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Prototype of a Human Breath Alcohol Detection Device Using Three MQ Sensors Based on a Microcontroller

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A B S T R A C T

Alcohol consumption is a major contributor to road traffic accidents, a portable, affordable, real-time breath screening device is needed. This study designs and evaluates a microcontroller-based detector using MQ3, MQ2, and MQ7 sensors with IoT logging and alerts. An ESP32 reads sensor outputs, converts them to ppm via linear calibration, compares them with a Digital Breath Alcohol Tester (20 trials per sensor), and triggers a buzzer/Telegram notifications while sending data to Google Sheets. The system operated reliably with low error against the reference device (0.5–4.4%), MQ3 was the most accurate and stable. The prototype is feasible and effective. MQ3 is recommended, future work includes larger datasets and temperature-humidity compensation

INTRODUCTION

Road traffic accidents remain a significant public health problem in Indonesia, causing injury, death, and considerable socio-economic burden. National studies underscore the need for measurable prevention, including screening for alcohol influence among drivers as a modifiable risk factor (Buntara, 2019).

Alcohol consumption is associated with an increased risk of traffic-related injuries, especially among people of productive age in Indonesia. These epidemiological findings reinforce the urgency of a rapid, portable, low-cost breath alcohol detection device to support road safety enforcement in the field (Purbiantoro et al., 2019).

On the technology side, domestic research has demonstrated the feasibility of the MQ-3 sensor for detecting alcohol vapor in vehicles and in simple measurements. However, many implementations remain limited to basic detection without comprehensive testing on driver breath and without integrated alerting. This opens opportunities to develop more applied systems for field screening (Nugraha et al., 2022).

Advances in IoT have simplified the design of connected monitoring devices, for example using ESP32/ESP32-CAM with Telegram notifications and real-time logging. Domestic studies in security and automation demonstrate mature technical pathways to send immediate alerts, enable remote logging, and provide photo/text-based evidence—features relevant to breath alcohol detection systems in vehicles (Haripuddin et al., 2023).

Based on these needs, this study develops an ESP32-based breath alcohol detection prototype using a combination of MQ-3/MQ-2/MQ-7 sensors, equipped with Telegram alerts and direct data logging. Validation is performed by comparing sensor results against a Digital Breath Alcohol Tester (DBAT/Analyzer), as seen in national studies of breath measurement, to evaluate system accuracy and reliability in an Indonesian user context (Manela & Hidayat, 2018).

LITERATURE REVIEW

Alcohol

Alcohol (specifically ethanol) is a volatile organic compound that evaporates easily and is absorbed through the respiratory tract. Excessive consumption can impair central nervous system function and increase the risk of traffic accidents. Monitoring breath alcohol concentration is important to prevent such hazards. Detected alcohol levels cause changes in sensor resistance, which are converted into output voltage values for microcontroller processing (Ismail et al., 2021).

MQ3 Sensor

The MQ-3 is a metal-oxide semiconductor (MOS) gas sensor designed to detect alcohol vapor, gasoline, ethanol, and other organic vapors in air. It operates via resistance changes in the sensing element when exposed to target gas. When alcohol vapor is detected, the sensor's resistance changes significantly, producing an analog output signal that can be digitized and analyzed with a microcontroller (Ma'arif et al., 2017).

The MQ-3 uses SnO_2 (tin dioxide), which is highly sensitive to volatile gases. When alcohol gas contacts the sensor surface, a reaction occurs between the gas and oxygen adsorbed on the SnO_2 surface, changing resistance. An internal amplifier circuit translates this change into an electrical signal (Ismail et al., 2021).

MQ2 Sensor

The MQ-2 is an MOS gas sensor used to detect flammable gases such as LPG, propane, butane, methane, and smoke. It has high sensitivity and outputs an analog signal proportional to detected gas concentration. MQ-2 is widely used in household gas-leak detection systems because it integrates easily with microcontrollers like Arduino or ESP32 (O. A. et al., 2024).

