ITEJ
Information Technology Engineering Journals
eISSN : 2548-2157

Url : https://syekhnurjati.ac.id/journal/index.php/itej
Email : itej@syekhnurjati.ac.id

IoT-Based Cooking Oil Quality Monitoring System Using Thresholding Method on Android Application

Nida Dhia Ulhaq
telecommunications engineering
State Polytechnic of Sriwijaya
dhianida06@gmail.com

Irma Salamah
telecommunications engineering
State Polytechnic of Sriwijaya
irma_salamah@polsri.ac.id

Suroso
telecommunications engineering
State Polytechnic of Sriwijaya
osorus11@gmail.com

Abstract—The repeated use of cooking oil can lower its quality and pose health hazards, although these changes are not always visible to the human eye. This research aims to design a cooking oil quality monitoring system based on the Internet of Things (IoT) with a thresholding method approach integrated into an android application. The system uses a TCS3200 sensor to identify color changes, an LDR sensor to detect clarity levels, and a pH sensor to measure the acidity of the oil. The three sensor data are used to determine the quality category of oil, namely good, medium, and unfit oil, through majority classification logic. Testing was conducted on six oil samples, each with 60 data points collected. All data was sent in real-time to firebase and displayed via an android application. In addition, the system is equipped with automatic notification features through telegram to facilitate remote monitoring. The test results indicate that the system is capable of providing oil quality classification with an overall accuracy of 74%, with details of color sensor accuracy at 98%, LDR sensor at 83.33%, and pH sensor at 38.89%. This system is expected to be a practical solution in helping users effectively monitor oil quality and prevent health risks due to the use of used oil.

Keywords—Cooking Oil Quality, IoT Monitoring System, Thresholding Method, Android Application, Sensor Integration.

I. INTRODUCTION

Indonesia is known as an agrarian country with the agricultural sector as one of the main pillars in the economy, including oil palm plantations that contribute greatly to foreign exchange. Based on data from the Directorate General of Plantations, palm oil recorded the highest export value of US$17.60 billion as the main raw material for cooking oil[1]. Cooking oil is one of the food products that has the main content of triglycerides from vegetable materials[2]. Cooking oil is needed in the food industry and is usually reused to save production costs. The repeated use of cooking oil affects the quality and nutritional value due to changes in its fatty acid composition. Various reactions occur during the frying process that causes the oil to degrade, such as browning, becoming thicker, foaming, smoking, and leaving undesirable odors on the fried food[3],[4].

One of the quality controls in cooking oil starts from the quality of raw materials. The quality standard of cooking oil, such as palm oil commonly used in household frying activities, is considered good if it has several factors such as free fatty acid (FFA) content, moisture content, and dirt content remaining within the standard range of cooking oil quality[5].

Therefore, it is important to conduct research on the quality of cooking oil both before and after continuous use, in order to monitor the quality of the oil's usage[6]. The general public, especially small-scale food businesses and households often lack the knowledge and tools to accurately detect oil quality[7]. Along with the development of technology, the utilization of the Internet of Things has begun to be widely applied in food quality monitoring systems in real time[8].

Various innovations have emerged, such as smart packaging, QR code labels integrated with temperature sensors and freshness indicators, as well as enzymatic time-temperature indicators (TTI). These technologies enable real-time, non-destructive monitoring processes that are digitally connected. On the other hand, the use of nanotechnology-based sensors also enhances sensitivity and accuracy in measuring the quality and shelf life of food products. Enzymatic TTI devices also play a role by providing intuitive and easily understood visual indicators to show food quality during the storage process. Smart packaging that integrates sensor technology with Internet of Things (IoT) systems allows for comprehensive food quality monitoring through a user-friendly digital platform[9],[10],[11],[12],[13].

