

An Experimental Evaluation of Low-Cost MQ-Series LPG Sensors under Varying Temperature Conditions

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Received: 28 October 2025 | Revised: 14 November 2025 and 1 December 2025 | Accepted: 3 December 2025

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ABSTRACT

This study presents a comparative experimental evaluation of four low-cost MQ-series Liquefied Petroleum Gas (LPG) sensors (MQ2, MQ4, MQ5, and MQ6) under controlled temperature variations to assess their accuracy and reliability for practical gas detection applications. Although MQ sensors are widely employed in low-cost gas monitoring systems, comprehensive comparative analyses utilizing industry-grade reference instruments remain limited, particularly under varying thermal conditions. Experiments were conducted within a temperature range of 15–31 °C, and the results were validated against the Bosean BTY-S100 reference instrument. Among the tested sensors, the MQ2 exhibited the best overall performance, achieving a high coefficient of determination ($R^2 = 0.96$), low Root Mean Square Error (RMSE) of 7–12, Relative Root Mean Square Error (RRMSE) of 2–7%, and deviation below 10%. These findings demonstrate that the MQ2 sensor offers superior accuracy, stability, and consistency across different temperature ranges, underscoring its potential as a reliable and cost-effective solution for practical LPG detection applications.

Keywords-MQ-series; Liquefied Petroleum Gas (LPG); low-cost; Bosean BTY-S100; comparative evaluation

I. INTRODUCTION

Liquefied Petroleum Gas (LPG) is widely utilized across household, transportation, and industrial sectors due to its high energy efficiency and relatively clean combustion characteristics [1-3]. Nevertheless, the potential for LPG leakage poses a significant safety concern, given its highly flammable nature and its tendency to accumulate in confined spaces, which can lead to fire or explosion incidents [4]. Therefore, the availability of highly reliable gas sensors capable of providing early detection of LPG leakage is crucial for safety monitoring systems in both domestic and industrial environments. Conventional gas sensors predominantly employ Metal-Oxide Semiconductor (MOS) technology, which offers

key advantages such as low manufacturing cost, simple structural design, and wide commercial availability [5, 6]. Among the widely utilized MOS-based sensors for LPG detection are the MQ2, MQ4, MQ5, and MQ6 sensor series. However, the performance of these sensors is highly susceptible to environmental factors, particularly temperature and humidity, which can induce significant variations in sensitivity and long-term stability, as demonstrated in previous studies [7, 8]. Such strong environmental dependence ultimately limits detection accuracy, especially when these sensors are deployed under uncontrolled or fluctuating operating conditions. In an effort to address these limitations, numerous studies have focused on developing advanced

materials and hybrid nanostructures to enhance gas sensor performance. For example, reduced Graphene Oxide (rGO)-based composites integrated with metal oxides such as TiO₂ have been reported to exhibit high sensitivity toward LPG at room temperature, significantly lowering the detection limit while improving response time, as demonstrated in previous studies [9-11]. Additionally, silver nanostructure-based sensors have shown the capability to detect LPG with exceptionally high sensitivity, even below the Lower Explosive Limit (LEL), making them highly relevant for applications with critical safety requirements. Furthermore, two-dimensional (2D) materials such as MoS₂ have demonstrated strong potential for LPG sensing, characterized by rapid response and recovery behaviors that have been experimentally validated [12, 13]. Meanwhile, a system for LPG leakage detection using the MQ5 sensor has been proposed in [14], however, this work did not evaluate the capabilities of other MQ-series sensors, leaving the comparative accuracy and performance across the sensor family insufficiently established.

Recent studies have emphasized the increasing need for portable and low-cost gas detection technologies to enhance safety monitoring across environmental and industrial applications. Despite substantial progress in the development of advanced sensing materials, there remains a notable gap in the literature: comprehensive experimental comparisons of multiple low-cost MQ-series sensors under systematically varied environmental conditions are still scarce. This gap limits the ability to assess sensor robustness and real-world applicability. A rigorous comparative methodology is essential for identifying performance trade-offs including sensitivity, response dynamics, environmental stability, and operational cost that are critical for practical deployment. The adoption of standardized testing protocols involving controlled gas concentrations, temperature, and humidity would enable more reliable benchmarking and facilitate evidence-based selection of the most appropriate sensor type for specific operational contexts.

Based on this background, this study is designed to experimentally compare the performance of several LPG sensors, MQ2, MQ4, MQ5, and MQ6, using the Bosean BTY-S100 as the reference instrument that complies with international standards [15]. The experimental procedure was conducted under three testing schemes, the first at 15–20 °C, the second at 21–25 °C, and the third at 26–31 °C. The analysis focuses on key performance indicators, including accuracy, linearity, stability, and the influence of environmental factors. The findings are expected to contribute to the selection of the most suitable sensor technology for LPG leakage detection in both domestic and industrial settings, while also providing insights into future directions for sensor optimization and development.