The MQ-2 relies on the conductivity of SnO_2, which changes when reacting with target gases. Upon detection, the surface resistance decreases and is converted to an analog voltage. It requires preheating via an internal heater to stabilize performance; this warm-up period is important for accuracy (Hasim et al., 2023).

MQ7 Sensor

The MQ-7 is an MOS gas sensor designed primarily to detect carbon monoxide (CO) at low to moderate concentrations. It is used in air-quality monitoring and hazardous gas detection in industrial and household environments (Zidni et al., 2022).

Using an SnO_2 sensing element, the MQ-7 exhibits CO sensitivity. When CO is present near the sensor surface, reactions with adsorbed oxygen on the semiconductor change its resistance, which is converted to an analog voltage readable by a microcontroller (Wijanarko et al., 2022).

NodeMCU ESP32

The ESP32 microcontroller, developed by Espressif Systems as the successor to ESP8266, offers more features and capabilities: dual-core CPU, larger memory, support for multiple wireless protocols, and extensive peripherals for diverse applications (Ramschie et al., 2021). In this design, the ESP32 acts as the microcontroller and as the bridge to the monitoring application. It supports analog/digital I/O, PWM, SPI, I^2C, and more (Al Sarfini & Irawan, 2024).

Arduino IDE

The Arduino IDE is software from arduino.cc for developing sketches (programs) for Arduino boards. As an integrated development environment, it offers a menu-based interface and essential tools.

The Arduino IDE enables writing, compiling, and uploading code to Arduino boards. Its simple, intuitive interface is well-suited for beginners. Users write in a simplified C/C++ called a "sketch" (Widyatmika et al., 2021). The IDE is cross-platform (Windows, macOS, Linux) and open-source, enabling community-driven extensions via libraries and add-ons (Handayani et al., 2022).

Linear Regression

Simple Linear Regression (SLR) models a straight-line relationship between one independent (predictor) variable and a dependent (response) variable. Many observed outcomes are influenced by other variables (Padilah &

Adam, 2019). SLR is often used in production and quality forecasting for both qualitative and quantitative characteristics (Wijayanto, 2008).

METHODOLOGY

This research uses simple linear regression to design and test a human breath alcohol detector with three MQ sensors on a microcontroller platform. The workflow includes:

Block Diagram

The integrated system uses three MQ sensors (MQ-3, MQ-2, MQ-7) and an ESP32 to automatically detect alcohol content. The system can detect alcohol using all three sensors concurrently.

Operating Principle

The system continuously reads MQ-3, MQ-2, and MQ-7. Logic thresholds are applied as follows:

1. **MQ-3:** if ppm ≤ 52, the buzzer is off and a Telegram notification indicates alcohol detected; if ppm ≥ 52, the buzzer is on and Telegram indicates alcohol detected.
2. **MQ-2:** if ppm ≤ 100, buzzer off and Telegram indicates alcohol detected; if ppm ≥ 100, buzzer on and Telegram indicates alcohol detected.
3. **MQ-7:** if ppm ≤ 200, buzzer off and Telegram indicates alcohol detected; if ppm ≥ 200, buzzer on and Telegram indicates alcohol detected.

All notifications are delivered to a smartphone via the Telegram app, and readings are logged to Google Sheets.

Hardware Design

Hardware comprises electronics and mechanics. The electronic circuit is transferred to a PCB (Printed Circuit Board). The mechanical design defines the device enclosure. Component selection considers quality to ensure proper operation.

Software Design

Software includes flowcharting, linear-regression-based data processing, and Telegram bot notification logic.

RESULTS AND DISCUSSION

MQ-3 Sensor Testing and Analysis

Testing of the MQ-3 sensor's alcohol readings was carried out to determine the measurement error relative to a reference instrument, the reference instrument used was a Digital Breath Alcohol Tester. The sensor was tested over 20 trials. A comparison of alcohol readings obtained with the MQ-3 sensor and the Digital Breath Alcohol Tester (DBAT) is shown in Table 1 below.

