Received : 11 December 2023
Revised : 24 May 2024
Accepted : 25 May 2024
Published: 8 June 2024
Issued : 30 June 2024

DOI: doi.org/10.21009/1.10108

Educational Tool for Determining Viscosity Coefficient of Cooking Oil Using Arduino UNO

F. Shoufika Hilyana[1,2,a)], Putut Marwoto[2,b)], Sunyoto Eko Nugroho[2,c)]

[1]*Elementary Teacher Education Department, Faculty of Teacher Training and Education, Universitas Muria Kudus, Kudus 59327, Indonesia*
[2]*Natural Science Education Department, Faculty of Mathematics and Natural Sciences, Universitas Negeri Semarang, Semarang 50229, Indonesia*

✉: [a)]farah.hilyana@umk.ac.id, [b)]pmarwoto@mail.unnes.ac.id, [c)]ekonuphysed@mail.unnes.ac.id

Abstract

The research aims to determine the quality of cooking oil based on the viscosity coefficient using an Arduino UNO-based viscosity coefficient determining tool. By integrating the Arduino UNO into the viscosity measurement process, this research shows innovation in adapting widely available technology for scientific purposes. The series of tools for determining the value of the viscosity coefficient work if an iron ball enters the fluid and will be detected by magnetic sensors 1 and 2 if it passes through the sensor, which is placed at a predetermined distance. Research was conducted to test the quality of cooking oil by determining the viscosity coefficient. The method research is analyzing recorded videos of the motion of objects falling in oil with Tracker Software. By tracking the video recording of the motion of an object falling in a liquid, data, and graphs of the speed of the falling motion can be obtained. Then from the data obtained, the viscosity value is obtained using the equation. The results of the 5 cooking oils, using the tool, were that oil 1 had a viscosity coefficient of 0.2732 Pa.s; oil 2 with 0.3077 Pa.s; oil 3 with 0.3127 Pa.s; oil 4 with 0.3186; and oil 5 with 0.3218 Pa.s. Meanwhile, the results of the oil viscosity coefficient using manual calculations showed that oil 1 had 0.2733 Pa.s; oil 2 with 0.3089 Pa.s; oil 3 with 0.3136 Pa.s; oil 4 with 0.3188; and oil 5 with 0.3219 Pa.s. The percentage of error that occurs from the tool is 0.17%. The oil with a smaller viscosity coefficient is coconut oil (better quality than palm oil), while the quality of bulk oil is indicated by a larger viscosity coefficient. It could be asserted that the oil's quality improves as the viscosity coefficient decreases.

Keywords: viscosity, cooking oil, Arduino UNO

INTRODUCTION

Based on data from the Indonesian Palm Oil Entrepreneurs Association (Gapki), palm oil consumption in Indonesia was 1.98 million tonnes in September 2023. Looking at the trend, domestic palm oil consumption has tended to increase since January 2020. The figure also set a record high in August 2023 which reached 2.04 million tons. Indonesia's palm oil production reached 4.54 million tons in September 2023. The amount increased by 7.49% compared to August 2023 which was 4.22 million tons (Dimopoulos et al., 2023). Cooking oil or what is called RBD (Refined, Bleached, Deodorized) Olein is one of the processed palm oil products which is a staple food ingredient that receives special attention from the government. Palm cooking oil is divided into two types, namely bulk cooking oil and branded packaged cooking oil (Asmara, 2019). In Indonesia, the most popular cooking oil consumed for frying is palm oil. This is because Indonesia is the largest palm oil-producing country. After palm oil, coconut oil is the most widely used in Indonesia (Laelia et al., 2019).

Low-quality cooking oil often contains high levels of trans fats, saturated fats, and free radicals, which are detrimental to cardiovascular health. Prolonged consumption can increase the risk of heart disease, stroke, and other cardiovascular conditions (Mozaffarian et al., 2006). Low-quality cooking oil is deficient in essential nutrients and may contain harmful substances due to improper processing or contamination. Consuming such oil can lead to nutritional deficiencies (Asraf et al., 2018) and jeopardize overall health (Mays, 2021). Some low-quality cooking oils contain carcinogenic compounds formed during processing or due to contamination. Regular consumption of such oils can increase the risk of developing certain types of cancer (Rajendran et al., 2020). Contaminated or rancid cooking oil may contain toxins or pathogens that can weaken the immune system, making consumers more vulnerable to infections and diseases (Banerji et al., 2003).

Government bodies and regulatory agencies often establish quality standards and specifications for cooking oil to ensure consumer safety and product integrity. These standards may include parameters for purity, fatty acid composition, trans fat content, and levels of contaminants (Casanova et al., 2021). Regulations generally require accurate labeling for cooking oil products, including information on ingredients, nutritional content, manufacturing processes, and expiration dates. Clear and transparent labeling helps consumers make informed choices and avoid purchasing low-quality cooking oil (Scott & Sesmero, 2022).

Regulatory bodies conduct inspections and audits of food manufacturing facilities to ensure compliance with industry regulations. Violations can result in fines, product recalls, or legal action to protect consumer health and safety (Siahaan, 2023). Government agencies and health organizations often conduct public awareness campaigns to educate consumers about the importance of using high-quality cooking oil and how to identify signs of rancidity or contamination. These campaigns promote healthy cooking practices and empower consumers to make choices based on information (Capitão et al., 2022). Thus, low-quality cooking oil can pose serious risks to consumer health, emphasizing the need for stringent industry regulations to ensure product safety and integrity. By implementing quality standards, labeling requirements, quality control measures, inspections, and public awareness initiatives, regulatory bodies can mitigate these risks and protect public health.