Several other studies have also developed monitoring systems for cooking oil quality used as ingredients for frying food, using optical-based sensors and cloud-based data processing systems[14]. The IoT-based monitoring system is equipped with notifications using a telegram bot for environmental monitoring, but has not yet been specifically applied for classifying cooking oil quality based on certain parameters such as color, clarity, and pH[15]. The combination of several sensors in measuring new cooking oil and used cooking oil has also been done, but the monitoring results can only be seen on the LCD screen[16]. The use of capacitive and ultrasonic sensors has also been conducted; however, it has not been connected to real-time storage in the cloud or an android application interface as a visualization medium. This remains a hurdle in the implementation of detection systems in the field that require practicality, flexibility, and remote monitoring capabilities[17].

In response to this need, this research develops an IoT-based cooking oil quality monitoring system by integrating color, clarity, and pH sensors using thresholding methods for automatic classification of oil quality. This system is supported by an Android application that provides data visualization and real-time notifications, making it easier for users to determine when to replace the oil. With an efficient and economical design, this system is expected to be a suitable solution for household needs and micro-business actors in maintaining cooking oil quality more accurately and sustainably.

II. METHOD

A. Research Approach

This research framework begins with conducting a literature study, hardware and software preparation, hardware and software integration, system testing, data collection, and analysis in figure 1. The first stage is a literature review, which is conducted to obtain a theoretical foundation related to sensor technology, Internet of Things (IoT) systems, and methods for classifying the quality of cooking oil. Next, hardware and software preparations are carried out, including the selection and assembly of components such as the ESP32 microcontroller, TCS3200 color sensor, LDR, and pH sensor, as well as the development of a firebase based system, an android application, and telegram notifications. In the integration stage, all hardware is connected to the software so that it can operate in a unified manner within the oil quality monitoring system. After the integration is complete, system testing is conducted to ensure that all components work optimally in reading, sending, and displaying oil quality parameter data in real-time. The next stage is data collection, where the system is used to record changes in color, clarity, and acidity levels of cooking oil over several usage cycles. Finally, the obtained data is analyzed using methods to classify oil quality, as well as to evaluate the accuracy of the system in providing alerts to users about the ideal time to change the cooking oil.

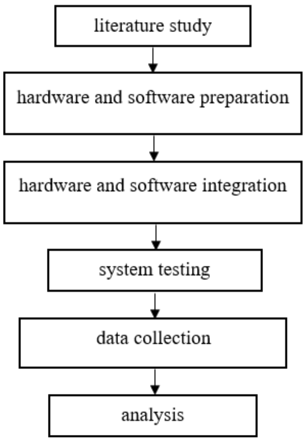

Figure 1. Research Framework

B. Research Objects and Samples

The subjects in this study were bulk cooking oils that had undergone various levels of repeated use, i.e. new cooking oil up to five times of reuse. A total of six oil categories were used as samples, with the same frying variables in terms of cooking ingredients selection and length of time in frying. This object selection was done to see the safe limit of oil use.

C. Implementation Of Research Procedures

The procedure begins with sensor calibration to establish the threshold value. Based on SNI 01-3741-2013, the color of cooking oil that meets the standard is white to pale yellow and yellow. In addition to the color aspect, there are various other parameters that must be met for the oil to be declared suitable for consumption, one of which is the acidity level. The required pH value of cooking oil is in the range of 4.5 to 6[18]. The color value threshold is also adjusted based on international units (SI) in the range of 0-255 While the clarity level that can be measured by the sensor is based on the intensity of the light reflected on the sensor and converted to the ADC value.

D. Hardware and Software Implementation

In figure 2 shows the overall workflow diagram of the system. This design consists of three main parts, namely input, process, and output. In the input section, the system receives data from the object to be tested, which is the cooking oil sample. The data is collected through three sensors: a TCS3200 color sensor, an LDR light sensor, and a pH sensor. These three sensors detect the physical characteristics of the sample and send signals to the ESP32 microcontroller, which serves as the processing center. In the processing stage, the ESP32 reads the analog or digital data from the sensors, and then applies a thresholding method to perform oil quality classification. In addition, the ESP32 also manages the data communication path with the cloud server. The classification result data is sent to firebase, which acts as a cloud storage and becomes the data source for the android app. In the output part, the classification result is displayed directly on the hardware as well as accessible by the user through the android app connected to firebase.

