to detect concentration in Free Fatty Acid in palm oil.

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CHAPTER 3

METHODOLOGY

3.1 Introduction

This chapter describes all of the methods that have been and will be used to achieve desired results. This project is divided into two parts: hardware and software. The hardware part entails the development of an open path optical method for measuring free fatty acid concentrations. Light sources, optical fibers, cuvette holders, spectrometers, USB cables, and a laptop or computer are among the hardware components. SpectraSuite Software developed the software product.

3.2 Flowchart

Flow charts are essential for describing the sequence of processes required to complete a task. It represents a process with symbols. Each process step is represented by a separate symbol and includes a brief description of the process. The beginning will be at the top of the flowchart. Then, there will be a process of preparing equipment and palm oil samples that are heated to various temperatures. Testing on the oil will take place at this stage, as well as data collection. The purpose of the data collection was to look at how free fatty acid absorption in heated palm oil works. In addition, other influencing factors are identified in order to evaluate the effect that heating has on the cooking oil sample, and the result is released once it has been collected successfully. A flowchart for measuring fatty acid absorption in oil is shown below.

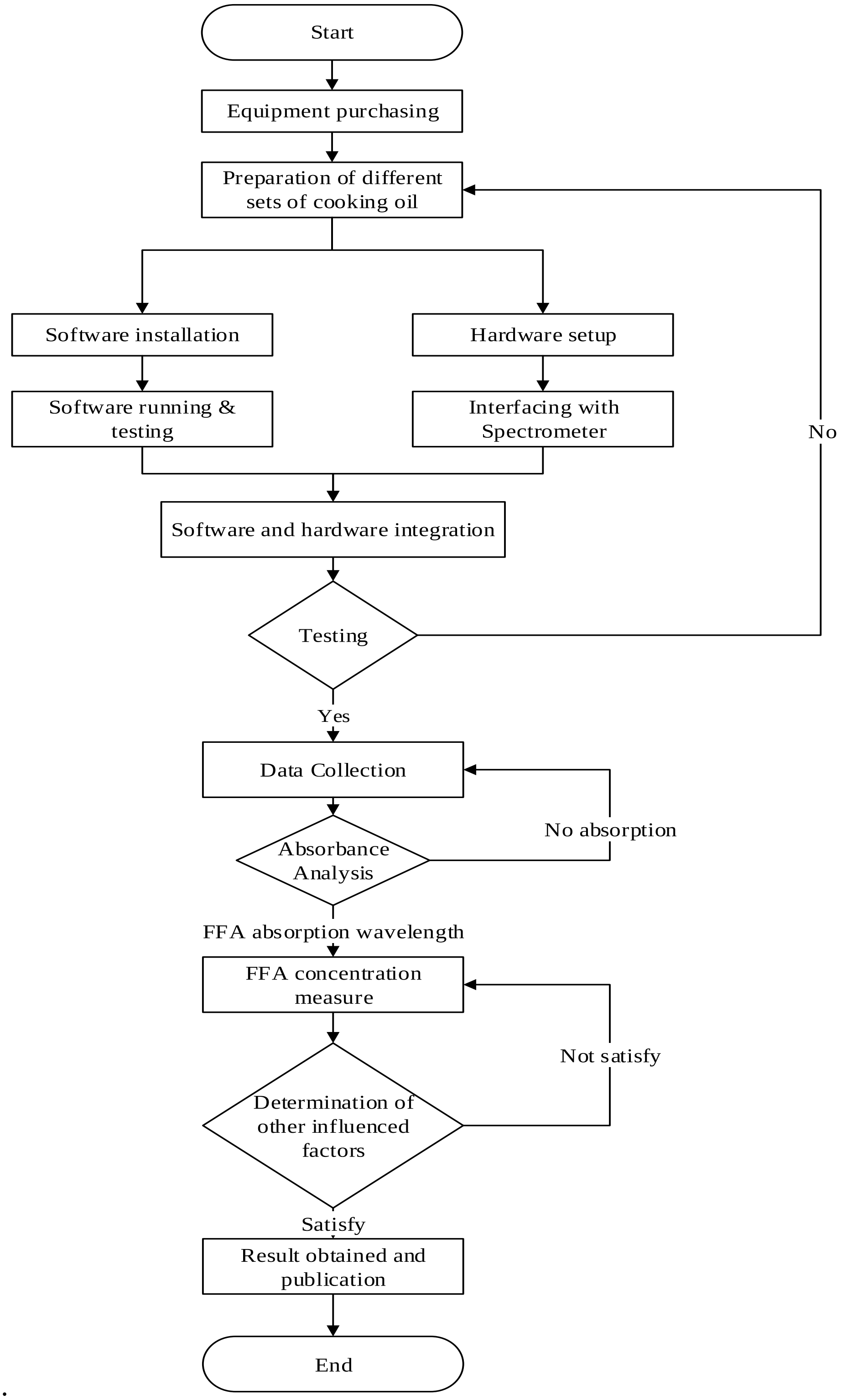

Figure 6: Flow chart of the open path optical method to measure the concentration of free fatty acid

3.3 Equipment

Equipment is needed to prove the efficiency of the open path optical method for measuring the concentration of free fatty acids as well as the applications that have been developed in order to evaluate the systems functioning. The following is a list of the components and functions that will be used in this project:

3.3.1 DH-2000-BAL Deuterium Tungsten Halogen Light Sources

The DH-2000-BAL uses innovative filtering technology to produces a smooth spectrum across entire UV-NIR range. This technology also eliminates the alpha deuterium line in the visible region. Using a combination of deuterium and halogen lamps, the DH-2000 is ideal for measuring a sample that has multiple features in different spectral regions or for analyzing a variety of different samples(Ave, 2000).

Figure 7: DH-2000 Deuterium-Halogen Light Source

3.3.2 Extreme Solarization Resistant Fibers cables