Many methods can be used to test the quality of cooking oil, such as solubility test, melting point, polymorphism, boiling point, softening point, slipping point, shot melting point, specific gravity, viscosity, refractive index, turbidity point, smoke point, flash point. and hotspots and others (Rosalina & Kadarisman, 2018). Viscosity is a determination of the flow rate of a liquid. The greater the density of a liquid, the more friction an object will experience. From this situation, through the magnitude of the speed of an object, the frictional force on an object moving in a liquid with a greater density can be determined. The friction force experienced by a ball moving in a liquid whose density is greater according to Stokes' law. The viscosity coefficient is defined as the resistance that arises in a flowing liquid (Pratiwi & Luthfia, 2023).

The viscosity of a fluid is the resistance caused by friction between fluid molecules, which can resist fluid flow so that it can be expressed as an indicator of the level of viscosity. According to Sir George Stokes, the drag force experienced by a ball when it moves at a certain speed in a fluid. When it starts to fall into the fluid, the ball accelerates so that its speed increases. This speed is called terminal speed (Sidiq & Samyono, 2016). Khairunnisa (2019) measured water viscosity using a tracker-based damped oscillation method. The tracker is used to analyze videos by determining position over time, presents graphs, and uses the fit builder feature to determine the attenuation coefficient. Viscosity is a measurement that states the amount of friction in a fluid. Fast-flowing fluids have a small viscosity while slow-flowing fluids have a large viscosity. One of the properties of liquids is that they have different viscosity coefficients (Soper, 2019).

According to Stokes, the friction force is given by what is called Stokes' formula:

$$F = 6\pi r\eta v \tag{1}$$

F is the gravity force which is precisely balanced with the friction force and the ball falls with a constant speed of v so that the equation applies

$$F = mg = 6\pi r\eta v \tag{2}$$

An upward force also acts on the ball, Archimedes' force is equal to the weight of the displaced fluid, which is equal to

$$F_{Arch} = V\rho_f g = \frac{4}{3}\pi r^3 \rho_f g \tag{3}$$

where V is the volume of the ball and ρ_f is the density of the liquid. By writing down the mass value of the ball, then

$$m = V\rho_b \Rightarrow F = V\rho_b g = \frac{4}{3}\pi r^3 \rho_b g \tag{4}$$

With the value of ρ_b being the density of the ball, the magnitude of the ball's gravity is reduced by the Archimedes force, so that the Stokes equation becomes:

$$F = mg = 6\pi r\eta v$$

$$F - F_{Arch} = \frac{4}{3}\pi r^3 \rho_b g - \frac{4}{3}\pi r^3 \rho_f g = 6\pi r\eta v \tag{5}$$

Then it produces a viscosity (η):

$$\eta = \frac{\frac{4}{3}\pi r^3(\rho_b - \rho_f)g}{6\pi r v} \tag{6}$$

$$\eta = \frac{2r^2(\rho_b - \rho_f)g}{9v} \ or = \frac{2}{9}\frac{r^2 g(\rho_b - \rho_f)}{v} \tag{7}$$

F = Gravity Force (N)
F_{Arch}= Archimedes Force (N)
m = mass (Kg)
g = Acceleration due to gravity = 9,8 (m/s^2)
r = Radius of ball (m)
ρ_b = density of the ball (Kg/m^3)
ρ_f = fluid density (Kg/m^3)
v = Speed of falling ball (m/s^2)

So by knowing the value of the density of the ball, the density of the fluid, by measuring the radius of the ball r, and also determining the value of the speed of the ball falling in the fluid, the value of the viscosity coefficient of the fluid can be determined. The SI unit of viscosity is defined as mm2/s or cm2/s, where 1 cm2/s is equivalent to 1 St (Stokes) (Young 2002). Another viscosity unit is Poise (P), 1P = 1 Ns/m2 (Regina et al., 2018).

Traditional viscometers, such as capillary and rotational types, offer high accuracy, widespread use, and durability, making them reliable and globally recognized for measuring fluid viscosity. However, they are often expensive, require specialized training for accurate use, and need regular maintenance and calibration. In contrast, Arduino-based instrumentation provides a cost-effective alternative, being significantly cheaper and highly flexible due to programmable customization with various sensors. This makes them ideal for educational purposes and budget-constrained research. Despite their affordability and accessibility, Arduino-based tools generally have limited accuracy, require knowledge of programming and electronics, and may lack the robustness and long-term reliability of traditional viscometers.

Tissos et al. (2014) have researched measuring fluid viscosity but using the Hall Effect sensor UGN3503 and Arduino Uno 328. Arduino performs calculations automatically to obtain fluid viscosity values. The value of the fluid viscosity is then displayed on the LCD. Arduino is a simple hardware development platform that is flexible and easy to use (Corno & Mannella, 2023). Testing the accuracy of the tool is realized, after obtaining the data from the test, the next step is to analyze the data and carry out an analysis of the value of the percentage of success and percentage of error on the fluid viscosity tool. The formulas for finding the error percentage are based on the following equation.

$$\%Error = \frac{Calculated\ value - Measured\ value}{Calculate\ value}\ x\ 100\%$$

This research aims to determine oil quality based on the viscosity coefficient value using an Arduino UNO-based viscosity coefficient determining tool. New technologies such as the Arduino UNO offer great potential for adaptation in a variety of scientific and industrial applications. However, research on the use of Arduino UNO for viscosity measurements is still limited. By bridging this gap, this research can combine innovative technology with viscosity measurement practice, opening new opportunities for the development of better and more affordable tools. This research is one of the learning processes that can facilitate students to investigate real phenomena from the real world by utilizing technology to overcome the limitations of human observational abilities. Teachers need to consider utilizing technology that can help students retrieve data, present data and interpret data resulting from investigations into science phenomena from the real world more accurately.