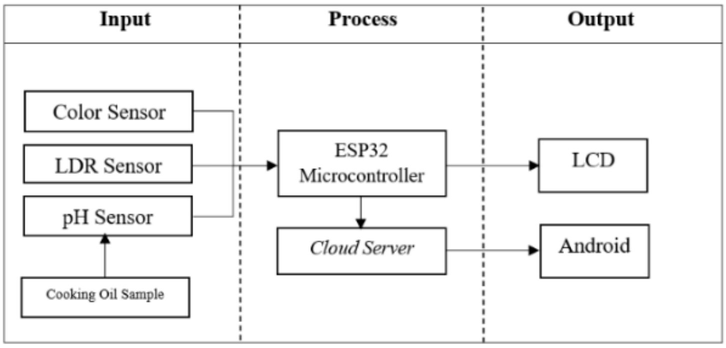

Figure 2. Block Diagram

E. Data Collection Process

Data collection in this study was carried out by testing the tools that have been designed. Data collection begins by placing the oil sample in the test container, then the TCS3200, LDR, and pH color sensors work to measure the value of the oil object. The data read by the sensor is measured 60 times, so that 360 sensor reading data is obtained to produce an accurate value. The value is then calculated the average value with the approach The value is then calculated the average value with the approach of the data value divided by the amount of data. The calculation of the average value is done automatically in the arduino IDE.

F. Classification Method

Classification uses thresholding, which is a method commonly applied in image processing to separate objects from the background based on threshold values. The basic principle is to compare each pixel value with a predefined threshold, and then convert the image into a binary format where areas that meet the threshold criteria are separated. In the context of this research, the concept of thresholding is adapted to evaluate the quality of cooking oil through sensor data. The output value of each sensor is compared with the calibration threshold, so that the oil quality category can be determined[19]. The output value of each sensor is compared with the threshold based on the SNI and the RGB value range of 0-255 and then classified into 3 categories, namely good, medium, and unfit oil. The final quality determination follows the majority rule, where two out of three sensors show the same category so that it becomes the final classification result. This mechanism increases the reliability of the classification on the sensor and ensures that the oil quality assessment is in accordance with regulatory requirements[20]. The overall accuracy of the system is calculated by comparing the number of data that is correctly classified against the total test data. The formula for overall accuracy uses the approach accuracy = number of correct predictions / total number of data x 100%, where the number of correct predictions is the total data that has been accurately classified by the sensor based on the predetermined categories, while the total data is the entire sample that was tested.

III. RESULT AND DISCUSSION

A. System Design

Figure 3. shows the hardware design which is one of the important stages in making the system. This design starts from the TCS3200 sensor connected to digital pins 18 (S0), 19 (S1), 2 (S2), 15 (S3), and 5 (SENSOR_OUT), a pH sensor connected to analog pin 34, an LDR sensor connected to analog pin 4, a 16x2 LCD with an I2C interface (address 0x27), and android as a monitoring medium to see real-time and remote results.