II. MATERIALS AND METHODS

The performance evaluation of the gas sensors was conducted experimentally under three testing schemes, 15–20 °C, 21–25 °C, and 26–31 °C, in order to assess the influence of environmental conditions on the sensor responses. This approach enables a comprehensive assessment of the reliability

and stability of the sensors across thermally varied conditions representative of real-world applications. The experimental procedures are detailed as follows.

A. Research Design

The conceptual design and implementation setup for the performance comparison of the sensors utilized in this study are illustrated in Figure 1, representing the system architecture developed to evaluate sensor performance under controlled and equivalent operational conditions. This configuration ensures that all sensors are exposed to identical test environments, thereby enabling objective, quantifiable, and reproducible performance assessment.

B. Materials and Equipment

The materials and equipment utilized to support this study are summarized as follows:

- Gas sensors: MQ2, MQ4, MQ5, and MQ6, which employ tin dioxide (SnO₂) as the primary sensing material in their MOS structure. The detailed specifications of these sensors are presented in Table I.
- Temperature sensor: DHT11, used to measure the ambient temperature within the testing chamber.
- Microcontroller: Arduino Uno R3, employed for signal acquisition and data processing.
- LCD module (16 × 2): Utilized for real-time data visualization.
- SD card module: Used as a data logger to store experimental results.
- Bosean BTY-S100: Served as a gas measuring instrument for LPG/CH₄ and as an internationally standardized reference device for performance comparison.
- Gas source: A commercial LPG cylinder containing a mixture of propane (C₃H₈) and butane (C₄H₁₀) was used as the gas sample.
- Test chamber: An airtight acrylic box with a total volume of 9 L was employed as the controlled testing environment.

TABLE I. DATASET OF MQ2, MQ4, MQ5, AND MQ6 SENSORS

Parameter	MQ2 [16, 17]	MQ4 [18, 19]	MQ5 [20, 21]	MQ6 [22, 23]
Sensing resistance	2–20 kΩ	10–60 kΩ	10–60 kΩ	10–60 kΩ
Concentrate slope rate	≤ 0.6	≤ 0.6	≤ 0.6	≤ 0.6
Temperature	20 ± 2 °C	20 ± 2 °C	20 ± 2 °C	20 ± 2 °C
Humidity	65 ± 5%	65 ± 5%	65 ± 5%	65 ± 5%
Detecting concentrate	Combustible gas: 300–10,000 ppm	Natural gas, CH ₄ : 20–10,000 ppm	LPG, natural gas: 200–10,000 ppm	LPG, iso-butane, propane: 300–10,000 ppm
Price	\$2	\$1.95	\$1.88	\$1.5