METHODS

This research was carried out by designing an Arduino UNO installation program with tools and materials assembled as in FIGURE 1. Arduino is an open source device and is often used to design and manufacture electronic devices. Plus the software is easy to use and helps users with their work. It has several uses, one of which is to develop devices that can work automatically.

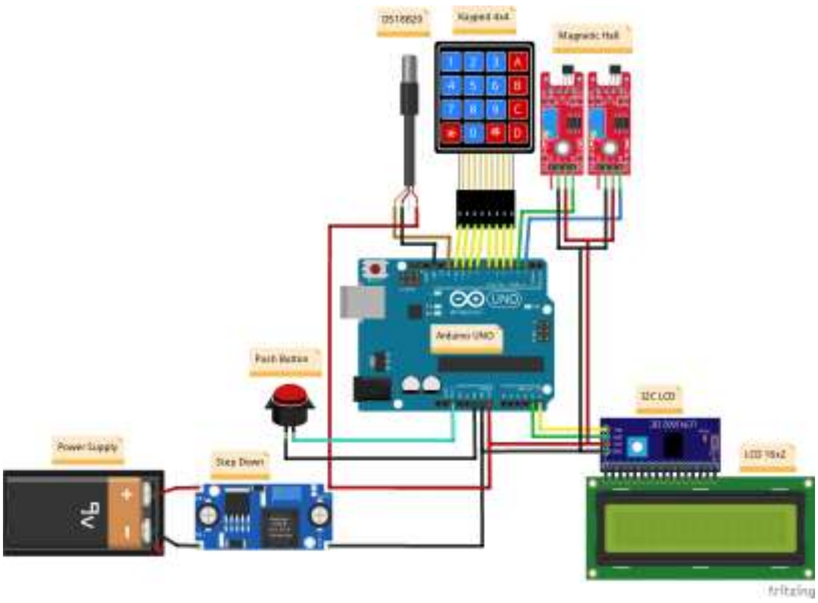

FIGURE 1. Arduino UNO circuit used in this research.

The devices used in this series of tools for determining the viscosity coefficient value are: (1) Arduino Uno, (2) 12v 2a power supply, (3) Step down, (4) 16x2 LCD, (5) 2 magnetic sensors, (6) Push button, and (7) Acrylic material with 10x3 mm raft cable. For how this tool works, you can see the flowchart in FIGURE 2.

Arduino Uno328 is a microcontroller chip that has been integrated with the ATmega328 microcontroller which is equipped with various features that provide convenience for users. The ATmega328 microcontroller consists of 14 digital input and output pins which can be used as PWM output with 6 pins and an analog input pin as many as 6 pieces and several other devices. This microcontroller can be connected directly to a computer using a USB cable without any other additional devices. The Arduino Uno contains a microprocessor and is equipped with a 16 MHz oscillator (which allows time-based operations to be carried out precisely), and a regulator (generator). voltage) 5 volts. Several pins are available on the board. Pins 0 to 13 are used for digital signals, which only have a value of 0 or 1. Pins A0-A5 are used for analog signals to hold data, 32KB flash memory, and Erasable Programmable Read-Only Memory (EEPROM) to store programs (Tissos et al., 2014).

The Hall Effect sensor is made of a layer of silicon and two electrodes. When there is no magnetic field affecting the sensor, a current flows through the electrode which results in the electrode being balanced and causing the output voltage to be 0 volts, and vice versa. The main working principle of this sensor is the Lorentz Force, which is a force that works due to the presence of electric charges moving in the sensor a magnetic field. The Lorentz force acting on a conducting plate given a magnetic field applies the equation: F = qV x B, where: F= Lorentz force (N); q= Electric charge (Coulomb); v=

Charge speed (m/s); B= Magnetic field (Tesla) (Tissos et al., 2014). DS18B20 has 3 leg pins consisting of Vs, ground, and input/output data. Vs itself functions as a voltage source. The voltage of the DS18B20 sensor is 3V-5.5V but Vs provides a voltage of 5V to the microcontroller because the microcontroller has a voltage of 5V. The ground leg is connected to the ground in the circuit. As a reference, the DS18B20 sensor has the following main specifications or features: 1) The interface communication used is only one cable (using a unique 1-wire protocol), 2) The onboard ROM is a storage place for sensor devices that have a 64-bit serial code, 3) Does not require additional components, and 4) Can also be used in the power range of 3 to 5.5v (Huda & Kurniawan, 2022).