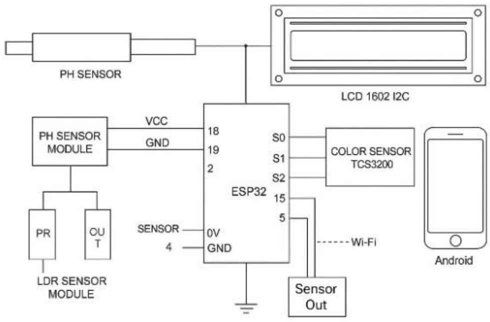

Figure 3. System Design

B. Sensor Measurement Results and Data Classification

At this stage, a series of tests were conducted on three types of sensors: the TCS3200 color sensor, LDR sensor, and pH sensor. Table 1 presents the measurement results of the first sample, which is bulk oil that has never been used. The reading results show RGB values of R=207, G=185, B=41, an ADC value for clarity of 2326, and a pH of 4.9. Subsequently, the oil was used to fry tempeh for about 15 minutes, with the food variable and frying time consistently controlled. The system classified the oil used 2 times as moderate earlier than the usage of 3-4 times. This occurred because the color R=133, G=106 indicated faster visual degradation, even though the amount used was smaller, influenced by the type of food and duration of heating[21],[22]. In the fifth usage cycle, the oil only produced values of R=54, G=0, B=0 and an ADC value of 2490, indicating a decline in quality due to increased turbidity and color change.

To compare sensor performance, further testing was conducted on the second bulk oil sample with a different frying ingredient, which was banana, while still maintaining a consistent frying duration of about 10 minutes. The sensor results from the second oil are shown in table 2. The fresh oil showed values of R = 217, G = 194, B = 54, an ADC of 2293, and a pH of 5.4. Meanwhile, the oil that had been used five times showed a significant decline in quality, with values of R = 155, G = 80, B = 0, and an ADC reaching 2565. The final quality classification process was based on a majority voting approach from the three sensor values to determine the final condition of the oil, thereby minimizing classification errors that could occur if only a single sensor was used.

Tabel 1. Sensor test results on bulk oil test 1

No.	Oil Sample	Sensor Testing Results					System Final Category
		R	G	B	ADC	pH	
1.	New Oil	207	185	41	2326	4.9	Good
2.	1x Used Oil	192	155	0	2334	5	Good
3.	2x Used Oil	133	106	0	2319	4.8	Medium
4.	3x Used Oil	164	108	0	2354	4.9	Medium
5.	4x Used Oil	154	89	0	2410	4.9	Medium
6.	5x Used Oil	54	0	0	2490	5.1	Unfit

Tabel 2.Sensor test results on bulk oil test 2

No.	Oil Sample	Sensor Testing Results					System Final Category
		R	G	B	ADC	pH	
1.	New Oil	217	194	54	2293	5.4	Good
2.	1x Used Oil	209	176	27	2323	5.3	Good
3.	2x Used Oil	186	141	0	2367	4.8	Medium
4.	3x Used Oil	170	115	0	2425	5	Medium
5.	4x Used Oil	170	106	0	2386	4.9	Medium
6.	5x Used Oil	155	80	0	2568	5	Unfit

C. Method Accuracy Analysis

Based on the results of sensor testing on cooking oil samples in two different scenarios, namely in the first and second tests which used different types of oil and frying materials. It was found that the new cooking oil provided readings that were closest to the ideal condition. Therefore, the data from table 1 and table 2 are considered representative to be used as a reference in the sensor calibration process. A summary of the calibration results and sensor readings is presented in table 3. Based on these measurement results, it is evident that the sensor is capable of providing fairly accurate results in detecting color parameters within the RGB range (0-255). The color sensor exhibits optimal performance with an accuracy rate reaching 98%. This sensor has proven to be consistent and precise in recognizing object colors[23]. New cooking oil, or oil that has only been used once, tends to show relatively high values of R (red), G (green), and B (blue). In contrast, oil that has been reused shows a decrease in G and B values. Fresh oil generally still predominantly reflects red and green light, while the blue reflection tends to be low, in accordance with the optical characteristics of pure oil compounds. This pattern is consistent with the visual attributes of cooking oil suitable for consumption[24],[25].