Table 1. MQ-3 Sensor Alcohol Concentration Testing

Experiment	Adc Value	MQ3Sensor (ppm)	DBAT (ppm)	Measurement Difference	Error (%)
1st	209	50	49,2	0,8	1,62
2nd	211	52,3	51,2	1,1	2,14
3rd	210	50,6	49,85	0,75	1,50

4th	207	48,8	48,43	0,37	0,76
5th	214	54,1	52,92	1,18	2,07
6th	208	49,2	48,12	1,08	2,24
7th	206	48,8	48,46	0,38	0,78
8th	208	49,2	48,52	0,48	0,98
9th	218	56,25	54,94	1,31	2,38
10th	214	54,1	53,24	0,86	1,61
11th	211	51,1	49,89	1,21	2,42
12th	213	53,4	52,15	1,25	2,39
13th	203	45,15	44,34	0,81	1,82
14th	210	50,6	48,42	2,18	4,5
15th	215	54,75	52,97	1,78	3,36
16th	213	53,4	52,11	1,29	2,47
17th	210	50,6	49,18	1,42	2,89
18th	211	51,1	50,2	0,9	1,72
19th	209	50	48,64	1,36	2,79
20th	214	54,1	52,45	1,65	3,14
Total Error Average Error =					43,95 2,18

Based on the MQ-3 sensor testing results presented in Table 1, the authors aim to verify the ADC and ppm values using the prescribed formulas. In Trial 1, the authors provide a worked example to validate the ADC and ppm calculations using those formulas.

$$\text{ADC} = \frac{\text{Vout}}{\text{Vref}} \text{ x } 4095$$
$$= \frac{0{,}168}{3{,}3}\ x\ 4095$$
$$= 208{,}47$$

To compute the ppm value, the authors must first determine Rs:

$$\text{Rs} = \frac{\text{Vc}-\text{Vout}}{\text{Vout}}\ x\ Rl$$
$$= \frac{(3{,}3-0{,}168)}{0{,}168}\ x\ 200k\Omega$$
$$= 3728{,}57k\Omega$$

After getting the value of Rs, calculate the ratio, Rs/Ro

$$\text{Rs/Ro} = 3728{,}57/1000$$
$$= 3{,}728$$

Calculate the ppm value:

$$\text{Ppm} = 106{,}62 \text{ x } (3{,}728)^{-0{,}75}$$
$$= 106{,}62 \text{ x } 0{,}372$$
$$= 39{,}735$$
$$= 39{,}74\text{ppm}$$

From the first-trial calculations used to obtain the ADC and ppm values, the analysis shows that the ADC computed by formula is slightly lower than the ADC shown on the serial monitor (MQ-3 output). In Trial 1, the ADC from the formula is 208.47, whereas the serial monitor displays 209, yielding a difference of 0.53. For ppm, the formula gives 39.74 ppm, while the serial monitor shows 50 ppm, resulting in a difference of 10.26 ppm.

Thus, the discrepancy between the formula-based ADC value and the serial-monitor ADC is smaller than the discrepancy between the formula-based ppm value and the serial-monitor ppm.

As shown in Table 4.1 above, the MQ-3 sensor demonstrates satisfactory performance in measuring breath alcohol concentration, with an average error of 2.18% and a cumulative total error of 43.95%. This average error was obtained using the following formula:

$$\text{Average error} = \frac{\Sigma\, \text{error}}{\Sigma\, \text{trials}} \times 100\%$$

The average alcohol concentration measured by the MQ-3 was 51.38 ppm, whereas the Digital Breath Alcohol Tester recorded an average of 50.28 ppm. The mean difference between the two instruments is only 1.10 ppm, indicating a high level of agreement. The error is computed using the formula below:

$$Error = \frac{difference\ in\ reading\ values}{Measuring\ instrument\ value} \times 100\%$$

The following graph compares the alcohol content readings, which can be seen in Figure 1 below.