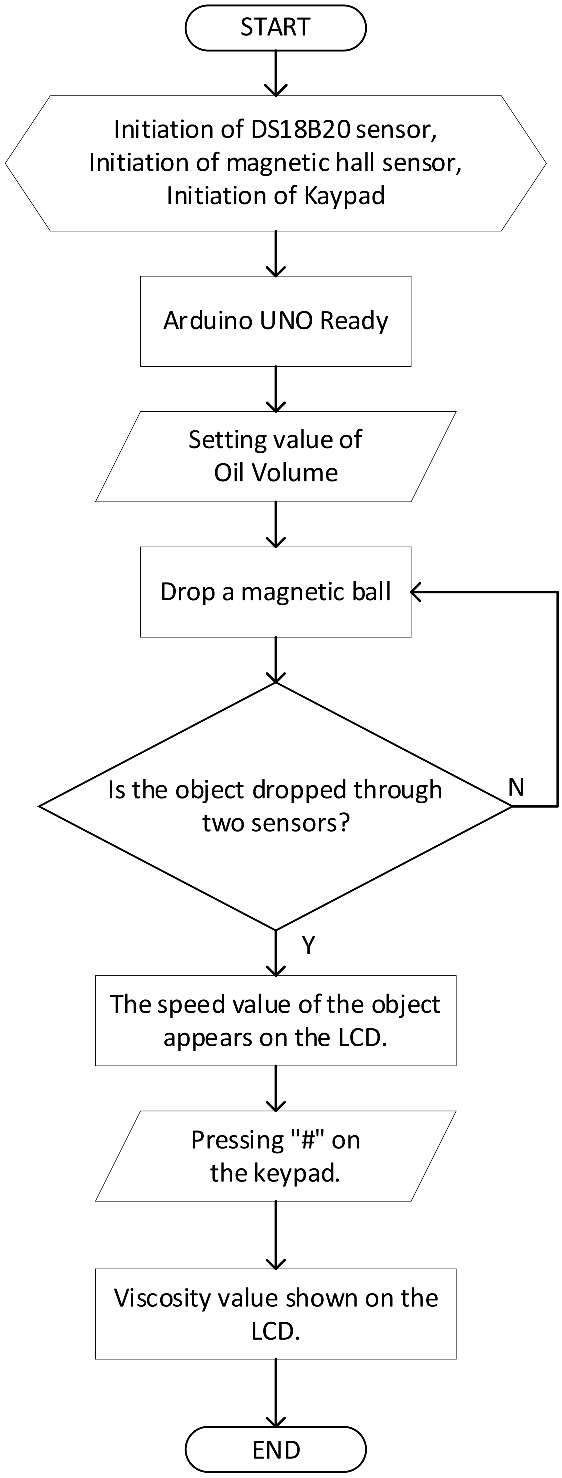

FIGURE 2. Flowchart of Arduino-based viscosity coefficient value determination program.

The way this tool works is, (1) Turn on the tool by plugging the adapter/power supply into 220vac electricity; (2) When the tool is on, set the oil volume according to the oil in the container that has been filled; (3) then set the oil volume value by pressing the "A" button on the keyboard; (4) After setting the oil volume, you can test the viscosity by dropping a load whose value has been input (in this case a magnetic ball), (5) After the object is dropped, the speed results will appear from the magnetic sensor readings obtained. from the travel time and distance between the two sensors on the LCD, and (6) After the speed value appears on the LCD, then press "#" on the keyboard to find out the viscosity value. Finished. If there is an error on the tool, please press the green button on the tool.

RESULTS AND DISCUSSION

The Arduino UNO device that has been designed is then assembled with a tube made of acrylic with a length of ± 150 cm, with sides of 3 x 3 cm. The results of the series of viscosity determination tools can be seen in FIGURE 3.

FIGURE 3. Arduino UNO-based viscosity determination tool circuit

One application that can be used to help study two-dimensional motion phenomena is Tracker Video Analysis. Developed by Java Open Source Physics (OSP), this application can track object motion to obtain the information needed in two-dimensional motion analysis. By recording motion phenomena using a video camera, the recording is then processed using Tracker Video Analysis, allowing students to obtain information such as the position of the object (x, y) at any time (t), which makes it easier to analyze the movement. In simple terms, Tracker can track object movement so that the information needed for motion analysis can be obtained. By recording real motion phenomena using a video camera and processing them with Tracker, the various data displayed can be interpreted, making it easier to analyze these motion phenomena.

The motion analysis procedure with a video tracker includes: importing the video to the tracker, then setting the frame, calibrating the stick, setting the x-axis and y-axis, determining the mass point of the object to be analyzed, and analyzing the object's motion with the autotrack command. The working principle of this program is that an iron ball that enters the fluid will be detected by magnetic sensors 1 and 2 if it passes through the sensor, which is placed at a predetermined distance. The distance between the magnetic ball detection sensors is determined by analyzing the video tracker produced at the beginning, as seen in FIGURE 4.

FIGURE 4. Determination of sensor distance at constant terminal speed.

FIGURE 4 is produced from video tracker analysis, constant speed values are produced at a minimum distance of 20 cm and a maximum of 110 cm. So magnetic sensors 1 and 2 are given a distance of approximately the distance range obtained. The balls used in the research were made of magnetic material, due to suggestions from research by Rahmani et al (2022), to choose a more effective type of sensor for magnetic balls and iron balls. If you still use a magnetic ball, choose a magnetic ball with strong magnetism and a larger diameter so that it will be detected more easily by the sensor.

Research was carried out to test oil quality by determining the viscosity coefficient value. The oils used in this research were: (1) oil 1 with the coconut oil category (B); (2) oil 2 in the palm oil category (Sc); (3) oil 3 in the palm oil (Sn) category; (4) oil 4 in the government oil (MK) category; (5) oil 5 with bulk oil category (C).

The main difficulty in the fluid viscosity test experiment using this tool for determining the value of the oil viscosity coefficient is when changing one oil to another oil, which requires accurate determination of the oil mass and oil height to obtain the oil volume value, by writing it on the LCD using the keypad so that the oil volume is recorded. that is measured. Then to find out the viscosity value, press the "#" button. The results displayed on the LCD will enter the serial monitor program if connected to a device such as a laptop. Arduino is a development of science and technology in the field of electronics. Arduino can be used to develop independent interactive objects or can be connected to software on a computer (Tupac-Yupanqui et al., 2022). The display of data results on a laptop device is shown in FIGURE 5.