The clarity sensor based on LDR operates by measuring the intensity of light that passes through the liquid. The more dissolved particles or frying residues present in used oil, the greater the scattering of light, leading to a decrease in the light received by the sensor and an increase in the ADC (Analog-to-Digital Converter) value. Variations in the type of fried food, the frequency of oil use, and the frying temperature significantly affect the content of harmful compounds such as 3-MCPDE and glycidyl esters (GE) in palm oil. Each type of food generates different residues and degradation products, impacting the physical and chemical characteristics of the oil, including its clarity[26]. Previous studies[27] indicate that LDR sensors have a good linear correlation with light intensity, with an average accuracy of 87.89% in detecting water turbidity levels. In this study, the LDR sensor showed an accuracy level of 83.33%. However, its accuracy can decline if there is inconsistency in lighting or the position of the object. Therefore, stable measurement conditions are needed to produce optimal data.

On the other hand, pH sensors show limitations in terms of accuracy when used for monitoring the quality of frying oil. These sensors only record an accuracy level of around 38.89%, caused by the narrow pH value range between oil categories and the influence of temperature on sensor output stability. In addition, pH sensors are highly sensitive to drift phenomena, which can reduce accuracy if calibration and temperature compensation are not performed regularly[28]. Thus, pH sensors are more suitable as supporting parameters in frying oil quality monitoring systems, rather than as primary indicators, to enhance the reliability and validity of detection results.

Sensor calibration is an important process in adjusting the output of measuring instruments to known standard values, in order to maintain consistency and accuracy of measurement results during the operational period of the sensor. Since sensor output can change due to environmental factors, age, and frequency of use, calibration becomes an important step to address deviations or drift[29],[30]. By creating a calibration equation model, deviations in reading results can be corrected so that the data becomes more valid, especially for applications in the thresholding method in frying oil quality classification systems. Therefore, calibration not only improves sensor performance but also serves as an important foundation to ensure overall measurement accuracy. Through a thresholding approach supported by sensor calibration, the system can achieve an overall true classification accuracy of 74%.

Table 3.Threshold Sensor to Method

No.	Parameters	Threshold Value					Result Thresold
		R	G	B	ADC	pH	
1.	Good Oil	>180	>150	> = 0	< 2350	> 5.5	Correct
2.	Medium Oil	124-210	90-150	0-60	2350-2440	4.5-5	Correct
3.	Unfit Oil	Out of Range	Out of Range	Out of Range	Out of Range	< 4.5	Correct

D. Android Application Implementation Results

An android application was developed as a user interface that serves to display the results of real-time cooking oil quality monitoring. The app was built using the React Native framework, which supports cross-platform development and allows direct integration with firebase realtime database as the main data storage and source. The application display consists of several main menus, namely the account login page, oil classification dashboard, reading graph, and reading history in table 4. After the user has successfully logged in, the system will display the oil quality status based on the data sent by the ESP32 device. The quality categories displayed consist of three levels, namely good, medium and unfit, with color indicators and brief descriptions to clarify the status. The information presented in the app is sourced directly from firebase and will be updated automatically whenever the system receives new sensor data. In addition, there is a classification history storage feature and can be browsed by time. This history records changes in oil quality values with timestamps for continuous evaluation and monitoring purposes. One important feature of the app is the integration of notifications via telegram bot, which automatically sends a warning message when the classification results indicate that the oil is no longer suitable for use. With this feature, users can receive information quickly without having to open the application manually.

Figure 4. Firebase Realtime Databased

Table 4. Functionality Testing Data on Android

No.	Display Name	Functionality	Does the application work?
1.	Login Page	Providing user authentication access before entering the main system. Users must enter their username and password to proceed to the dashboard.	Success
2.	Clasification Dashboard	Displaying the monitoring results of cooking oil quality based on the latest data from firebase. Quality information is presented in categories such as good, medium, or unfit for consumption in real-time.	Success
3.	Reading Chart	Presenting sensor readings (pH, color, clarity) in a visual form such as a bar chart or line chart. It makes it easier for users to understand trends in oil quality changes over time.	Success
4.	Reading History	Displaying the history of previous readings and classifications that have	Success

		been saved in Firebase, and being able to search data based on date or order of oil usage.	
5.	Notification Via Telegram	Sending automatic alerts to the telegram app when the oil quality is in an unsuitable condition. Providing quick and efficient information to users without the need to manually open the app.	Success