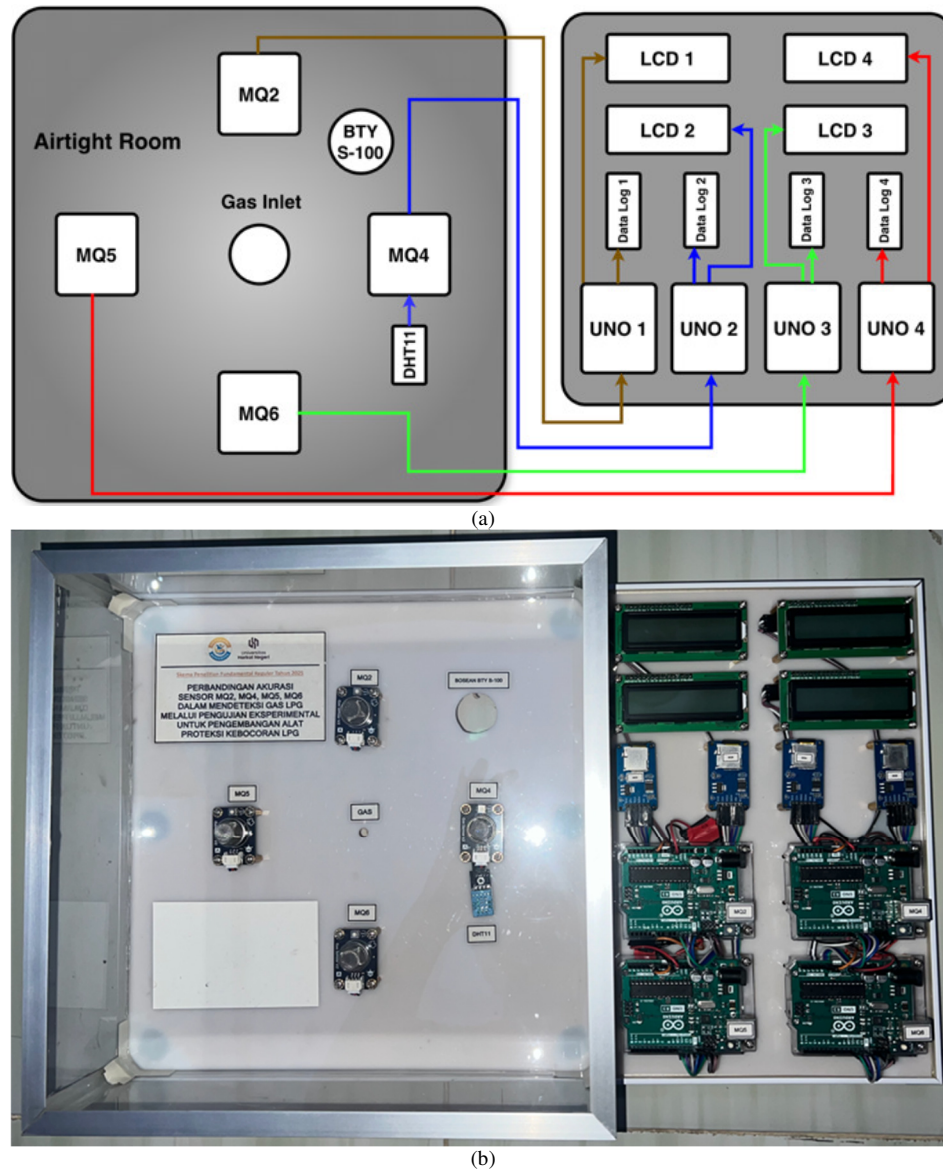


Fig. 1. (a) Conceptual design, (b) experimental setup for the performance comparison of MQ2, MQ4, MQ5, and MQ6 sensors against the Bosean BTY-S100 reference instrument.

C. Experimental Setup

Each gas sensor was independently integrated with the Arduino Uno R3, an LCD module (16 × 2), and an SD card module for stand-alone data acquisition. This isolated configuration was deliberately implemented to eliminate potential cross-interference among sensors and to ensure autonomous operation, thereby minimizing measurement bias. The schematic of the experimental setup is illustrated in Figure 2.

D. Calibration Protocol

Prior to experimentation, all sensors underwent a 24-hour preheating process to ensure proper stabilization of their sensing elements and to achieve optimal operational readiness for calibration. The calibration of the MQ-series gas sensors was performed using a validated mathematical model as

reported in [24], thereby enabling accurate evaluation of their sensitivity and quantitative measurement performance.

E. Measurement Procedure

The measurement procedure commenced with the activation of all gas sensors, MQ2, MQ4, MQ5, and MQ6, along with the reference instrument Bosean BTY-S100, followed by a stabilization phase to ensure that each device reached a steady baseline output. Once stability was achieved, LPG was introduced into the sealed acrylic test chamber containing all sensing devices to allow controlled exposure to the target gas concentration. Sensor responses were recorded in real time using the SD card data-logging module, ensuring both accuracy and continuity of data acquisition throughout the testing process.

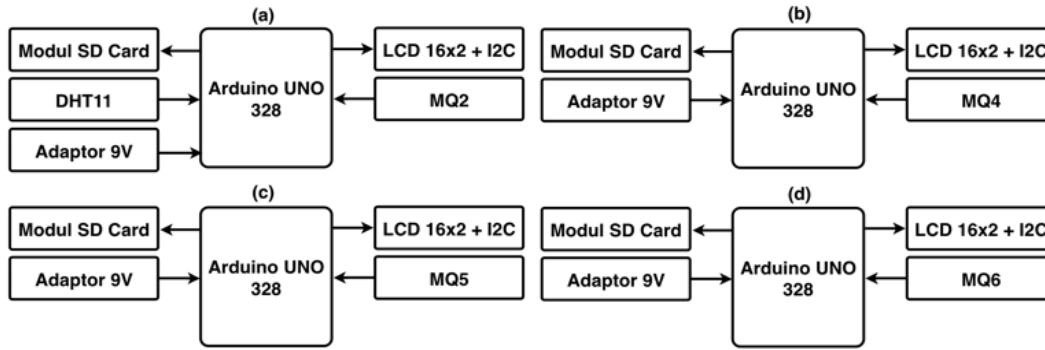


Fig. 2. (a) Experimental setup of the MQ2 sensor integrated with the DHT11 temperature sensor, (b) experimental setup of the MQ4 sensor, (c) experimental setup of the MQ5 sensor, and (d) experimental setup of the MQ6 sensor.

