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Design of sample display system on electronic nose for synthetic flavor classification

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ABSTRACT

This study aimed to design a controlled sample display system on an electronic nose and test its performance for classifying synthetic flavors. There are four primary components to the electronic nose design. They are a controlled sample display system, detector, signal conditioning and preprocessing, and pattern recognition software. The sample display system consists of six vials. The sample room temperature setpoint is set to 40 ℃. The controlled sample display system has one heater and two fans to even the room temperature. The one-time data collection process consists of flushing (120 s), collecting (180 s), and purging (180 s). The samples for the performance test were synthetic flavors with four different aromas; durian, mocca, orange, and strawberry. Data analysis of gas sensor response was done through two stages; pre-treatment data processing and principal component analysis (PCA). The four samples were clearly different from others, according to the PCA results. The scores of the PC-1, PC-2, and PC-3 cumulative variance were 98.28%.

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1. INTRODUCTION

Today, food development that much-circulated in the market always be related to the use of flavors. The flavor is a combination of taste and aroma, which become an important aspect of food products as it provides a special attraction for consumers [1]. Therefore, the use of flavoring gets serious attention from the industry. Flavors are one of the most critical aspects of the flavor industry to maintain product quality [2]. Various technologies have been developed to analyze synthetic flavorings with the character of volatile organic compounds (VOC). However, the conventional method is still widely applied in most industries in sensory testing. The flavor industry generally has a team of panelists to measure the organoleptic quality of the product. Although the panelists have good adaptability, conventional sensory testing has some weaknesses [3]. The human olfactory system is generally subjective because susceptible to subject's physical and psychological state [3]. The sensory test will also be difficult to quantify, impacting the difficulty of obtaining a consistent quality assessment. Also, the industry could find problems when producing synthetic flavors in large quantities and continuous equipment. The sensory test cannot be integrated with units on equipment process, which can be a barrier to modernization. Then, the industry, especially synthetic flavoring, requires a measuring instrument to overcome the weakness of the flavoring quality test.

The field of flavor analysis technologies has advanced significantly. Flavors are formed by a complex mixtures of VOC [4]. The method used the most frequently for flavor analysis is gas chromatography. Gas chromatography has excellent separation of compounds in flavor. Other instrumental analytical techniques, such as high-performance liquid chromatography, infrared spectroscopy, and gas chromatography-mass spectrometry, are excellent devices for flavor analysis [5], [6]. Therefore, these methods require skilled operators in their operation, are expensive, and take a long time to analyze the sample [7].

The electronic nose (e-nose) has become a modern olfactory technology as it can be applied in the analysis process of synthetic flavor. The e-nose is an easy-to-use device, affordable and fast in obtaining the analysis results [8]–[12]. Without having to be informed of every component of the chemical, the e-nose can recognize volatile organic compounds in a flavor as a whole [4], [13]. The e-nose is a tool comprised of several gas sensors equipped with a pattern recognition algorithm to evaluate basic or complex flavors [14]. The flavor of the sample is exposed to the surface of the gas sensor, which results in a gas sensor response. Important information from the gas sensor response is extracted through the pattern recognition method to be classified or identified [15], [16].

Numerous fields have used the e-nose extensively to detect, categorize, or identify products based on flavors. The e-nose used to rate the freshness of seafood [17], quality monitoring of roasted coffee [18], black tea classification [19]–[22], prediction of fruits storage time [6], [23], [24], egg storage time prediction [25], and has been reported by [26]–[28] applications in the food sector. Research related to the usage of the e-nose for the identification of synthetic flavors is still very limited. However, appliying the e-nose for categorizing artificial flavors by [3] has been performed through data analysis methods using a principle component analysis (PCA) to determine the level of distribution. The sample handling system, the detector, the signal conditioning and preprocessing portion, and the pattern identification software are the four primary components of the e-nose design. However, the operation of the e-nose needs a lot of time when switching one sample to the other sample. In addition, the unconditioned sample space will affect the evaporation rate of volatile organic compounds from liquid to gas. Therefore, the focus of the study is to design a sample display system of the e-nose and test its performance.

2. METHOD

2.1. Materials

The equipment was the e-nose which was developed by the Sub Lab. Agro control and robotics, EMP UGM. The e-nose consists of components; gas sensors, an ATmega 2560 microcontroller, a 5-volt relay, a temperature and humidity sensor (DHT11), a solenoid valve 3-way, a power supply, an oxygen tank, a flow meter, and a computer. Then, the e-nose was modified in the sample display by adding components, such as a temperature sensor (LM35), the sample room consisting of six vials, ten solenoid valves 3-way, solid-state relays, heaters, and fans. The research substance used in the e-performance nose's test is a synthetic flavor with a specific flavor from the same brand. The synthetic flavors were durian, mocca, orange, and strawberry.

2.2. Designing the hardware

The hardware was the e-nose prototype according to a series of gas sensors equipped with a controlled sample display system and integrated with a rinse system (air flow recovery). Figure 1 shows how the e-nose is made. The four primary components of the e-nose that was created, the sample display system, the detector, the signal conditioning and preprocessing, and the pattern recognition software. The new part in this e-nose design was the addition of a sample display system which is completed with a system for regulating environmental conditions, especially temperature. The sample display system are designed with six vials which allows putting some samples in one data collection. For other parts, the design is the same as before. Not only conditioning some related parameters such as temperature, sampling time, and sampling flow rate, but gas (O_2 gas) is also used to carry the sample to provide good performance. The performance test of the e-nose used a sample display room temperature of 40 ºC. The sample room is equipped with two fans so that the air temperature in the room is evenly distributed.