V. Conclusion

Based on the research results and discussion, it can be concluded that the developed cooking oil quality monitoring system has successfully operated well. Cooking oil that is still suitable for use generally has high red and green color compositions and low blue color values. With repeated use, there is a decline in oil quality, particularly in terms of color. The cooking oil quality monitoring system in this study is capable of classifying oil quality with an overall accuracy rate of 74% using a thresholding method. The color sensor demonstrated the best performance with an accuracy of up to 98%, while the LDR clarity sensor achieved 83.33%. However, the pH sensor has limitations with an accuracy of only 38.89%, making it more suitable for use as a supporting parameter. The majority-based decision-making strategy also proved effective in supporting the oil quality classification process. From the test results, it is obtained that oil that has been used two to four times still falls into the medium quality category and is still consumable. However, with the fifth use, the quality of the oil decreased significantly and was categorized as unsuitable for consumption. In addition, the type of food being fried also affects the level of oil degradation, as seen from the differences in results between oil tests one and two, which were used under different frying conditions and times. The oil clarity values showed fluctuations caused by differences in lighting intensity in the testing environment, especially in areas with low lighting, which caused the sensor readings to be less stable. For the future development of the system, it is recommended that the monitoring system be thoroughly improved in full integration between hardware and android-based software. The use of machine learning-based classification methods is also recommended to increase classification accuracy without the need for manual calibration processes. The android application system should be designed to be more interactive and comprehensive with the addition of features. Furthermore, testing should be expanded to involve various types of oil and different brands, ranging from low to high quality, to assess the comparison of oil quality before and after use.

References

[1] S. Tinggi, I. E. Swadaya, and R. R. Kurniawan, "Tata kelola perusahaan minyak goreng di Indonesia: studi literatur fenomena kelangkaan dan kenaikan harga minyak goreng di Indonesia," 2022.

[2] Husnah and Nurlela, "Analisa bilangan peroksida terhadap kualitas," *J. Univ. PGRI Palembang*, vol. 5, no. 1, pp. 65–71, 2020.

[3] B. Dwiloka, B. E. Setiani, and D. Karuniasih, "Pengaruh penggunaan minyak goreng berulang terhadap penyerapan minyak, bilangan peroksida dan asam lemak bebas pada ayam goreng," *Sci. Technol. Manag. J.*, vol. 1, no. 1, pp. 13–17, 2021, doi: https://doi.org/10.53416/stmj.v1i1.7.

[4] M. Nasir, "Perbandingan kualitas minyak sawit bermerk dan minyak kelapa menggunakan parameter viskositas dan indeks bias," *Sainstek J. Sains dan Teknol.*, vol. 12, no. 2, p. 36, 2020, doi: https://doi.org/10.31958/js.v12i2.2470.

[5] D. Levia and Mhubaligh, "Analisis proses produksi CPO untuk mengidentifikasi faktor-faktor yang mempengaruhi kualitas mutu CPO," *J. Teknol. dan Manaj. Ind. Terap.*, vol. 2, no. 2, pp. 82–89, 2023, doi: https://doi.org/10.55826/tmit.v2i2.72.