F. Data Analysis

The collected measurement data were analyzed to evaluate key sensor performance parameters, including accuracy, linearity, and stability, as well as the influence of environmental conditions on the detection capability of the MQ2, MQ4, MQ5, and MQ6 sensors for LPG concentration measurement. Subsequently, the sensor outputs were compared against the reference values obtained from the Bosean BTY-S100 instrument, which served as the international standard benchmark. This comparative assessment was employed to identify the sensor with the highest measurement fidelity relative to the reference, thereby determining the most optimal sensor performance among the four evaluated MQ-series gas sensors. To quantitatively assess the performance of the evaluated sensors in comparison with the reference instrument (Bosean BTY-S100), three statistical performance metrics were utilized: Root Mean Square Error (RMSE), Relative Root Mean Square Error (RRMSE), the coefficient of determination (R^2), and relative deviation (%). RMSE is calculated to quantify the average magnitude of the difference between the sensor readings (y_i) and the reference values (\hat{y}_i), as expressed in (1). Furthermore, RRMSE, presented in (2), is employed to evaluate the relative proportion of measurement error with respect to the reference values:

$$\text{RMSE} = \sqrt{\frac{1}{n} \sum_{i=1}^n (y_i - \hat{y}_i)^2} \quad (1)$$

$$\text{RRMSE} = \frac{\text{RMSE}}{\bar{y}} \times 100 \quad (2)$$

The coefficient of determination (R^2) is utilized to assess the strength of the linear correlation between the sensor measurements and the reference values, as defined in (3):

$$R^2 = 1 - \frac{\sum (y_i - \hat{y}_i)^2}{\sum (y_i - \bar{y})^2} \quad (3)$$

Furthermore, the relative deviation (%) is calculated for each measurement point using (4):

$$\text{Deviation}(\%) = \frac{|\hat{y}_i - y_i|}{y_i} \times 100 \quad (4)$$

where:

- y_i = reference measurement value (actual value)
- \hat{y}_i = value measured by the sensor

- n = number of observations
- \bar{y} = average value of the reference measurements

These statistical metrics were computed for each experimental scheme to comprehensively evaluate the accuracy, linearity, and consistency of sensor responses under varying temperature conditions.

For practical verification, all statistical parameters were additionally computed using built-in functions in Microsoft Excel. Specifically, RMSE was obtained using the formula $=\text{SQRT}(\text{AVERAGE}((Y_range - X_range)^2))$, the coefficient of determination (R^2) was validated using $=\text{RSQ}(Y_range, X_range)$, and the relative deviation (%) was calculated using $=\text{ABS}((Y - X)/X) * 100$. The resulting values were found to be identical to those obtained through manual calculation, thereby confirming the consistency and reliability of the data processing procedures implemented in this study. The dataset is available from the corresponding author upon request.

G. Safety Considerations

Given the flammable nature of LPG, all experimental procedures were conducted in a laboratory environment equipped with adequate ventilation and an active exhaust system. A Class B fire extinguisher was positioned within immediate reach, and all operations adhered to standard laboratory safety protocols for handling and testing flammable gases to mitigate potential hazards.

III. RESULTS AND DISCUSSION

The experiments were conducted under testing schemes, specifically 15–20 °C, 21–25 °C, and 26–31 °C, to assess the influence of thermal variation on gas sensor performance. A total of 3,000 measurement data were collected, with 1,000 data points distributed in each temperature scheme. All measurement results were subsequently compared with the Bosean BTY-S100 reference instrument to assess the accuracy and response consistency of each sensor. The results revealed variations in sensor response characteristics across the different temperature conditions, indicating thermal sensitivity to environmental changes. These response variations are visualized using scatter plots, as shown in Figure 3, to provide a quantitative representation of the linear relationship between the MQ sensor output and the reference values.