UV radiation <300 nm degrades signal transmission in standard silica fibers, resulting in solarization (increased light absorption in the UV that can invalidate measurements). Solarization-resistant fiber assemblies use polyimide or aluminum buffers that mitigate the effects of UV degradation.

Figure 8: Extreme Solarization Resistant Fibers

3.3.3 SPC-CVH-10-xx Cuvette Holder Spectroscopy

The SPC-CVH-10-xx Cuvette Holders accept a standard 10-mm path length cuvette for liquid or powder samples. SMA-terminated optical fibers are used to couple light sources and spectrometers to the device. The Cuvette Holder is compatible with Mightex's fiber coupled LED sources, Mightex's spectrometers, as well as any other light sources or spectrometers with SMA termination.

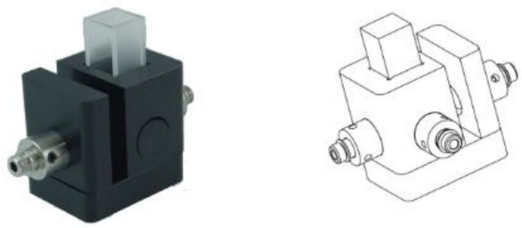

Figure 9: SPC-CVH-10-xx cuvette holder spectroscopy

3.3.4 USB A to B cable

USB connections, also known as Universal Serial Bus cables, are common in the modern as technology advances. Almost all electronic gadgets require specific components (USB cables) to connect to other electronic devices or, in the case of wireless devices, to charging-itself. The USB A to B Cable was chosen to connect the spectrometer to a laptop or computer installing SpectraSuite software in this project. It also aids with data transmission from the spectrometer to a laptop or computer for display via the SpectraSuite software.

Figure 10: USB cable A to B

3.3.5 Laptop or computer

SpectraSuite can perform three spectroscopic tests based on absorption, reflection, and emission, as well as absolute radiation, colour, and chemical concentration, using absorption, reflection, and emission (Optics, n.d.). To observe the spectrum output, SpectraSuite must be installed on a laptop or PC.

Figure 11: Laptop device

3.3.6 Spectrometer

The Maya2000Pro Series Spectrometers feature the Hamamatsu FFT-CCD back-thinned detector, which offers excellent performance characteristics. Because of their great native UV-response, FFT-CCD detectors do not require UV-sensitive coatings, eliminating batch-to-batch variations. Other performance advantages of this detector include great signal-to-noise characteristics, low dark current and good signal processing speed.

Figure 12: The Maya2000Pro Series

3.4 Software

SpectraSuite is a completely modular, Java-based spectroscopy software platform that operates on Windows, Macintosh and Linux operating systems. The software can control any Ocean Optics USB spectrometer and device, as well as any other manufacturer's USB instrumentation using the appropriate drivers. The SpectraSuite interface looks and feels the same on all operating systems yet retains the familiar.