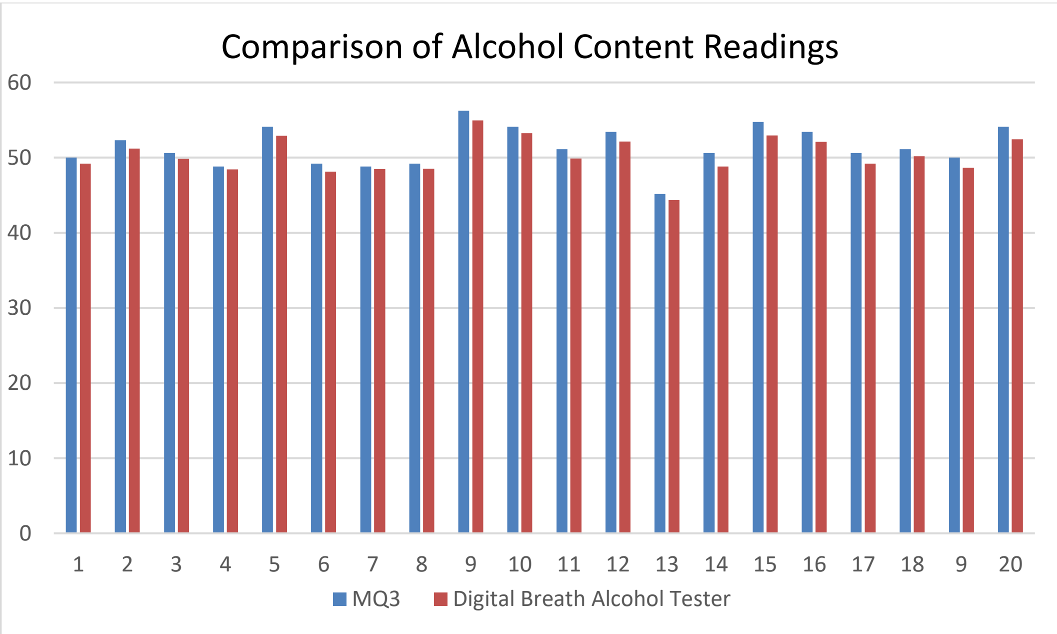

Figure 1. Alcohol Content Reading Graph

Based on Figure 1, the MQ-3 sensor is generally suitable for simple alcohol-concentration measurements; however, under certain conditions calibration or repeated data acquisition is needed to minimize errors, particularly to maintain accuracy in environments where the temperature remains relatively stable.

MQ-2 Sensor Testing and Analysis

Testing of the MQ-2 sensor's alcohol readings was carried out to determine the measurement error relative to a reference instrument, the reference instrument used was a Digital Breath Alcohol Tester. The sensor was tested over

20 trials. A comparison of alcohol readings obtained with the MQ-2 sensor and the Digital Breath Alcohol Tester (DBAT) is shown in Table 2 below.

Table 2. MQ-2 Sensor Alcohol Concentration Testing

Experiment	Adc Value	MQ2Sensor (ppm)	DBAT(ppm)	Measurement Difference	Error (%)
1st	933	6,84	6,80	0,04	0,58
2nd	934	6,82	6,80	0,02	0,29
3rd	933	6,86	6,85	0,01	0,14
4th	935	6,95	6,91	0,04	0,59
5th	935	6,78	6,74	0,04	0,59
6th	935,5	6,8	6,78	0,02	0,29
7th	936	6,61	6,58	0,03	0,45
8th	936,5	6,76	6,70	0,06	0,89
9th	937	5,44	5,41	0,03	0,55
10th	937,5	7,05	7	0,05	0,71
11th	938	6,97	6,85	0,12	1,75
12th	938,5	7,25	7,20	0,05	0,69
13th	939	6,35	6,30	0,05	0,79
14th	939,5	6,66	6,62	0,06	0,90
15th	940	7,2	7,18	0,02	0,27
Experiment	Adc Value	MQ2Sensor (ppm)	DBAT(ppm)	Measurement Difference	Error (%)
16th	940,5	6,74	6,72	0,02	0,29
17th	941	6,68	6,65	0,03	0,45
18th	941,5	6,82	6,80	0,02	0,29
19th	943	7,9	7,88	0,02	0,25
20th	940	7,2	7,18	0,02	0,27
Total Error					10,98
Average Error					0,549