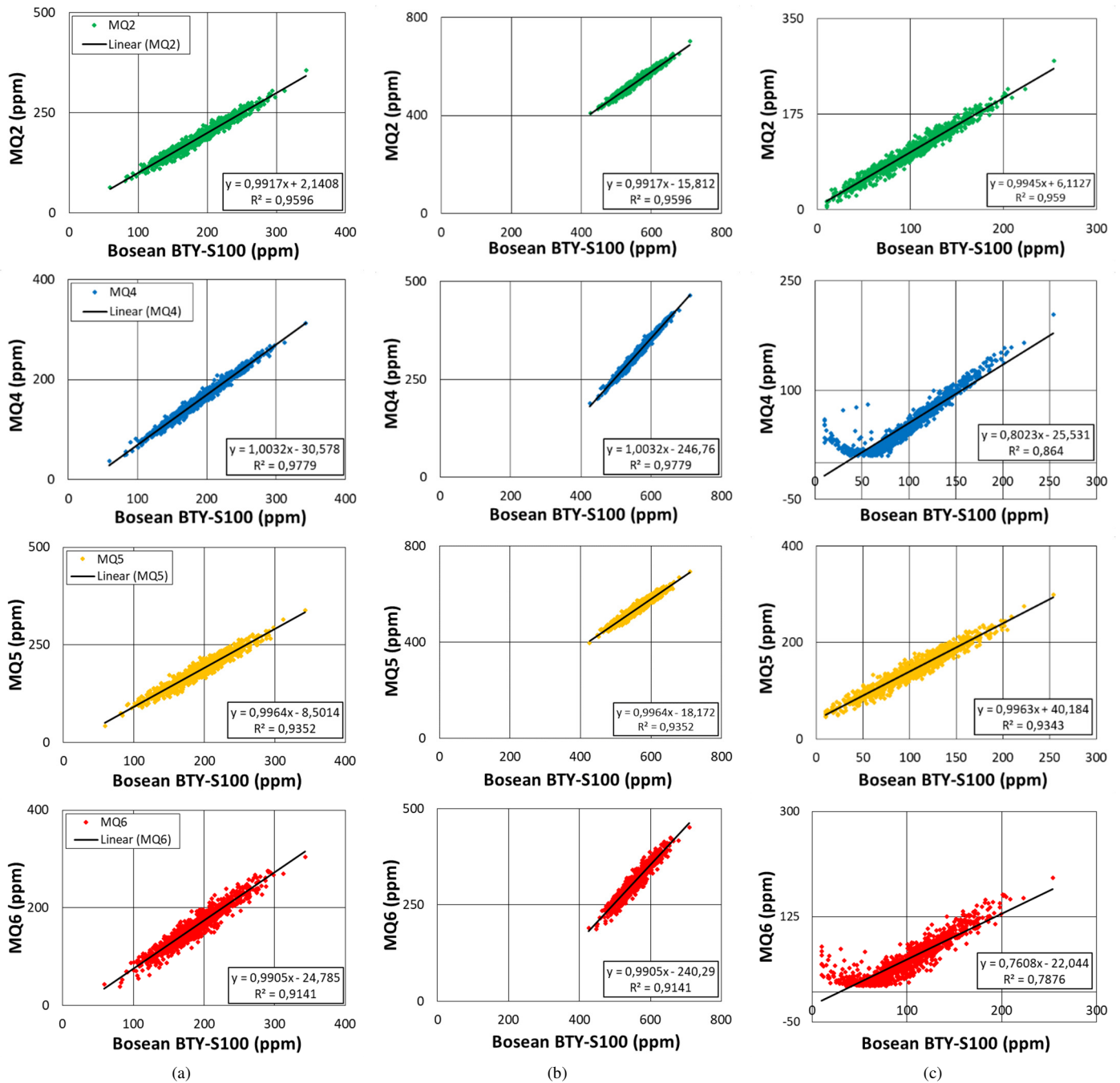


Fig. 3. Scatter distribution of MQ2, MQ4, MQ5, and MQ6 sensor measurements with linear regression against the Bosean BTY-S100 reference under three temperature ranges: (a) 15–20 °C, (b) 21–25 °C, and (c) 26–31 °C.

Figure 3 indicates that each temperature scheme has different effects on the performance of MQ2, MQ4, MQ5, and MQ6 sensors relative to the readings of the reference instrument. Scatter plots show that sensor readings generally cluster around the linear regression line, whereas in scheme (c), the data points deviate from the line, which highlights the significant influence of temperature on MQ sensor performance in measuring LPG concentrations.

A. Qualitative Evaluation

The performance of each sensor was quantitatively assessed using four key parameters: RMSE, RRMSE, R², and relative deviation (%). These metrics provide a comprehensive quantitative insight into the accuracy, linearity, and stability of the sensor measurements relative to the reference values obtained from the Bosean BTY-S100.

1) RMSE, RRMSE (%), R^2 , and Relative Deviation (%) of the 15–20 °C Temperature Scheme

Based on the quantitative analysis presented in Table II, the four MQ-series gas sensors (MQ2, MQ4, MQ5, and MQ6) were compared against the Bosean BTY-S100 reference sensor. The results indicate that each sensor exhibits varying levels of accuracy and linearity in response to changes in LPG gas concentration.

TABLE II. SUMMARY OF THE 15–20 °C SCHEME

Sensor	Range (ppm)	RMSE	RRMSE (%)	R^2	Relative deviation (%)
MQ2	63–357	7.87	4.15	0.96	4.30
MQ4	36–313	34.85	18.36	0.98	16.21
MQ5	41–338	9.80	5.16	0.94	3.92
MQ6	38–303	42.77	22.54	0.91	23.76

The coefficient of determination (R^2) indicates that all sensors exhibit a strong linear correlation with the reference instrument, with R^2 values ranging from 0.91 to 0.98. MQ4 demonstrated the highest R^2 value of 0.98, indicating the strongest linear relationship with the Bosean BTY-S100. However, an RMSE of 34.85, an RRMSE of 18.36%, and a relative deviation of 16.21% suggest that despite the high linear correlation, the sensor shows considerable absolute and relative measurement errors.

In contrast, the MQ2 sensor demonstrated a more balanced performance, with an RMSE of 7.87, an RRMSE of 4.15%, an R^2 of 0.96, and a relative deviation of 4.30%, indicating superior numerical accuracy and relative stability. MQ5 also exhibited satisfactory performance, with an RMSE of 9.80, an RRMSE of 5.16%, an R^2 of 0.94, and the lowest relative deviation among all tested sensors at 3.92%. Conversely, MQ6 showed the poorest performance, with an RMSE of 42.77, an RRMSE of 22.54%, an R^2 of 0.91, and a relative deviation of 23.76%, indicating considerable reading instability due to environmental factors, especially temperature.

