Implementation Of Iot-Based Optical Sensors For Real-Time Monitoring In Palm Oil Processing

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ABSTRACT

Optical sensors are widely used in various industrial sectors, including petrochemical and medical industries, with applications ranging from oxygen level measurement, concentration of substances in a liquid, object detection, and more. Optical sensors can be used to detect the water content in oil, such as palm oil or other oils. In an industrial process, especially in the palm oil industry, the water content in oil must meet a maximum standard of 4.5%. Optical sensors can measure water content using various methods, such as Total Internal Reflection (TIR) or Mid-Infrared (MIR), and can be monitored in real-time using IoT-based applications. The utilization of sensitive optical technology takes advantage of changes in the refractive index caused by variations in water content in palm oil. The method employed involves the development of an optical sensor based on the Mid-Infrared principle, which measures the amount of light absorbed by water and the light reaching the sensor for comparison. The results of water content measurements in palm oil that have been conducted can only be implemented for water content measurements of 0-5% in palm oil, with a sensor response that is less than linear above 5% water content. By correcting the non-linearity error of the sensor, the data is reduced to produce measurement results that are closer to the actual water content in palm oil, which will be displayed on local monitoring and real-time or continuous monitoring through IoT using smartphones and PCs wirelessly via IoT-based applications.

I. Introduction

Palm Oil is an initial product from raw palm fruit that has a CPO standard according to market demand. The quality standard of CPO is determined by several parameters, including the water content in CPO, which affects the quality and potential damage to the product. Measuring water content in CPO is a crucial step in the palm oil industry. Excessive water content in CPO can trigger various issues, from product quality degradation to damage to production equipment. Optical sensors have become an effective solution to address these challenges. The Importance of Water Content Measurement for Product Quality; High water content can cause microorganism growth, increase in free fatty acids, and changes in the color of CPO. This significantly lowers the quality of the final product and reduces its market appeal. Water in CPO can cause corrosion in production equipment, increase energy consumption, and reduce process efficiency. CPO with high water content is more prone to damage during transportation and storage, which can result in significant financial losses for producers. The palm oil industry has strict quality standards regarding water content in CPO. Exceeding the set maximum limit may lead to product rejection by buyers.

Optical Sensors in Water Content Measurement are capable of providing highly accurate and precise measurement results, enabling better quality control. Measurements can be conducted continuously and in real-time, allowing early detection of any changes in water content. Optical sensor measurements are non-destructive, making them suitable for online process monitoring. These sensors can be integrated with automated control systems, reducing reliance on human labor. Optical sensor measurements are faster and more efficient than conventional methods. Optical Sensors Work; Optical sensors measure changes in the refractive index of light passing through the CPO sample. These changes in the refractive index are directly related to the water content in the sample. As a result, optical sensors can provide accurate quantitative data regarding water content.

II. The Proposed Method

A. Basic Consep Optic sensor

Infrared radiation is an electromagnetic wave with a wavelength range between 0.78 µm and 1000 µm. Infrared radiation is emitted by objects that have an absolute temperature above 0 Kelvin. Based on their wavelengths, infrared radiation has several types that are used in various devices and functions. Near-infrared radiation is one type of infrared radiation with a wavelength between 0.78 µm and 1.4 µm. This type of infrared is at the edge of the visible light spectrum, making it almost close to the range that can be seen by the human eye. Near-infrared is widely used in various technological applications, such as fiber optic communication, remote controls, and infrared sensors. Its ability to penetrate fog, smoke, and adverse weather conditions makes it very useful in remote sensing and thermal imaging devices. Additionally, near-infrared is often used in the medical field, particularly in therapy and biological imaging due to its non-invasive nature.

Far-infrared radiation is a type of infrared radiation with a wavelength between 3 µm and 1000 µm, and it is part of the electromagnetic spectrum that is not visible to the human eye. Due to its longer wavelength, far-infrared is often associated with heat emissions from objects with low to moderate temperatures. In many applications, far-infrared is used to detect and monitor thermal radiation, such as in thermal imaging systems for security, military, and environmental monitoring.