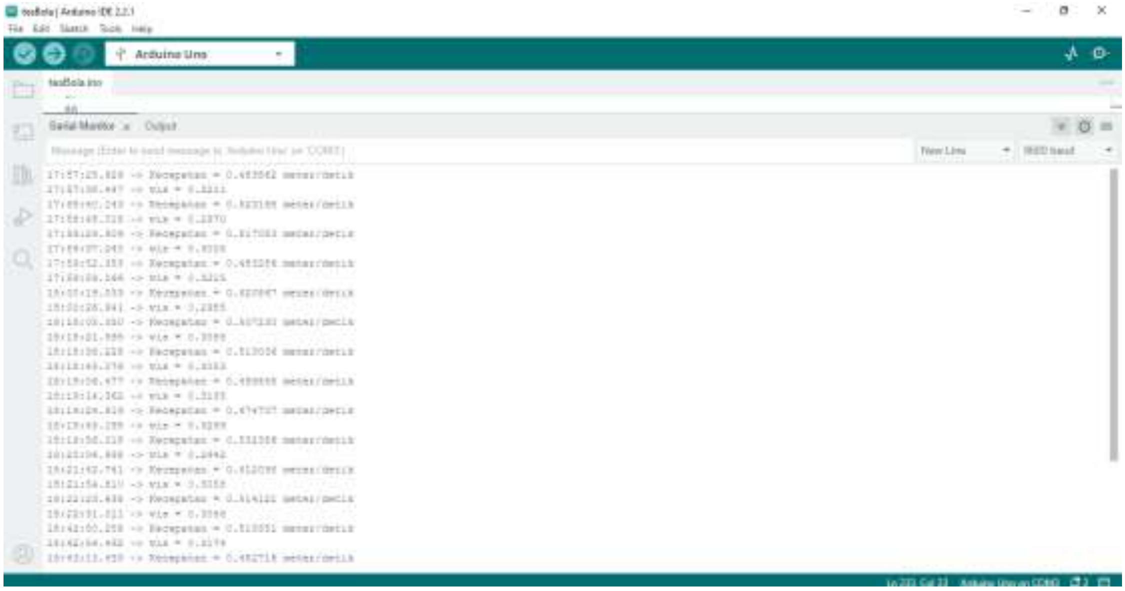

FIGURE 5. Data results obtained from the Arduino UNO serial monitor program.

The results of the 5 oils, after experiments were carried out using the Arduino UNO-based viscosity value determination tool, can be seen in TABLE 1. Oil 1 obtained a viscosity coefficient value of 0.2732 Pa.s; oil 2 with 0.3077 Pa.s; oil 3 with 0.3127 Pa.s; oil 4 with 0.3186; and oil 5 with 0.3218 Pa.s.

TABLE 1. Results of oil viscosity value data from an Arduino UNO-based viscosity determining tool.

Exp.	Oil 1		Oil 2		Oil 3		Oil 4		Oil 5	
	v (m/s)	η (Pa.s)	v (m/s)	η (Pa.s)	v (m/s)	η (Pa.s)	v (m/s)	η (Pa.s)	v (m/s)	η (Pa.s)
1	0.57	0.2702	0.52	0.2970	0.51	0.3088	0.51	0.3174	0.50	0.3288
2	0.54	0.2856	0.48	0.3211	0.51	0.3053	0.48	0.3377	0.52	0.3177
3	0.59	0.2646	0.52	0.3005	0.50	0.3135	0.53	0.3102	0.51	0.3223
4	0.58	0.2689	0.48	0.3215	0.51	0.3058	0.53	0.3100	0.51	0.3194
5	0.56	0.2768	0.52	0.2985	0.47	0.3299	0.51	0.3175	0.51	0.3208
Rate	0.57	0.2732	0.50	0.3077	0.50	0.3127	0.51	0.3186	0.51	0.3218

Meanwhile, the results of the oil viscosity value using manual calculation using equation (7) obtained the results shown in TABLE 2. Oil 1 obtained a viscosity coefficient value of 0.2733 Pa.s; oil 2 with 0.3089 Pa.s; oil 3 with 0.3136 Pa.s; oil 4 with 0.3188; and oil 5 with 0.3219 Pa.s.

TABLE 2. Data results for oil viscosity values from formula calculations.

Exp.	Oil 1		Oil 2		Oil 3		Oil 4		Oil 5	
	v (m/s)	η (Pa.s)	v (m/s)	η (Pa.s)	v (m/s)	η (Pa.s)	v (m/s)	η (Pa.s)	v (m/s)	η (Pa.s)
1	0.57	0.2721	0.52	0.2990	0.51	0.3071	0.51	0.3196	0.50	0.3283
2	0.54	0.2873	0.48	0.3239	0.51	0.3071	0.48	0.3396	0.52	0.3157
3	0.59	0.2629	0.52	0.2990	0.50	0.3132	0.53	0.3076	0.51	0.3219
4	0.58	0.2674	0.48	0.3239	0.51	0.3071	0.53	0.3076	0.51	0.3219
5	0.56	0.2770	0.52	0.2990	0.47	0.3332	0.51	0.3196	0.51	0.3219
Rate	0.57	0.2733	0.50	0.3089	0.50	0.3136	0.51	0.3188	0.51	0.3219

The two data results obtained, shows a small difference, the percentage error that occurs from the oil viscosity-determining tool is 0.17%. The second result of the oil viscosity coefficient value data can be seen in FIGURE 6.