Figure 13: SpectraSuite Sofware

3.5 Experiment Setup

i. Investigation on cooking oil optical properties

Figure 14 shows an experimental setup for testing the optical properties of cooking oil. The experimental setup consists of deuterium light source, cuvette holder, spectrometer and PC installed with SpectraSuite software. Light source is arranged so that the light beam is perpendicular to the cuvette holder. Cuvette will be filled with the cooking oil. The deuterium light beam will transmit through the cooking oil, and the transmitted light will be directly channelled to the spectrometer via an optical fibre cable(Jadon et al., 2017). This is known as an open path optical method because the light travels outside the optical cable during the interaction process with the cooking oil. The information will be analysed using SpectraSuite software, and the transmission results for various types of cooking oil will be analysed(Norazmi, 2018).

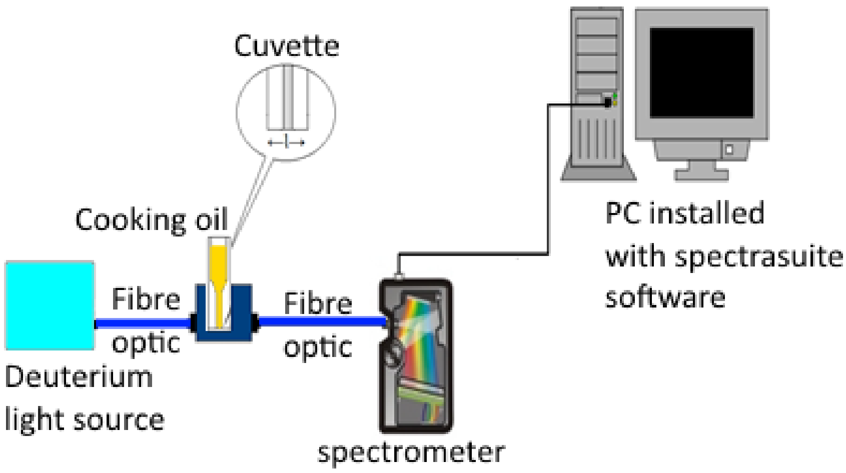

Figure 14: Experiment setup

ii. Determination of Free Fatty Acid (FFA) concentration and other influenced factors

Once the absorption spectrum for Free Fatty Acid (FFA) is determined. The level of the FFA concentration can be determined by referring the level of absorption. The higher the absorption value at a specific wavelength, the higher the level of Free Fatty Acid (FFA) concentration. However, there are other factors that can influence the absorption value, resulting in errors in Free Fatty Acid (FFA) concentration determination. The accuracy of the Free Fatty Acid (FFA) concentration measurement will be limited by factors such as cross sensitivity with other cooking oil elements, temperature, viscosity, and so on. In order to develop an accurate Free Fatty Acid (FFA) sensing device in the future, fundamental studies on these influencing factors must be conducted.

3.6 Beer's Lambert Law formula and calculations

. In this experiment, a UV-Vis spectrometer was used to analyse concentration and UV wavelength absorption to detect free fatty acids (FFA). Beer's Lambert derivative formula establishes the absorption cross section for each Fatty Acid (FFA) concentration. It is used to define a sample area's ability to absorb UV photons with long wavelengths. For this, Fatty Acid (FFA) can only absorb at a specific UV wavelength. Due to the chemical characteristics of fatty acid (FFA), which may absorb UV light radiation, different concentrations essentially have a continuous absorption cross section.

The relationship of absorbance, A and absorption cross-section, σ can be interpreted by the following formula of Beer's Lambert law or equations.

$A = \varepsilon c l$

$A = \log_{10} (I_o/I_T)$ (1.0)

$\sigma = (\log_{10} (I_o/I_T) * 2.303) / (N*b)$ (1.1)

A=absorbance

ε=molar absorptivity, a constant as a specific value belongs to chemical characteristics of the experimental sample

c=concentration

ɭ or b= path length

I_o=Incident light intensity

I_T=Transmitting light intensity

N=concentration in molecules/cm3 unit.

The equation calculations show that even at different concentrations, the absorbance cross-section of Free Fatty Acid (FFA) can be the same or very close to the same value. This is due to the molecular structure of Free Fatty Acid (FFA), which is unique in terms of UV absorbance effects(Jadon et al., 2017). This experiment required a sample of palm cooking oil heated repeatedly at different times to measure the absorption of free fatty acids (FFA) in the cooking oil.