2) RMSE, RRMSE (%), R^2 , and Relative Deviation (%) of the 21–25 °C Temperature Scheme

As presented in Table III, the coefficient of determination (R^2) indicates that all MQ sensors exhibit a strong linear correlation with the Bosean BTY-S100 reference sensor, with values ranging from 0.91 to 0.98. MQ4 achieved the highest R^2 value of 0.98, demonstrating excellent linearity in its output response relative to the reference sensor.

TABLE III. SUMMARY OF THE 21–25 °C SCHEME

Sensor	Range (ppm)	RMSE	RRMSE (%)	R^2	Relative deviation (%)
MQ2	409–703	12.38	2.22	0.96	2.31
MQ4	188–465	239.67	43.05	0.98	41.47
MQ5	397–694	20.47	3.68	0.94	3.81
MQ6	184–451	261.50	46.97	0.91	48.70

Nevertheless, the relatively high RMSE of 239.67, an RRMSE of 43.05%, and relative deviation of 41.47% indicate

substantial absolute and relative measurement errors, suggesting that, despite its strong linear correlation, the sensor's accuracy remains limited.

Furthermore, the MQ2 sensor exhibited the most consistent and balanced performance, with an RMSE of 12.38, RRMSE of 2.22%, R^2 of 0.96, and relative deviation of 2.31%. These results indicate that MQ2 provides high accuracy, good stability, and reliable detection capability across variations in LPG gas concentration. MQ5 also demonstrated positive performance characteristics, with an RMSE of 20.47, RRMSE of 3.68%, R^2 of 0.94, and relative deviation of 3.81%, reflecting low relative error and reasonably stable measurements.

In contrast, MQ6 showed the poorest performance among all tested sensors, with an RMSE of 261.50, RRMSE of 46.97%, R^2 of 0.91, and relative deviation of 48.70%, highlighting substantial inaccuracy and excessive sensitivity to environmental variations, which can compromise measurement consistency in LPG detection applications.

3) RMSE, RRMSE (%), R^2 , and Relative Deviation (%) of the 26–31 °C Temperature Scheme

As presented in Table IV, the coefficient of determination (R^2) indicates that the MQ2 sensor exhibits a strong correlation with the reference sensor, with an R^2 value of 0.96, accompanied by an RMSE of 7.09, RRMSE of 7.03%, and relative deviation of 9.09%. This combination confirms that MQ2 delivers optimal performance, achieving a balanced trade-off between measurement accuracy and data stability. The sensor effectively represents variations in LPG gas concentration in a linear and consistent manner relative to the reference standard.

TABLE IV. SUMMARY OF THE 26–31 °C SCHEME

Sensor	Range (ppm)	RMSE	RRMSE (%)	R^2	Relative deviation (%)
MQ2	5–273	7.09	7.03	0.96	9.09
MQ4	10–204	41.20	40.83	0.86	69.83
MQ5	45–298	11.25	11.15	0.93	9.96
MQ6	8–189	47.53	47.11	0.79	74.27

The MQ5 sensor also demonstrated relatively good performance, with an R^2 of 0.93, an RMSE of 11.25, an RRMSE of 11.15%, and relative deviation of 9.96%. These results indicate that MQ5 provides satisfactory accuracy and linearity, although slightly lower than that of MQ2.

In contrast, the MQ4 and MQ6 sensors exhibited suboptimal performance, characterized by high RMSE and RRMSE values of 41.20 and 47.53, respectively, and large relative deviations of 69.83% and 74.27%. Their relatively low R^2 values, 0.86 and 0.79 for MQ4 and MQ6, respectively, indicate the nonlinear responses and substantial measurement errors, likely due to excessive sensitivity to environmental fluctuations such as temperature and humidity.

B. Error-Bar Regression Analysis

The error-bar analysis presented in Figure 4 is employed to quantify the measurement uncertainty, stability, and repeatability of each sensor. The error bars are derived from the

95% confidence interval of the grouped data, such that their magnitude reflects the degree of inter-repetition variability. Smaller error bars indicate improved measurement stability and greater consistency in the sensor response.