Based on the MQ-2 sensor testing results presented in Table 2, the authors aim to verify the ADC and ppm values using the prescribed formulas. In Trial 1, the authors provide a worked example to validate the ADC and ppm calculations using those formulas.

$$\text{ADC} = \frac{\text{Vout}}{\text{Vref}} \text{ x } 4095$$
$$= \frac{0{,}75}{3{,}3} \text{ x } 4095$$
$$= 930{,}681$$
$$= 930{,}68\text{ppm}$$

To compute the ppm value, the authors must first determine Rs:

$$\text{Rs} = \frac{\text{Vc}-\text{Vout}}{\text{Vout}}\ x\ Rl$$
$$= \frac{(3{,}3-0{,}75)}{0{,}75}\ x\ 5\ k\Omega$$
$$= 17k\Omega$$

After getting the value of Rs, calculate the ratio Rs/Ro:

$$Rs/Ro = 17/3{,}3$$
$$= 5{,}151$$

Calculate the ppm value:

$$Ppm = 0{,}198 \times (5{,}15)^{-0{,}21}$$
$$= 0{,}198 \times 0{,}708$$
$$= 0{,}140$$
$$= 0{,}14ppm$$

From the first-trial calculations used to obtain the ADC and ppm values, the analysis shows that the ADC computed by formula matches the ADC displayed on the serial monitor (MQ-2 output). In Trial 1, the formula-based ADC is 1051 and the serial-monitor ADC is also 1051. For ppm, the formula yields 0.14 ppm, whereas the serial monitor shows 6.84 ppm, giving a difference of 6.70 ppm. Thus, the ADC value from the formula is identical to the ADC shown on the MQ-2 serial monitor, while the formula-based ppm value is lower than the ppm shown on the serial monitor.

In Table 2 above, the MQ2 sensor demonstrates quite good alcohol content measurement performance, with an average error of 0.54% and a total error of 10.98%. This average error value is obtained using the following formula:

$$\text{Average } error = \frac{\Sigma\, error}{\Sigma \text{ trials}} \times 100\%$$

The average alcohol content measured by the MQ2 was 6.83 ppm, while the Digital Breath Alcohol Tester recorded an average of 6.80 ppm. The difference in average alcohol content between the two devices was only 0.03 ppm, indicating a fairly high degree of agreement between the measurement results. The error value was obtained using the following formula:

$$Error = \frac{difference\ in\ reading\ values}{Measuring\ instrument\ value} \times 100\%$$

The following graph compares the alcohol content readings, which can be seen in Figure 2 below.