3.7 Chemical test

The purpose of the oil quality test strip is to determine the quality of cooking oil that is used on a regular basis. It is one of the tests for determining Free Fatty Acid in cooking oil with Test Strip, which can assist users in determining Free Fatty Acid in Cooking Oil. This chemical test is easy to use, quick to do, and accurate to measure. It also comes with a set of scales with number and colour scales. As illustrated in figure 15, the colour scale is ideal, cautious, and poor, while the number scale is 0, 0.3, 0.5, 1.5, 2.5, 3.0, and 5.0.

Figure 15: Oil quality test trips

3.7.1 Instructions

i. Immerse test strip into cold oil (50-86^{o}F/10-30^{o}) for 2 seconds and then remove the trips.
ii. Hold the strip horizontally for 120 seconds.
iii. Compare against the colour chart and read immediately within 30 seconds to get accurate readings.

3.8 Conclusion

This chapter focuses on the approach for conducting the experiment as well as the equipment that will be used. The technique involved creating numerous samples of palm oil with varied temperatures to determine the concentration of free fatty acid. The functionality of the equipment and software used are also discussed. In fact, according to the flowchart presented, the technique of doing the experiment is also detailed.

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CHAPTER 4

RESULTS AND DISCUSSION

4.1 Introduction

This chapter focuses on the experimental results obtained by measuring the Free Fatty Acid content in palm oil cooking oil using an open path optical method to assess the increase in Free Fatty Acid in heated palm oil using a spectrometer provided in the lab. Palm oil samples must be heated for several hours to see the state of Free Fatty Acid. In addition, at wavelengths between 300 and 400 nm, the absorption of Free Fatty Acids will rise.

4.2 Palm oil samples heated at various temperatures.

The purpose of this experiment was to measure the concentration of Free Fatty Acids in heated palm cooking oil. The time taken to heat the oil ranged from 1 to 10 hours, with just a 1 hour difference between samples. As a result, ten samples were made for the experiment, and various physical characteristics of the cooking oil changed, such as the colour darkened, the smell grew unpleasant, and the oil became more concentrated. However, in order to see the absorption of Free Fatty Acid in cooking oil, a spectrometer and SpectraSuite software must be used.

Figure 16: 10 palm oil samples were heated repeatedly.

4.2.1 Cooking oil absorption

The Absorption Graph for ten samples of cooking oil heated at various times is shown in Figure 17. For the 10 samples measured in this experiment, the absorbance graph showed an increase at a wavelength of 300-400nm. The 10 samples ranged from 1 hour to 10 hours, to produce a constant time and each sample only differs by 1 hour. In addition, as seen in figure 17, the wavelength increases as the frying oil heats up longer, but this does not affect this experiment because the wavelength used is just 300-400nm.