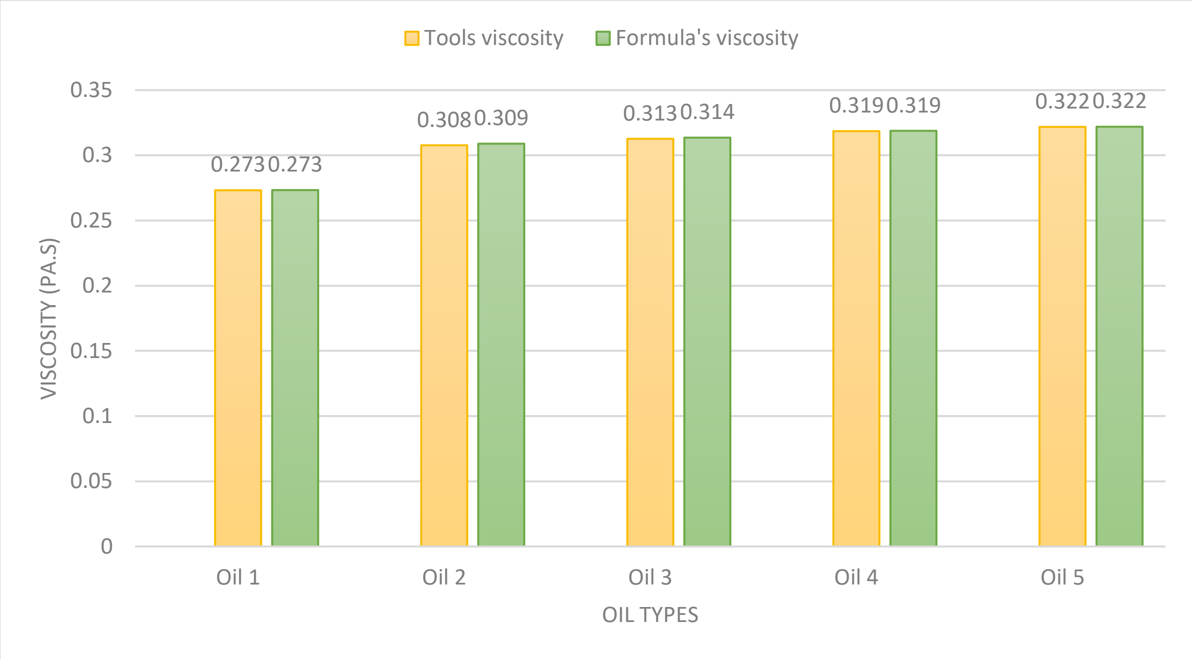

FIGURE 6. Oil coefficient value with tools and formula calculations.

Based on FIGURE 6, it can be seen that the oil with a smaller viscosity coefficient value is coconut oil (better quality than palm oil), while the bulk oil quality is indicated by a larger viscosity coefficient value. So from the data obtained, it can be stated that the smaller the oil viscosity value, the better the quality of the oil. So for the best quality, the oil studied was oil 1 in the coconut oil category (B) with the result of obtaining a viscosity coefficient value of 0.273 Pa.s, and the next order was occupied by oil 2, oil 3, oil 4, and finally oil 5 (oil category bulk) which gets a viscosity coefficient value of 0.322 Pa.s. This is following previous research conducted by Budianto, which found that the viscosity coefficient value for cooking oil in SI units was (0.23 ± 0.002) Pa.s. (Setyanamurwan et al., 2022).

The accuracy of the results obtained by this tool is the readability of the object that passes through the sensor, if it is not readable then you have to repeat it. In using this research tool, there are certainly obstacles to be faced, including sometimes the sensor does not read when an object passes through it, so it has to be repeated several times to produce data. Apart from that, researchers often forget to restart the tool before using it again during repetition to retrieve data. Traditional techniques for measuring viscosity, such as viscometers, have been widely used due to their high accuracy and reliability. These instruments are essential in various industries, particularly in assessing oil quality for applications in food processing and industrial use, where precise measurements are critical. However, these traditional tools are often expensive and require specialized training for proper operation and maintenance. As a cost-effective alternative, Arduino-based instrumentation provides a more affordable and flexible solution. These tools can be customized with various sensors and programmed for specific applications, making them suitable for educational purposes and budget-constrained research. Although Arduino-based instruments may not match the precision of traditional viscometers, their lower cost and adaptability make them valuable for preliminary assessments and real-time monitoring in diverse settings. This shift towards more accessible technology could significantly impact the field of oil quality assessment, enabling broader adoption and facilitating advancements in academic research and practical applications.

Research findings in the field of cooking oil quality assessment have significant implications in various applications, such as food processing and industrial use. Careful quality assessments ensure that the oils used in food production meet safety standards and do not contain contaminants that are harmful to health. This is highlighted in research by Harwood & Aparicio, (2017) which shows that better knowledge of oil composition can help in choosing the right oil to use in frying food. In addition, better quality assessment can also increase efficiency in the frying process, resulting in more consistent and quality products (Ahmad et al., 2021). The implications of this research also include the impact on sustainability, where selecting oil from sustainable sources can reduce the environmental impact of oil production and minimize the waste of raw materials (Aires & Ferreira, 2022). In addition, research in this area supports innovation in the food industry, enabling the development of more innovative and high-quality products to meet increasingly diverse consumer needs. Thus, research in the assessment of cooking oil quality not only has an impact on the quality of the products produced, but also on process efficiency, sustainability, and innovation in the food industry (Harwood & Aparicio, 2017; Ahmad et al., 2021).

Viscosity values of oil are believed to provide valuable insights into the composition and stability of oil during the frying process. This study utilized reliable and accurate methods for viscosity measurement to evaluate oil quality, and the research findings indicated a significant relationship between viscosity values and the quality of oil used in food processing. These findings offer a deeper understanding of the significance of viscosity measurement in assessing and ensuring the quality of oil used in the food industry (Deng et al., 2018).