[6] M. Bersalin, D. I. Pmb, H. J. Nurhaedah, and K. Bone, "Jurnal Suara Kesehatan," vol. 7, no. 1, pp. 1–10, 2021.
[7] Suhanto, F. Faizah, Kustori, Setiyo, and Suwito, "Implementing fuzzy logic as a control and monitor of oil quality using Android," *J. Phys. Conf. Ser.*, vol. 1845, no. 1, pp. 1–7, 2021, doi: https://doi.org/10.1088/1742-6596/1845/1/012056.
[8] N. Aliyah et al., "Tantangan dan peluang penggunaan IoT pada agrokompleks: systematic literature review," vol. 9, no. 1, pp. 1216–1223, 2025.
[9] H. Zhang, Y. Xu, M. Luo, et al., "Integrated food quality monitoring QR code labels with simultaneous temperature and freshness sensing in real-time," *Food Measure*, vol. 17, pp. 4834–4842, 2023, doi: https://doi.org/10.1007/s11694-023-02007-2.
[10] T. Ghosh, G. V. S. B. Raj, dan K. K. Dash, "A comprehensive review on nanotechnology based sensors for monitoring quality and shelf life of food products," *Measurement: Food*, vol. 7, Art. no. 100049, 2022, doi: https://doi.org/10.1016/j.meafoo.2022.100049.
[11] A. T. Pandian, S. Chaturvedi, dan S. Chakraborty, "Applications of enzymatic time–temperature indicator (TTI) devices in quality monitoring and shelf-life estimation of food products during storage," *Food Measure*, vol. 15, pp. 1523–1540, 2021, doi: https://doi.org/10.1007/s11694-020-00730-8.
[12] A. Dodero, A. Escher, S. Bertucci, M. Castellano, dan P. Lova, "Intelligent packaging for real-time monitoring of food-quality: Current and future developments," *Applied Sciences*, vol. 11, no. 8, Art. no. 3532, Apr. 2021, doi: https://doi.org/10.3390/app11083532.
[13] A. M. Kaimal, M. Dhingra, dan R. S. Singhal, "Monitoring of oil quality from commercial fried foods—A case study from India," *Journal of Food Processing and Preservation*, vol. 46, no. 1, Art. no. e16138, Oct. 2021, doi: https://doi.org/10.1111/jfpp.16138.
[14] A. Desy and N. Utomo, "Rancang bangun sistem pendeteksi kualitas minyak goreng pada pembuatan kerupuk berbasis IoT (studi kasus: UKM Darjaya Kerupuk Rambak)," vol. 12, no. 2, pp. 3259–3264, 2025.
[15] W. Priayanto, "Implementation of IoT-based optical sensors for real-time monitoring in palm oil processing," vol. 9, no. 2, pp. 482–489, 2024, doi: https://doi.org/10.31572/inotera.Vol9.Iss2.2024.ID395.
[16] U. Pratiwi and A. Luthfia, "Pengukuran viskositas oli dan minyak goreng menggunakan sensor mini reed switch magnetic berbasis Arduino," *ORBITA J. Pendidik. dan Ilmu Fis.*, vol. 9, no. 2, p. 277, 2023, doi: https://doi.org/10.31764/orbita.v9i2.17342.
[17] C. Satria, M. N. Zakaria, and F. A. Soelistianto, "Rancang bangun pendeteksi kualitas minyak goreng kelapa sawit dengan menggunakan metode sensor ultrasonik dan sensor kapasitif berbasis smartphone," *J. Jartel J. Jar. Telekomun.*, vol. 10, no. 3, pp. 140–143, 2020, doi: https://doi.org/10.33795/jartel.v10i3.83.
[18] L. Qothrunnada, I. Yanti, and M. Pauzan, "Implementasi logika fuzzy pada alat pendeteksi kualitas minyak goreng berdasarkan pH dan tingkat kejernihan," *J. Teknol. Inf. dan Ilmu Komput.*, vol. 11, no. 1, pp. 225–234, 2024, doi: https://doi.org/10.25126/jtiik.20241118289.
[19] M. A. Restuning Pamuji and D. Putra Pamungkas, "Segmentasi citra daun bawang merah menggunakan metode thresholding Otsu," *Nusant. Eng.*, vol. 6, no. 2, pp. 169–174, 2023, doi: https://doi.org/10.29407/noe.v6i2.20553.
[20] Muljono and N. Adhipurna, "A weighted majority voting ensemble model for disease prediction boosted by PSO: the case of type 2 diabetes," *Int. J. Comput.*, vol. 22, no. 4, pp. 475–484, 2023, doi: https://doi.org/10.47839/ijc.22.4.3354.
[21] G. Agung and R. Rismaya, “Pengaruh Suhu Pemanasan terhadap Karakteristik Mutu Minyak Goreng Bekas Pakai Pedagang Gorengan”, *agritekno*, vol. 13, no. 1, pp. 15-23, Jan. 2024.
[22] O. M. Almrhag and F. L. Abookleesh, "Evaluation of oxidative stability of vegetable oils during deep frying," *The Arab Journal of Sciences & Research Publishing*, vol. 2, no. 2, pp. 90–97, 2021, doi: https://doi.org/10.26389/ajsrp.o15216.