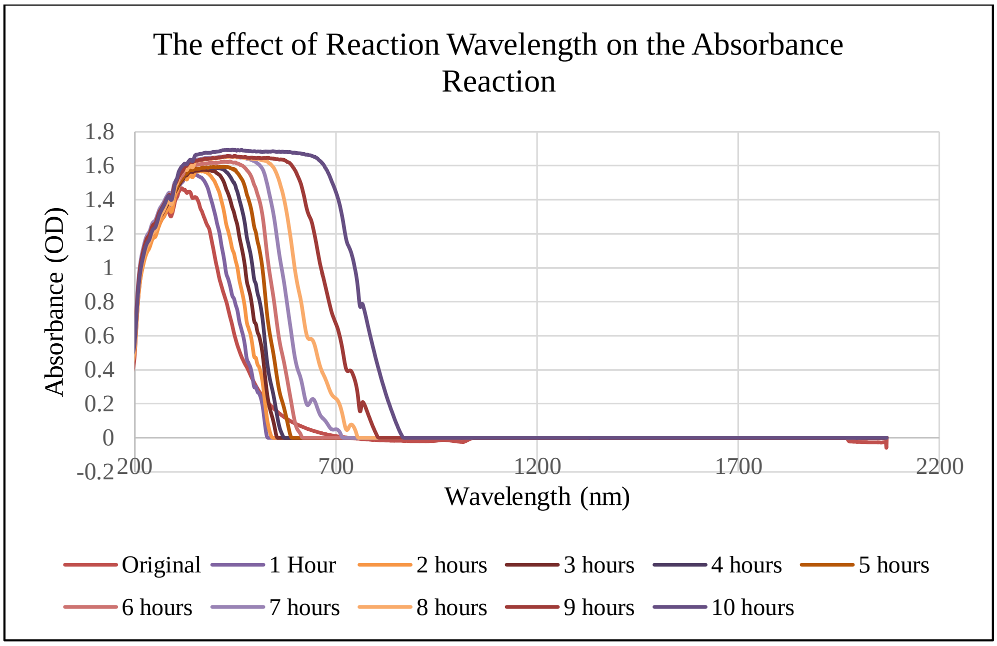

Figure 17: The graph of absorbance for 10 samples

4.2.2 Absorption of cooking oil at 364 nm

These are the absorption data traced at a wavelength of 364nm for 10 samples of palm oil heated repeatedly from 1 hour to 10 hours of heating. This absorption is only taken at a wavelength of 364nm only because that is the wavelength to detect Free Fatty acid. Data from 1 hour to 10 hours of heating cooking oil repeatedly increased as the heating time was longer. Therefore, the Free Fatty Acid concentration also increased when the absorption at 364nm increased as indicated in the absorbance graph.

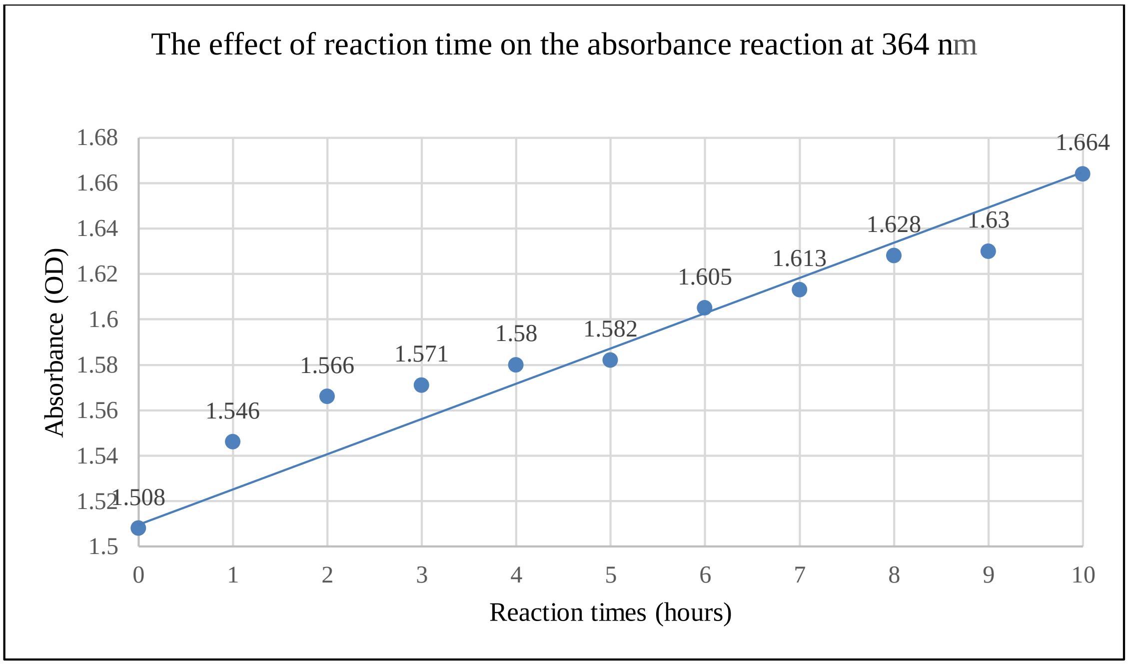

Figure 18: Absorption of cooking oil at 364nm

Times (Hours)	Absorbance
0	1.508
1	1.546
2	1.566
3	1.571
4	1.580
5	1.582
6	1.605
7	1.613
8	1.628
9	1.630
10	1.664

Table 1: Data on 364nm absorption

4.2.3 Chemical test

The purpose of the chemical test is to examine if the results of the chemical test match or differ from the results of the spectrometer test. Oil quality test strips were used to measure Free Fatty Acid in the heated oil in this experiment. Test trips are one of the tests to recognise Free Fatty Acid; it is simple to use and respond to, and the results can be obtained in a matter of seconds. In reality, as illustrated in figure 19, these test strips use colour and number scales to indicate the scale of each sample examined.