Implementing the viscosity measurement experiment using Arduino UNO in education offers a practical and innovative approach to deepen students' understanding of viscosity concepts and microcontroller technology. By designing and building their viscosity measurement tool, students not only grasp the basic principles of viscosity but also learn about Arduino UNO programming and sensor integration in a real-world context. This aligns with project-based learning approaches that encourage active engagement and direct application of theoretical concepts. Introducing Arduino UNO technology into the curriculum enables students to develop problem-solving skills, creativity, and digital literacy required in today's digital age (Sari et al., 2022). This approach also supports STEM learning goals by integrating various disciplines such as physics, engineering, and computer science (Reynante et al., 2020). Thus, implementing this experiment can enhance the quality of student learning and prepare them for real-world challenges in the fields of science and technology.

CONCLUSION

Oil quality based on the viscosity coefficient value with an Arduino UNO-based viscosity coefficient determination tool was obtained from experiments carried out with an iron ball that entered the oil and was detected by magnetic sensors 1 and 2 if it passed through the sensor. Constant speed values are produced at a minimum distance of 20 cm and a maximum of 110 cm so that magnetic sensors 1 and 2 are given a distance of approximately the distance range obtained. The oils used in this research were: (1) oil 1 with the coconut oil category (B); (2) oil 2 in the palm oil category (Sc); (3) oil 3 in the palm oil (Sn) category; (4) oil 4 in the government oil (MK) category; (5) oil 5 with bulk oil category (C). The percentage of error that occurs from the tool for determining oil viscosity is 0.17%. So for the best quality, the oil studied was oil 1 in the coconut oil category (B) with the result of obtaining a viscosity coefficient value of 0.273 Pa.s, and the next order was occupied by oil 2, oil 3, oil 4, and finally oil 5 (oil category bulk) which gets a viscosity coefficient value of 0.322 Pa.s. This research fosters innovation in the food industry, allowing for the creation of diverse, high-quality products to meet evolving consumer demands. Overall, research in cooking oil quality assessment affects product quality, process efficiency, sustainability, and innovation. Future investigations may delve into complex fluid dynamics, comparative studies with traditional methods, and integration with emerging technologies like IoT or machine learning. Collaboration across disciplines can further drive innovation, leading to the development of new methodologies and technologies for viscosity measurement, thus contributing to the advancement of knowledge in this area.

REFERENCES

Ahmad, M.H., Shahbaz, Z., Imran, M., Khan, M.K., Muhammad, N., Iqbal, S., Ahmed, W. and Ahmad, T. (2021). Monitoring of frying process in canola oil blend using fourier transform infrared and chemometrics techniques. *Food Science & Nutrition*, 9(11), pp.6089–6098. doi:https://doi.org/10.1002/fsn3.2558.

Aires, R.F. de F. and Ferreira, L. (2022). A New Multi-Criteria Approach for Sustainable Material Selection Problem. *Sustainability*, 14(18), p.11191. doi:https://doi.org/10.3390/su141811191.

Asmara, A. (2019). Penentuan Bilangan Peroksida Minyak Rbd (Refined Bleached Deodorized) Olein PT. Phpo dengan Metode Titrasi Iodometri. *AMINA*, 1(2), pp.79–83. doi:https://doi.org/10.22373/amina.v1i2.39.

Asraf H, M., Md Tahir, N., Dalila K.A., N. and Hussain, A. (2018). An Agricultural Tele-Monitoring Method in Detecting Nutrient Deficiencies of Oil Palm Leaf. *International Journal of Engineering & Technology*, 7(4.11), p.227. doi:https://doi.org/10.14419/ijet.v7i4.11.20812.

Banerji, R., Karkee, A., Kanojiya, P. and Saroj, S.D. (2021). Pore-forming toxins of foodborne pathogens. *Comprehensive Reviews in Food Science and Food Safety*, 20(3), pp.2265–2285. doi:https://doi.org/10.1111/1541-4337.12737.

Capitão, C., Martins, R., Feteira-Santos, R., Virgolino, A., Graça, P., Gregório, M.J. and Santos, O. (2022). Developing healthy eating promotion mass media campaigns: A qualitative study. *Frontiers in Public Health*, 10. doi:https://doi.org/10.3389/fpubh.2022.931116.

Casanova, E., Knowles, T.D.J., Mulhall, I., Sikora, M., Smyth, J. and Evershed, R.P. (2021). Generation of Two New Radiocarbon Standards for Compound-Specific Radiocarbon Analyses of Fatty Acids from Bog Butter Finds. *Radiocarbon*, 63(3), pp.771–783. doi:https://doi.org/10.1017/rdc.2021.15.

Corno, F. and Mannella, L. (2023). Security Evaluation of Arduino Projects Developed by Hobbyist IoT Programmers. *Sensors*, [online] 23(5), p.2740. doi:https://doi.org/10.3390/s23052740.

Deng, N., Cao, N., Li, P., Peng, Y., Li, X., Liu, L., Pu, H., Xie, S., Luo, J., Wu, Z. and Liu, M. (2018). Microfluidic evaluation of some edible oil quality based on viscosity and interfacial tensions. *International journal of food science & technology*, 53(4), pp.946–953. doi:https://doi.org/10.1111/ijfs.13667.

Dimopoulos, A., Zournatzis, I., Gan, T.-H. and Chatzakos, P. (2023). Multi-Response Optimization of Ti6Al4V Support Structures for Laser Powder Bed Fusion Systems. *Journal of Manufacturing and Materials Processing*, [online] 7(1), p.22. doi:https://doi.org/10.3390/jmmp7010022.

Harwood, J. and Aparicio, R. (2017). *Handbook of Olive Oil: Analysis and Properties*. Gaithersburg, MD, USA: Aspen: Springer.