[23] I. N. Azhar, “IoT based smart palm oil seed segregator using RGB color sensor,” *Journal of Advanced Research in Applied Mechanics*, vol. 118, no. 1, pp. 40–53, 2024, doi: https://doi.org/10.37934/aram.118.1.4053.

[24] M. N. Marofi, A. S. Nugroho, and S. A. Wibowo, "Rancang Bangun Sistem Klasifikasi Kualitas Minyak Goreng menggunakan Sensor Warna TCS3200 dan LDR dengan Metode Naïve Bayes," *Jurnal Pengembangan Teknologi Informasi dan Ilmu Komputer*, vol. 6, no. 8, pp. 3761-3766, 2022. [Online]. Available: https://j-ptiik.ub.ac.id/index.php/j-ptiik/article/view/12057

[25] X. Jiang, J. Cheng, F. Yang, Z. Hu, Z. Zheng, Y. Deng, B. Cao, and Y. Xie, "Visual colorimetric detection of edible oil freshness for peroxides based on nanocellulose," *Foods*, vol. 12, no. 9, p. 1896, May 2023, doi: https://doi.org/10.3390/foods12091896.

[26] J. Zhang, "Effects of food types, frying frequency, and frying temperature on 3-monochloropropane-1,2-diol esters and glycidyl esters content in palm oil during frying," *Foods*, vol. 10, no. 10, p. 2266, Oct. 2021, doi: https://doi.org/10.3390/foods10102266.

[27] B. E. Cahyono, I. D. Utami, N. P. Lestari, and N. S. Oktaviany, “Karakterisasi sensor LDR dan aplikasinya pada alat ukur tingkat kekeruhan air berbasis Arduino UNO,” *Jurnal Teori dan Aplikasi Fisika*, vol. 7, no. 2, pp. 179–186, Jul. 2019. [Online]. Available: https://jtaf.fmipa.unila.ac.id/index.php/jtaf/article/view/219

[28] S. Munirathinam, "Drift Detection Analytics for IoT Sensors," *Procedia Computer Science*, vol. 180, pp. 903–912, 2021, doi: https://doi.org/10.1016/j.procs.2021.01.341.

[29] T. Chaudhuri, M. Wu, Y. Zhang, P. Liu, dan X. Li, "An Attention-Based Deep Sequential GRU Model for Sensor Drift Compensation," *IEEE Sensors Journal*, vol. 21, no. 6, pp. 7908-7917, Mar. 2021, doi: https://doi.org/10.1109/JSEN.2020.3044388.

[30] G. Zhao, J. Yin, L. Wu, dan Z. Feng, "Ultrastable and Low-Noise Self-Compensation Method for Circuit Thermal Drift of Eddy Current Sensors Based on Analog Multiplier," *IEEE Transactions on Industrial Electronics*, vol. 67, no. 10, pp. 8851-8859, Oct. 2020, doi: https://doi.org/10.1109/TIE.2019.2949511.