Figure 19: Oil quality test strips

Figure 20 shows 10 samples of cooking oil detected using Oil Quality Test Strips to determine Free Fatty Acid in cooking oil. Based on figure 21 showing an ascending chemical test graph, it proves that Free Fatty Acid increases when cooking oil is heated for several hours. When the color of the test strips from dark green to bright green, this indicates that Free Fatty Acid is high on bright green. This proves that the chemical test produced a positive result in this experiment. Next, chemical test showed an increase from 2 hours of heating to 10 hours of heating and this graph uses a number scale to be plotted on the graph as shown in figure 21.

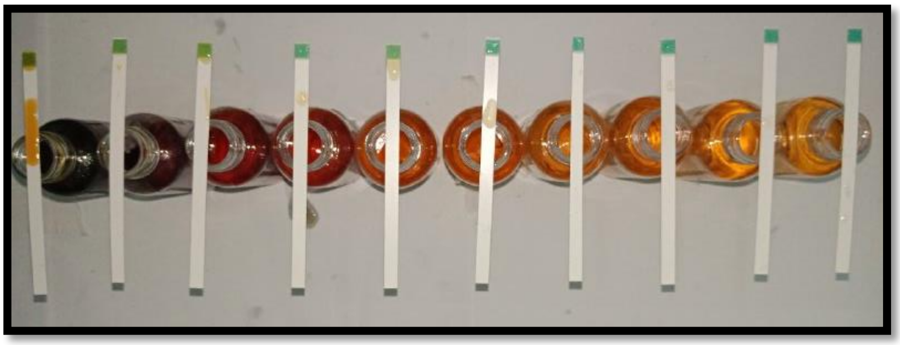

Figure 20: Test for Free Fatty Acid

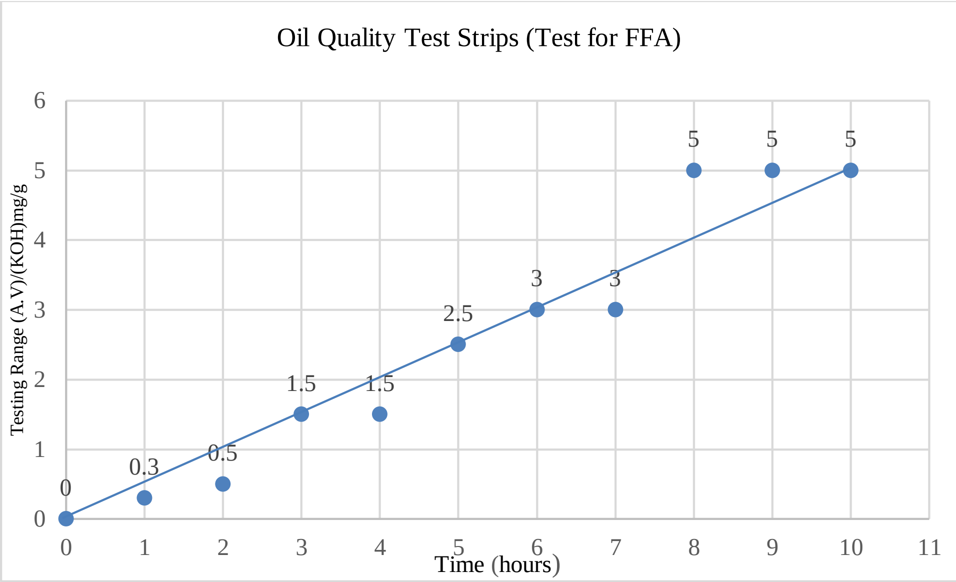

Figure 21: Graph of free fatty acids test

CHAPTER 5

CONCLUSION

The open path optical method has shown that cooking oil contain free fatty acids (FFA), which increase when heated repeatedly. The light absorbance of heated palm oil increased from 1 to 10 hours after heating. Free Fatty Acid is discovered using a spectrometer even while cooking oil is not heated, but the absorbance graph is not high and has less adverse effects on humans. The absorbance graph increases with a time difference of only 1 hour when the oil is heated for a longer period of time. As a consequence, the Free Fatty Acid concentration rises. It also undergoes physical changes, such as darkening of colour, increased viscosity, and the production of an unpleasant stench. Physical investigation reveals that the quality of the heated cooking oil has deteriorated to the point that it is no longer fit for usage. As a result, it has important implications for health, including cholesterol, heart disease, cancer, and obesity. These new optical qualities will have a significant impact on society when it comes to testing the effectiveness of cooking oil. It's also crucial to make sure that the light source produced by these optics is safe to use when cooking with it.

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