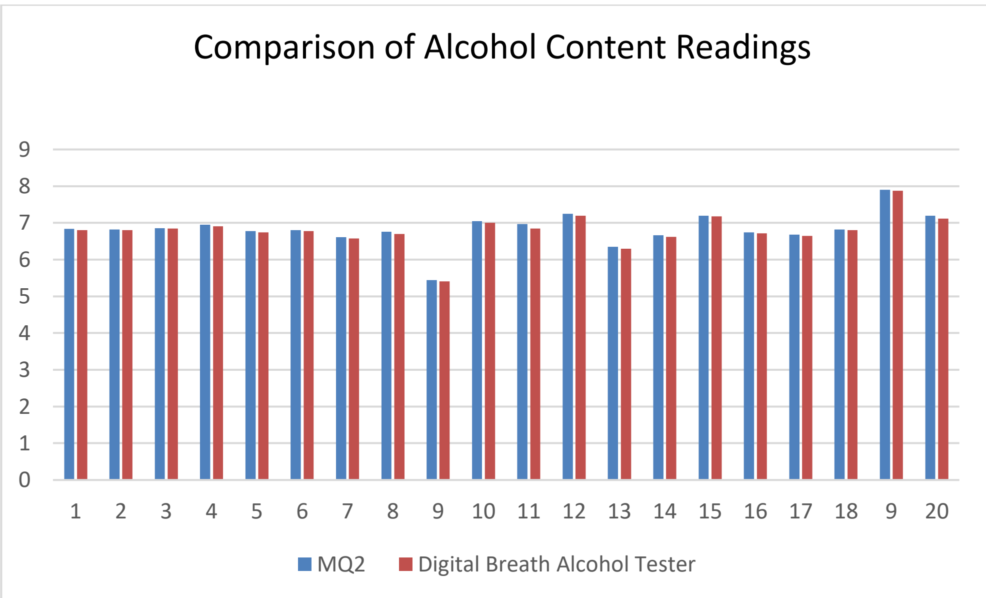

Figure 2. Alcohol Content Reading Graph

Based on Figure 2, it can be seen that overall the MQ2 sensor is still suitable for simple alcohol content measurements, but for sensitivity and accuracy with alcohol, the author prefers the MQ3 sensor.

MQ-7 Sensor Testing and Analysis

Testing of the MQ-7 sensor's alcohol readings was carried out to determine the measurement error relative to a reference instrument, the reference instrument used was a Digital Breath Alcohol Tester. The sensor was tested over 20 trials. A comparison of alcohol readings obtained with the MQ-2 sensor and the Digital Breath Alcohol Tester (DBAT) is shown in Table 3 below.

Table 3. MQ-7 Sensor Alcohol Concentration Testing

Experiment	Adc Value	MQ7Sensor (ppm)	DBAT(ppm)	Measurement Difference	Error (%)
1st	1559	41,65	40,5	1,15	2,83
2nd	1564	42,04	41	1,04	2,53
3rd	1632	47,67	46,5	1,17	2,51
4th	1590	44,12	43,02	1,1	2,55
5th	1580	43,31	42,1	1,21	2,87
6th	1535	39,8	37,5	2,3	6,13
Experiment	Adc Value	MQ7Sensor (ppm)	DBAT(ppm)	Measurement Difference	Error (%)
7th	1596	44,61	42,88	1,73	4,03
8th	1575	42,9	41,3	1,6	3,87
9th	1619	46,55	44,5	2,05	4,60
10th	1595	44,53	42,3	2,23	5,27
11th	1484	36,17	34,75	1,42	4,08
12th	1614	46,12	43,23	2,89	6,68
13th	1606	45,45	43,1	2,35	5,45
14th	1753	59,32	57,08	2,24	3,92
15th	1591	44,2	42,50	1,7	4
16th	1559	41,65	39,98	1,69	4,22
17th	1590	44,12	42,15	1,97	4,67
18th	1580	43,21	40,78	2,43	5,95
19th	1596	44,61	42,31	2,3	5,43
20th	1575	42,9	40,45	2,45	6,05
Total Error					87,64
Average Error					4,38

Based on the MQ-7 sensor testing results presented in Table 3, the authors aim to verify the ADC and ppm values using the prescribed formulas. In Trial 1, the authors provide a worked example to validate the ADC and ppm calculations using those formulas.

$$\text{ADC} = \frac{\text{Vout}}{\text{Vref}} \times 4095$$

$$= \frac{1{,}25}{3{,}3} \times 4095$$

$$= 1551{,}136$$
$$= 1551{,}14$$

To compute the ppm value, the authors must first determine Rs:

$$Rs = \frac{Vc - Vout}{Vout} \; x \; Rl$$
$$= \frac{(3{,}3 - 1{,}25)}{1{,}25} \; x \; 5 \; k\Omega$$
$$= \; 8{,}2 k\Omega$$