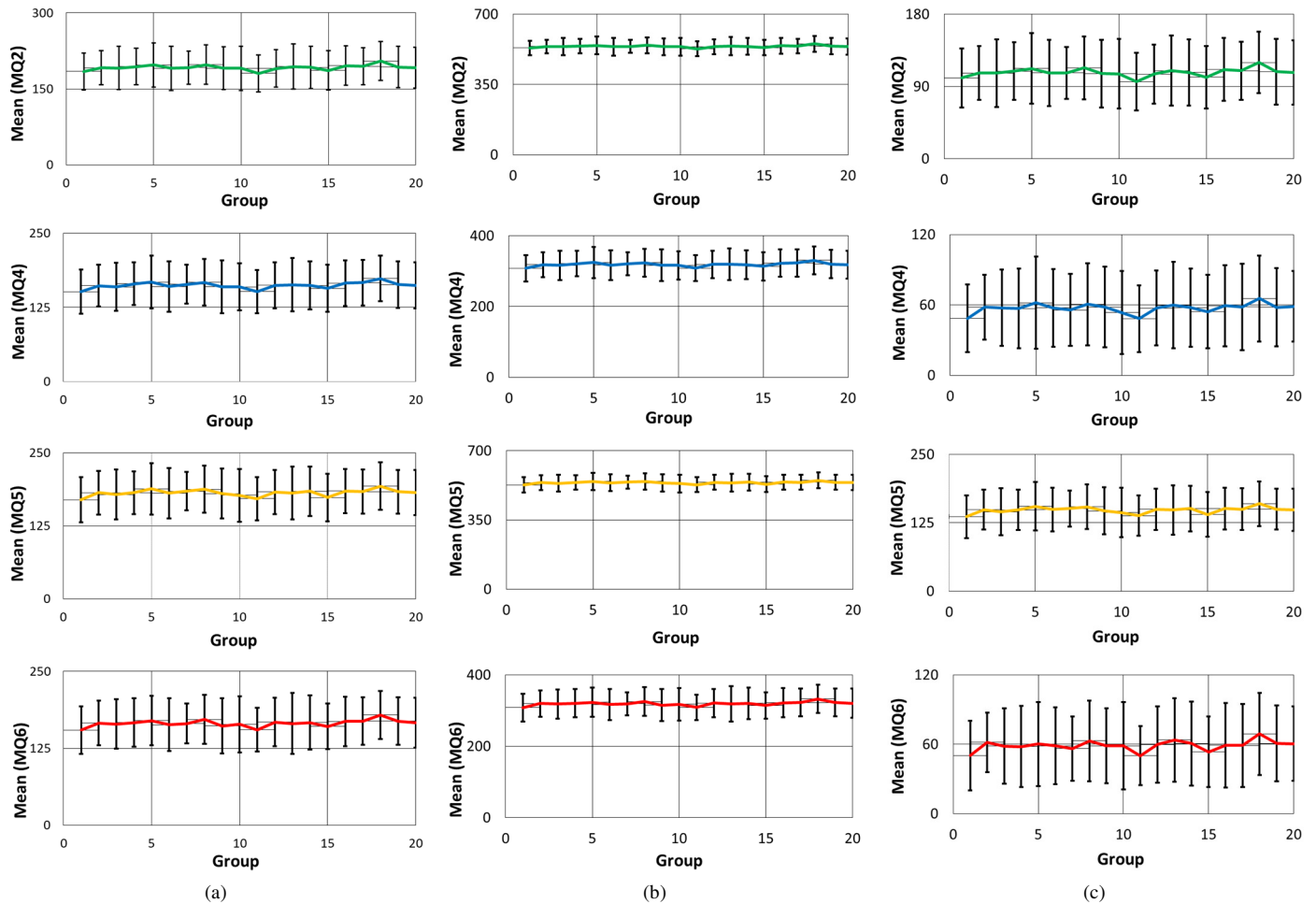


Fig. 4. Error bar regression analysis of MQ2, MQ4, MQ5, and MQ6 sensor measurements at temperature ranges of: (a) 15–20 °C, (b) 21–25 °C, and (c) 26–31 °C.

MQ2 exhibits the smallest and most uniform error bars, reflecting minimal inter-trial variability and highly consistent responses across all test conditions. Its strong sensitivity and near-linear behavior toward LPG underpin its superior accuracy and repeatability, making MQ2 an appropriate reference sensor for calibrating lower-performing devices. MQ5 also demonstrates relatively small and controlled error bars, indicating adequate stability and consistent LPG response; although less accurate than MQ2, its performance can be effectively enhanced through proper calibration. In contrast, MQ4 shows large and fluctuating error bars, signifying high variability and limited stability, likely influenced by environmental sensitivity, extended heater warm-up, and noise at low concentrations. MQ6 presents similar but more pronounced instability, with substantial error bars, response fluctuations, cross-sensitivity, and notable short-term drift. These characteristics indicate that MQ4 and MQ6 require rigorous calibration and environmental or signal-processing

compensation, and without such measures, they are more suitable for qualitative or threshold-based detection rather than quantitative concentration estimation.

C. Discussion

The testing of the four MQ sensors (MQ2, MQ4, MQ5, and MQ6) revealed significant variations in accuracy, linearity, and stability relative to the Bosean BTY-S100 reference sensor. The coefficient of determination (R^2) values, ranging from 0.79 to 0.98, indicate that all sensors exhibited relatively strong linear correlations with the reference, albeit with differing levels of the measurement accuracy.