The intensity of infrared radiation passing through a chemical compound can change due to energy absorption by the compound. When infrared radiation penetrates the compound, it causes vibrations between the compound's molecules, resulting in changes in bond distances and angles between atoms. These changes then affect the dipole moment of the compound. If the oscillation frequency of the atoms in the compound matches the frequency of the infrared photons, energy absorption will occur. The greater the change in the dipole moment of the compound, the higher the intensity of the absorbed infrared radiation.

The infrared absorption coefficient of a medium is a measure of how effectively that medium absorbs infrared radiation at a specific wavelength. This coefficient can vary depending on the type of medium, concentration, temperature, and the wavelength of the radiation considered. Here are some important points regarding the infrared absorption coefficient of a medium.

Table 1. Table1 :Absorption coefficients for several media at specific wavelengths.[7]

Infrared	**Absorption Infrared coefficients Saveral Media**		
	Medium	***Wave Length***	***Coefisien Absorbtion***
Light	Name	**(µm)**	**(mm^{-1})**
1	Water	1.0	0.2
2	Water	1.2	1.5
3	Carbon Dioksida	4.2	100
4	Metana	3.3	200
5	Oksigen	0.76	0.1

This absorption coefficient provides insight into how well each medium absorbs infrared radiation, which is important for various scientific and technological applications. Below is a table of the infrared absorption coefficients of water in the wavelength range of 0.78 µm to 1.4 µm (780 nm to 1400 nm).[7]

Table 2 Infrared absorption coefficients of water in the wavelength range of 0.78 µm to 1.4 µm

Infrared	**Infrared Absorption Coefficient**		
	Wavelength	***Wavelength***	***Cofficient Absorbs***
	(µm)	**(nm)**	**(mm⁻¹)**
1	0.78	780	0.04
2	0.80	800	0.05
3	0.90	900	0.1
4	1.00	1000	0.2
5	1.10	1100	0.5
6	1.20	1200	1.5
7	1.30	1300	3
8	1.40	1400	1.0

This study provides values of the absorption coefficients for water across a wide wavelength range, including the near-infrared range you inquired about. The range of absorption coefficients for water shows a significant increase in the infrared region due to water's strong ability to absorb radiation at specific wavelengths.

One optical parameter that can be measured through changes in infrared intensity is the absorption coefficient of the medium. The infrared absorption coefficient of a medium is a measure that indicates the probability of the number of photons absorbed per unit length of the medium traversed by the infrared radiation

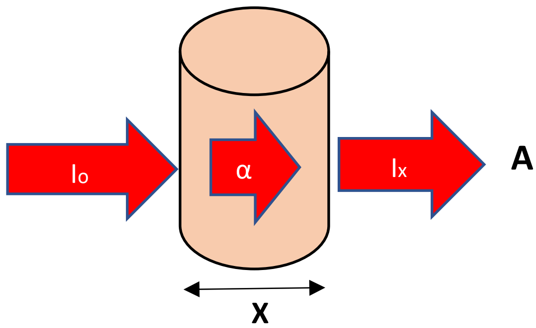

Fig 1 illustrates the process of infrared intensity absorption

Figure 1 illustrates the process of light intensity absorption in general, and specifically for infrared radiation as it passes through a medium. Equation (1) shows the relationship between light intensity (I) and the absorption coefficient of the medium (α):[6]

$$A = \ln\left[\frac{Ix}{Io}\right] = \alpha X \qquad 1$$

If the medium through which the infrared radiation passes is a chemical compound, then equation (1) can be derived to produce the equation for the molar absorptivity coefficient of the compound. This derivation is based on Beer-Lambert's law (2):

$$A = \varepsilon C X \qquad 2$$

Thus, equation (3) is obtained, showing the relationship between the infrared absorption coefficient, the molar absorptivity coefficient (ε), and the concentration of the compound (C) :

$$\propto = \varepsilon C \qquad 3$$

The measurement of changes in infrared light intensity after passing through a medium can be performed using near-infrared light and appropriate detectors. The intensity of the infrared light captured by the detector will be converted into a DC voltage value, which will be used as data in processing that can be displayed on both local and wireless monitoring systems.