Huda, M.B.R. and Kurniawan, W.D. (2022). Analisa Sistem Pengendalian Temperatur Menggunakan Sensor DS18B20 Berbasis Mikrokontroler Arduino. *Jurnal Rekayasa Mesin*, 7(2), pp.18–23.

Khairunnisa, K. (2019). Pembelajaran Fisika Berbasis Tracker dalam Penentuan Viskositas Air Menggunakan Metode Osilasi Teredam (Vol. 1, No. 1). In: *Prosiding Seminar Nasional Pendidikan MIPA dan Teknologi II* . pp.108–115.

Laelia, R. and Kurnia, P. (2019). Pengaruh frekuensi penggorengan terhadap angka asam dan angka peroksida pada berbagai jenis minyak . *Ilmu Gizi Indonesia*, 3(1), pp.23–34.

Mays, K.A. (2021). Designing Oral Health Curriculum That Facilitates Greater Integration of Oral Health Into Overall Health. *Frontiers in Dental Medicine*, 2. doi:https://doi.org/10.3389/fdmed.2021.680520.

Mozaffarian, D., Katan, M.B., Ascherio, A., Stampfer, M.J. and Willett, W.C. (2006). Trans fatty acids and cardiovascular disease. *New England Journal of Medicine*, 354(15), pp.1601–1613. doi:https://doi.org/10.1056/NEJMra054035.

Pratiwi, U. and Luthfia, A. (2023). Pengukuran Viskositas Oli dan Minyak Goreng Menggunakan Sensor Mini Reed Switch Magnetic Berbasis Arduino. *Orbita*, 9(2), pp.277–277. doi:https://doi.org/10.31764/orbita.v9i2.17342.

Rahmani, Y., Hamdani, D. and Risdianto, E. (2022). Pengembangan alat peraga eksperimen fisika dasar 1 pada materi viskositas fluida. *Amplitudo: Jurnal Ilmu Dan Pembelajaran Fisika*, 1(2), pp.128–137. doi:https://doi.org/10.33369/ajipf.1.2.128-137.

Rajendran, P., Alzahrani, A.M., Rengarajan, T., Veeraraghavan, V.P. and Krishna Mohan, S. (2020). Consumption of reused vegetable oil intensifies BRCA1 mutations. *Critical Reviews in Food Science and Nutrition*, 62(5), pp.1222–1229. doi:https://doi.org/10.1080/10408398.2020.1837725.

Regina, O., Sudrajad, H. and Syaflita, D. (2019). Measurement of Viscosity Uses an Alternative Viscometer. *Jurnal Geliga Sains: Jurnal Pendidikan Fisika*, 6(2), p.127. doi:https://doi.org/10.31258/jgs.6.2.127-132.

Reynante, B.M., Selbach-Allen, M.E. and Pimentel, D.R. (2020). Exploring the Promises and Perils of Integrated STEM Through Disciplinary Practices and Epistemologies. *Science & Education*, 29(4), pp.785–803. doi:https://doi.org/10.1007/s11191-020-00121-x.

Rosalina, D.R. and Kadarisman, N. (2018). Pengukuran Viskositas Minyak Goreng pada Berbagai Variasi Suhu dengan Menggunakan Sensor Fiber Optik. *Jurnal Ilmu Fisika dan Terapannya (JIFTA)*, 7(1), pp.15–22.

Sari, U., Çelik, H., Pektaş, H.M. and Yalçın, S. (2022). Effects of STEM-focused Arduino practical activities on problem-solving and entrepreneurship skills. *Australasian Journal of Educational Technology*, 38(3), pp.135–149. doi:https://doi.org/10.14742/ajet.7293.

Scott, F. and Sesmero, J.P. (2022). Market and welfare effects of quality misperception in food labels. *American Journal of Agricultural Economics*, 104(5). doi:https://doi.org/10.1111/ajae.12287.

Setyanamurwan, A.O., Astuti, I.A.D. and Suhendar, E. (2022). Analisis Koefisien Kekentalan Fluida pada Berbagai Merek Minyak Goreng Menggunakan Tracker. *Schrodinger Jurnal Ilmiah Mahasiswa Pendidikan Fisika*, 3(1), pp.42–50.

Siahaan, N.F. (2023). Consumer Protection Against the Production and Sale of Syrup Drugs Suspected of Being Contaminated with Hazardous Materials. *Journal of Social Research*, 2(3), pp.748–754. doi:https://doi.org/10.55324/josr.v2i3.722.

Sidiq, M.F. and Samyono, D. (2016). Nilai Koefisien Viskositas diukur dengan Metode Bola Jatuh dalam Fluida Viskos. *Engineering*, 7(2), p.7. doi:https://doi.org/10.24905/eng.v7i2.816.

Soper, A.K. (2019). Is water one liquid or two? *The Journal of Chemical Physics*, 150(23), p.234503. doi:https://doi.org/10.1063/1.5096460.

Tissos, N.P., Yulkifli, Y. and Kamus, Z. (2014). Pembuatan Sistem Pengukuran Viskositas Fluida Secara Digital Menggunakan Sensor Efek Hall UGN3503 Berbasis Arduino Uno328. *Jurnal Saintek*, 4(1), pp.71–83.

Tupac-Yupanqui, M., Vidal-Silva, C., Pavesi-Farriol, L., Sanchez Ortiz, A., Cardenas-Cobo, J. and Pereira, F. (2022). Exploiting Arduino Features to Develop Programming Competencies. *IEEE Access*, 10, pp.20602–20615. doi:https://doi.org/10.1109/access.2022.3150101.

Young, H.D. (2002). *Fisika untuk Universitas Jilid I*. Jakarta: Erlangga.