After getting the value of Rs, calculate the ratio Rs/Ro:

$$Rs/Ro = 8{,}2/3{,}3$$
$$= 2{,}48$$

Calculate the ppm value:

$$Ppm = \; 60{,}144 \times (2{,}48)^{-0{,}542}$$
$$= 60{,}144 \times 0{,}61$$
$$= 36{,}687$$
$$= 36{,}\, 69 ppm$$

From the formula-based calculations used to obtain the ADC and ppm values, the analysis indicates that the ADC computed by formula is slightly lower than the ADC shown on the serial monitor (MQ-7 output). In Trial 1, the formula-based ADC is 1556, whereas the serial monitor displays 1559, yielding a difference of 3. For ppm, the formula likewise gives a lower value than the serial monitor 36.69 ppm versus 41.65 ppm, a difference of 4.96 ppm. As presented in Table 3 above, the MQ-7 sensor shows comparatively poor performance for alcohol-concentration measurement, with an average error of 4.38% and a cumulative total error of 87.64%. This average error is obtained using the following formula:

$$\text{Average } error = \frac{\Sigma \, error}{\Sigma \, \text{trials}} \times 100\%$$

The average alcohol concentration measured by the MQ-7 was 59.32 ppm, whereas the Digital Breath Alcohol Tester recorded an average of 57.68 ppm. The mean difference between the two instruments is only 1.68 ppm, indicating a high level of agreement between measurements. The error is calculated using the formula below:

$$Error = \frac{difference \; in \; reading \; values}{Measuring \; instrument \; value} \times 100\%$$

The following graph compares the alcohol content readings, which can be seen in Figure 3 below.

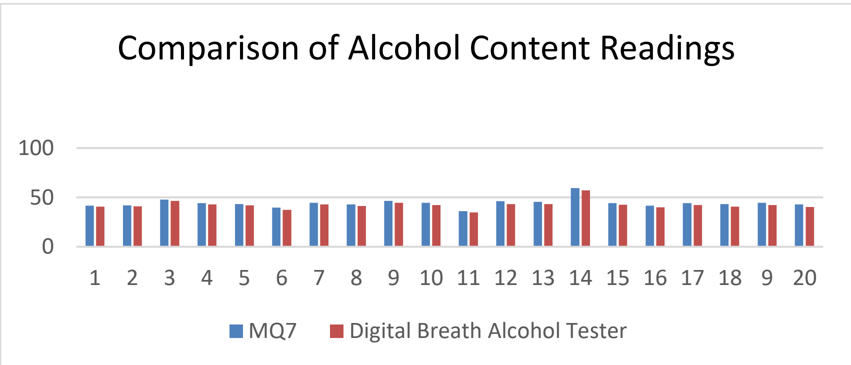

Figure 3. Alcohol Content Reading Graph

Based on Figure 3, it can be seen that overall the MQ7 sensor is not recommended for simple alcohol content measurements, because the MQ7 sensor is more sensitive to detecting carbon monoxide (CO) gas.

CONCLUSIONS AND RECOMMENDATIONS

This study successfully detects alcohol in human breath automatically and periodically transmits the data to Google Sheets, enabling real-time monitoring via the Telegram application. The MQ-3 sensor was effectively applied for breath-alcohol detection, yielding an average measured concentration of 51.38 ppm. The MQ-2 sensor was likewise implemented, with an average measured concentration of 6.83 ppm. The MQ-7 sensor was also implemented, with an average measured concentration of 44.25 ppm. Based on the testing of all three sensors, the authors conclude that the MQ-3 is the recommended sensor for alcohol detection because it shows the highest average ppm and fluctuations consistent with changes in concentration.

FURTHER STUDY

Before implementing simple linear regression, it is important to understand its fundamental concepts. This understanding facilitates the valid estimation of alcohol concentration in human breath. For future research, it is recommended to increase the dataset size and diversify scenarios (different individuals, environmental conditions, blowing distance and duration) so the model becomes more robust. The goal is to obtain data that are more accurate and valid.

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