B. IoT Realtime Monitoring

This research uses an Internet of Things (IoT)-based approach to automatically monitor and collect data from sensor devices. IoT enables connected objects or devices to transmit data independently through a network without requiring direct interaction from computers or humans. Sensors are installed on the objects or in the environment to be monitored. These sensors are responsible for measuring predetermined parameters such as moisture levels, humidity, temperature, or light intensity, among others. The data measured by the sensors is automatically collected by the connected IoT devices. Any change in the values detected by the sensors is transmitted in real time to the data processing system.

The Blynk application is used as a platform connecting IoT devices and users. Blynk allows data collected from sensors to be sent to the user's mobile device via the internet. Users can monitor the condition of the devices directly through the Blynk application's interface. Data transmitted by the IoT devices is wirelessly communicated to the server through an internet connection. Blynk serves as the interface, displaying the data in a user-friendly format. This information can be accessed remotely via a mobile device.

Blynk is not only used for data monitoring but also to control devices remotely. Users can send commands through the application to adjust the device's settings or functions based on the received data. With this IoT system, the data processing becomes faster and more efficient. The data obtained can be immediately analyzed without the need for manual collection, and the monitoring results can be viewed in real-time. Through this method, the research is able to deliver accurate, efficient, and automated results, enabling continuous monitoring without the need for direct interaction.

III. Method

Figure 2 shows the arrangement of the equipment for collecting CPO sample data. A near-infrared LED light source is supplied with voltage from a 5V DC source. The infrared light generated by the IR LED passes through a glass tube containing the CPO sample toward the infrared detector. Data from the infrared detector is acquired by a transducer, converting it into a standard voltage signal that can be processed by the ESP8266 microcontroller. The results are displayed on an LCD screen for local monitoring and are also transmitted wirelessly to a smartphone or PC. This allows remote monitoring as long as the device is connected to the Internet, utilizing the Internet of Things concept through the free Blynk application.

After setting up the equipment, observations were made on the changes in palm oil content by gradually adding water contamination. Starting with 100 ml of palm oil, water was added in increments of 0.25 ml up to 5 ml. The purpose was to observe whether changes in the level of water contamination in the palm oil affect the measurement results of the infrared light intensity received by the infrared sensor, along with testing the sensitivity of the infrared sensor. The test results of palm oil samples, conducted using the technique of mixing palm oil with water as an emulsifier, can be seen in Table 3.

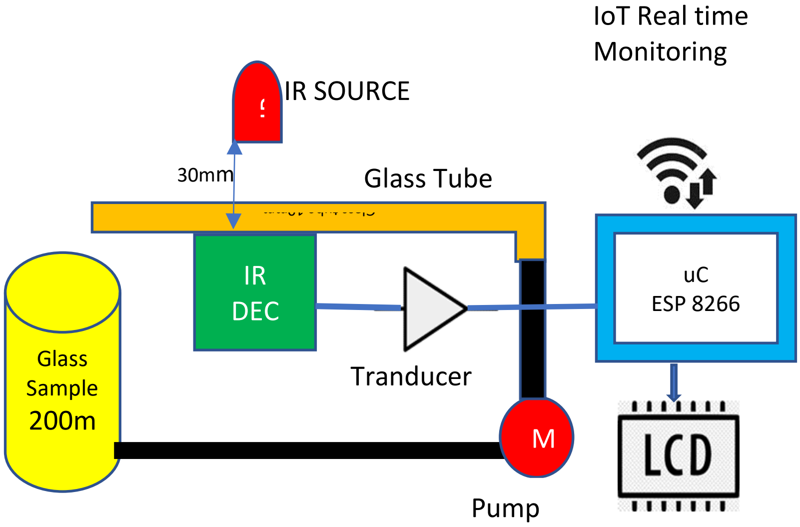

Fig 2: Arrangement of Equipment for Testing Water Content in CPO

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Table 3: Sample CPO Testing Composition and Sensor Output