Overall, the MQ2 sensor demonstrated the best performance across all test schemes, with a high R^2 of 0.96, RMSE of 7–12, RRMSE of 2–7%, and relative deviation below 10%. These metrics indicate stable and accurate LPG detection, a consistent linear response, and a low signal-to-noise ratio,

making MQ2 highly reliable under various environmental conditions, as supported by previous studies [7, 8].

The MQ5 sensor exhibited relatively good performance, with an R^2 of 0.93–0.94 and low RMSE and RRMSE values, resulting in stable measurements with relative deviations of 3–10%. This indicates that MQ5 can serve as a potential alternative for LPG detection systems requiring a balance between sensitivity and measurement stability.

In contrast, the MQ4 and MQ6 sensors demonstrated suboptimal performance. Although MQ4 recorded the highest R^2 value of 0.98, its high RMSE and RRMSE values (ranging from 41–230 and 18–43%, respectively) indicate significant absolute and relative measurement deviations. This highlights that high linear correlation does not necessarily imply high absolute accuracy, particularly when discrepancies in response scale relative to gas concentration are present.

Meanwhile, the MQ6 sensor exhibited the lowest performance, with the lowest R^2 values of 0.79–0.91 and the highest errors and relative deviations, up to 74%. This indicates that MQ6 is highly sensitive to environmental variations, particularly temperature and humidity, resulting in signal fluctuations and reduced detection consistency. These characteristics highlight the need for temperature compensation or additional calibration to improve MQ6 accuracy for practical industrial applications.

Overall, RMSE and RRMSE values serve as quantitative indicators of absolute and relative measurement errors for each sensor, whereas relative deviation indicates stability under variations in gas concentration. Considering these three parameters alongside R^2 , it can be concluded that sensors with a combination of high R^2 and low error values, such as MQ2 and MQ5, are functionally optimal.

Practically, these findings confirm that the MOS-based MQ2 sensor, particularly with SnO_2 as the sensing material, is the most efficient and low-cost option for multi-temperature LPG detection, as it maintains strong linearity while minimizing measurement errors. MQ5 can serve as a stable alternative sensor, whereas MQ4 and MQ6 require additional calibration and temperature compensation to attain higher accuracy and measurement consistency. Their performance can be substantially enhanced through temperature-humidity compensation, given that these environmental parameters strongly influence the gas adsorption-desorption dynamics in MOS-based sensing materials. Elevated temperatures may reduce sensitivity due to accelerated desorption, whereas high humidity can hinder gas-sensor interactions through the formation of a surface water layer. These limitations can be effectively mitigated using temperature-humidity regression models, multivariate calibration techniques, or machine-learning-based compensation. When properly implemented, such methods markedly decrease error variability and improve the stability and accuracy of LPG detection for MQ4 and MQ6. These results further reinforce that gas sensor effectiveness is determined not only by sensitivity to the target gas but also by the ability to preserve stability and accuracy under varying temperature conditions, as validated in [25].

Long-term stability is a critical parameter in sensor performance evaluation, as it reflects the sensor's ability to maintain consistent response characteristics over extended periods of operation. Degradation in long-term stability is typically attributed to factors such as deterioration of the sensing-layer material, shifts in heater sensitivity, surface contamination, and drift induced by environmental fluctuations. Sensors exhibiting good long-term stability demonstrate minimal changes in baseline output and sensitivity to the target gas concentration. Consequently, periodic monitoring, routine calibration, and controlled operating conditions are essential strategies to ensure reliable measurement performance in long-term applications.

IV. CONCLUSIONS

The evaluation of MQ2, MQ4, MQ5, and MQ6 sensors against the Bosean BTY-S100 reference across the temperature range of 15–31 °C demonstrated a strong linear relationship, with coefficients of determination (R^2) ranging from 0.79 to 0.98, although their accuracy and stability varied. Among the tested sensors, MQ2 exhibited the best performance, characterized by a high R^2 of 0.96, low Root Mean Square Error (RMSE) of 7–12, Relative Root Mean Square Error (RRMSE) of 2–7%, and relative deviation below 10%, indicating both high accuracy and stable LPG detection. MQ5 also showed consistent performance, with low error and deviation, indicating it as a reliable alternative. In contrast, MQ4 and MQ6 exhibited suboptimal performance, with high error and deviation despite good linearity, particularly for MQ4. MQ2 is therefore recommended as the most optimal and low-cost sensor for multi-temperature LPG detection applications, whereas MQ4 and MQ6 require additional calibration and temperature compensation to enhance measurement accuracy and consistency.

ACKNOWLEDGMENT

The authors gratefully acknowledge the Ministry of Higher Education, Science, and Technology of the Republic of Indonesia for the financial support provided through the Regular Fundamental Research Program (PFR) Batch II, 2025, contract numbers 202/C3/DT.05.00/PL-BATCH II/2025 and 002/LL6/PL-BATCH II/AL.04/2025. The authors also express their gratitude to Universitas Harkat Negeri for the support extended throughout the conduct of this research.

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