Volume Palm Oil (ml)	**Palm oil with water emulsifier**				
	Volume Water (ml)	***Contamination (%)***	***Detector Vout (mV)***	***Display sensor (%)***	***Display Blynk IoT (%)***
100	0	0	59.5	0	0
100	0.25	0.25	60.4	0.2	0.2
100	0.5	0.5	61	0.4	0.4
100	0.75	0.75	61.4	0.5	0.5
100	1	1	62.7	0.65	0.65
100	1.25	1.25	63.3	0.8	0.8
100	1.5	1.5	63	1	1
100	1.75	1.75	63.6	1.3	1.3
100	2	2	64	1.6	1.6
100	2.25	2.25	64.2	1.9	1.9
100	2.5	2.5	65	2.3	2.3
100	2.75	2.75	65.8	2.5	2.5
100	3	3	65.9	2.7	2.7
100	3.25	3.25	66	2.95	2.95
100	3.5	3.5	67.2	3.1	3.1
100	3.75	3.75	68.8	3.4	3.4
100	4	4	72.6	3.8	3.8
100	4.25	4.25	74.1	4.11	4.11
100	4.5	4.5	76.2	4.4	4.4
100	4.75	4.75	78.1	4.7	4.7
100	5	5	80.5	4.9	4.9

IV. Results and Discussion

The absorption of infrared light, the intensity is closely related to the density of the CPO oil used, where higher water content results in higher CPO density. Based on equation (3) of the Beer-Lambert law, and CCC shows the relationship between the density of a compound and the infrared absorption coefficient of the compound. If we use concentration CCC in the Lambert-Beer equation and recall that concentration is related to density (mass per unit volume), then density ρ\rhoρ (g/mL) can be related to molar concentration CCC through the formula: C=ρM. From equation (3), we obtain an equation where ρ(rho) represents the density of the compound. From this equation, it can be seen that the greater the density of a compound, the larger the infrared absorption coefficient will be. A higher value of the close infrared absorption coefficient indicates that more photons are absorbed as infrared light passes through the compound, which ultimately leads to a decrease in the detected light intensity.

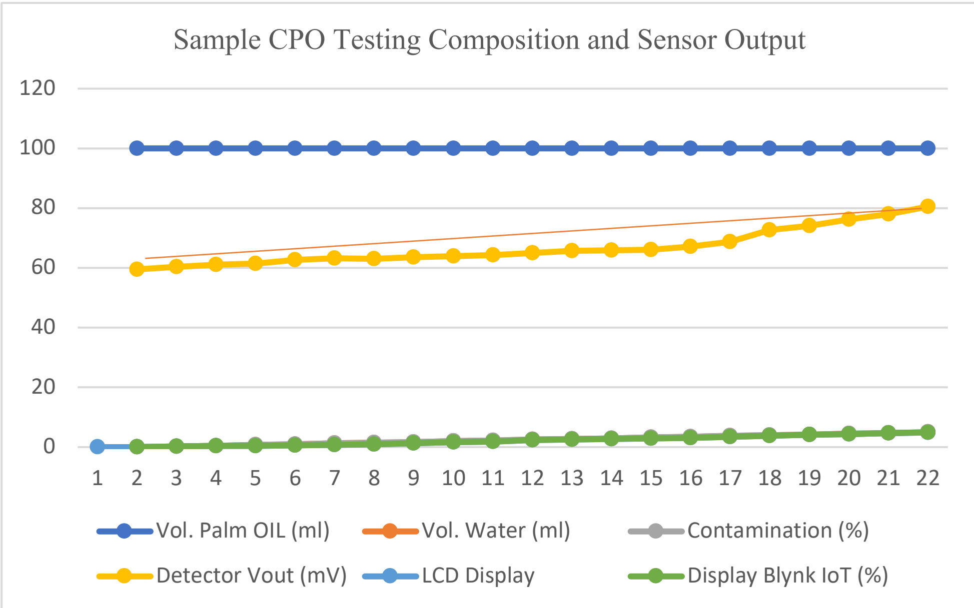

Fig 3: Sample CPO Testing Composition and Sensor Output

From the measurement results, the output voltage from the infrared sensor can be observed. As the water contamination in the CPO increases from the initial contamination of 0% with a sensor output of 59.5 mV, by gradually adding water contamination from 0.25 ml to 5 ml, the absorption of infrared light increases. This results in a higher output voltage from the IR sensor, reaching 80.5 mV at 5 ml of water contamination in the CPO. From the results in Table 3, which are translated into Figure 3, a non-linear response from the sensor can be observed. This is likely due to the cleanliness of the glass pipe medium and the presence of contaminants in the sample other than water, resulting in an error in the output of 12.5%

The measurement results of this CPO sample will be processed by an ESP8266 microcomputer, which will handle the data for display on an LCD monitor and transmit the measurement data wirelessly to smartphones and PCs via the internet. This allows real-time monitoring from anywhere and at any time by the person in charge of CPO handling or by consumers, without being limited by location or time.

Figure 4 shows the real-time monitoring results of water content in CPO using the Blynk application on a smartphone connected to IoT technology. The data obtained from the sensor is wirelessly transmitted through the internet to the application, allowing users to remotely monitor the water content in real-time. This display facilitates users in observing changes in water levels in CPO, ensuring a more efficient and responsive control process. With the Blynk application, monitoring can be done anytime and anywhere, providing flexibility and convenience for user. With Internet of Things (IoT)-based water content monitoring technology, the water content in Crude Palm Oil can be monitored in real-time, both during storage in industrial tanks and while being distributed to consumers. As long as an internet connection is available, water content information can be accessed anytime and anywhere. This not only ensures that the quality of CPO is maintained throughout the distribution process, but also enhances transparency and consumer trust in the received product.

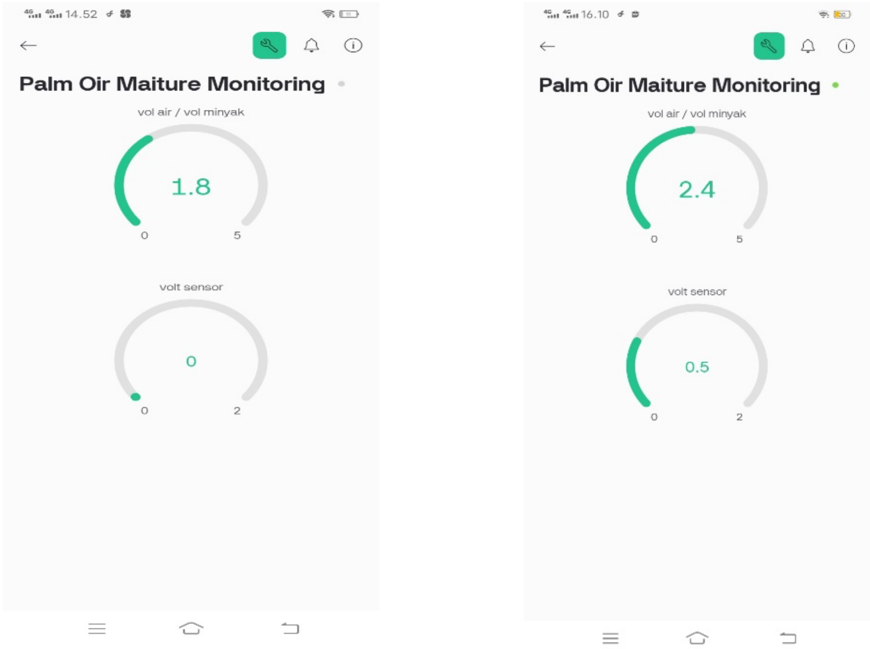

Fig 4. Display of a smartphone with the IoT Blynk application monitoring the water content in CPO.

V. Conclusion

Based on the results of the design and testing of the equipment that has been carried out, the following conclusions can be drawn: The real-time water content monitoring tool in oil allows for continuous monitoring of the quality of palm oil during the process, and if needed, trend records can be viewed wirelessly from anywhere. This real-time water content monitoring tool can only measure water content from 0 to 5%. The IR absorption method infrared sensor with IR LED source is less effective in measuring water content in oil if water contamination in the oil is more than 5%. The actual measurement results of palm oil are best at 0-4% water contamination input where it does not change the color and density of palm oil.

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