The detector part of the design employs a number of semiconductor-type gas sensors. The circuit uses MQ 1, MQ 2, MQ 3, MQ 4, MQ 5, MQ 6, MQ 7, and MQ 8 as the gas sensors. The detector is equipped with a signal conditioning device and a reader and interface. The data from the initial processing send to a computer that has function as a sensor signal processing unit to form flavor patterns and, at the same time, as a pattern recognition unit. The e-nose includes a recovery system built into it with the purpose of accelerating sensor recovery after sampling. The recovery system is designed with a combination of valves and purge gas supply lines that allow it to flow quickly. The research device is equipped with a controller which is controlled using an interface device designed on a computer aiming to manage the work of all the components.

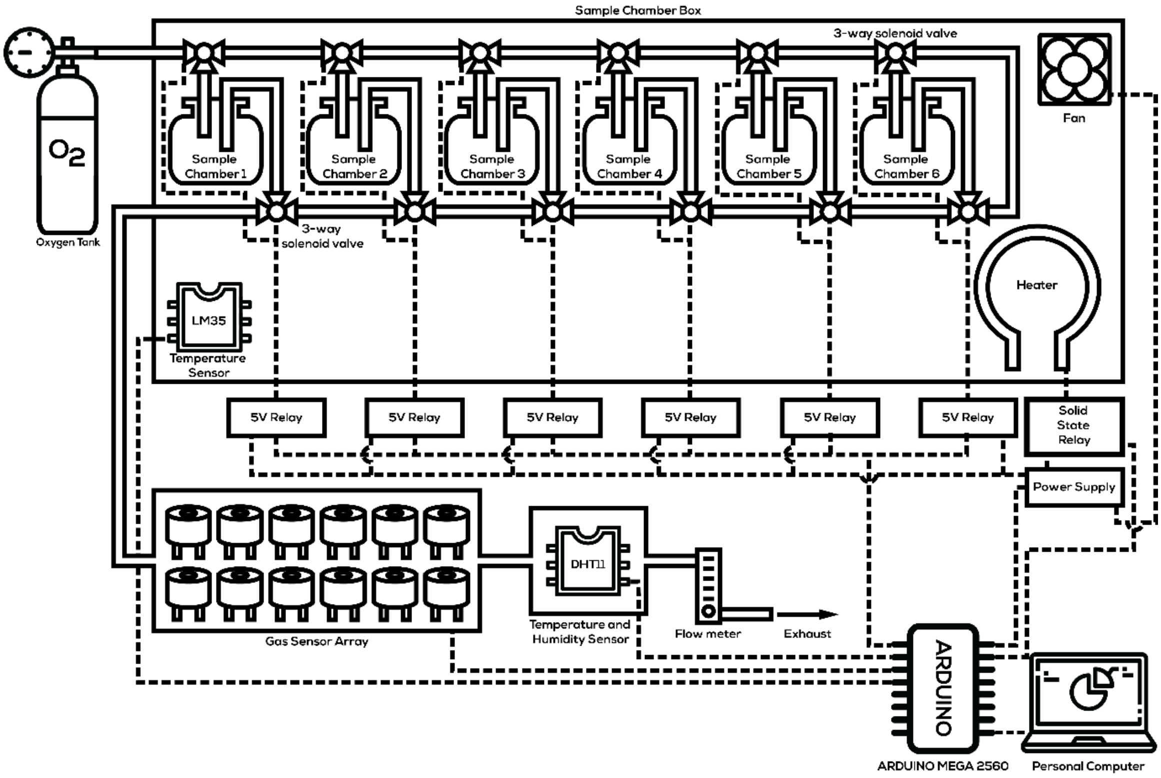


Figure 1. Design of an electronic nose

The software is designed to control the work of each element of the e-nose. The recovery system is integrated with the data acquisition software on the e-nose. The control device is designed to make the system works automatically, able to display the desired sample at the appropriate time, and speed and operate the entire system work.

2.3. Sample preparation

Six vials were prepared in a clean state without flavor contamination. Synthetic flavor samples were measured using a measuring cup of 5 ml. Then, the sample put into the prepared vials. The vials put in the sample display room.

2.4. Data collection procedure

After the hardware is constructed, it continues to the data collection stage. The sample is prepared at a predetermined place. The data collection stage occurs by turning on the e-nose and carrying out a cleaning process for 300 seconds without a sample to stabilize the gas sensor's response to clean air. The sample is then positioned in the sample room. The airflow is kept constant during the process of collecting data at 0.4 NL/min. Flushing, collecting, and purging are one cycle of data collection. Without a test sample, the sensor response for 120 seconds is the flushing. When in contact with fresh air, flushing serves as a reference value for sensor measurements. The sensor response in the collecting is exposed to the flavor for 180 seconds. The sensor response for 180 seconds without being exposed to the test sample is the purging phase. Eight minutes are required for a data collection process with six controlled sample displays. Then, 48 minutes are required for one cycle of data collecting. Each test sample's sampling techniques procedure was repeated 30 times.

2.5. Data analysis

The sample test data was obtained using a set of the e-nose. After that, it is processed using a computer. The sample test results are data of gas sensor response voltage value, temperature, and humidity stored in Microsoft excel. Data analysis was carried out in two stages: pre-treatment of data processing and pattern recognition. Pre-treatment of data processing is an absolute data method [3]. Pre-treatment is a process of collecting data from the pattern of a flavor containing the most important information that represents the entire pattern. The purpose of pre-treatment is to collect the most important information from a data set from a single sample to reduce computational time and improve the analysis accuracy of pattern recognition systems. A technique that employs absolute data from the gas sensor's reaction to the sample's scent is known as absolute data, presented in Figure 2. Pre-treatment data processing is represented in a radar graph using Microsoft excel. The radar graph shows the differences between one sample and another in a spider web. A principal component analysis (PCA) method using Matlab software is used in pattern recognition.

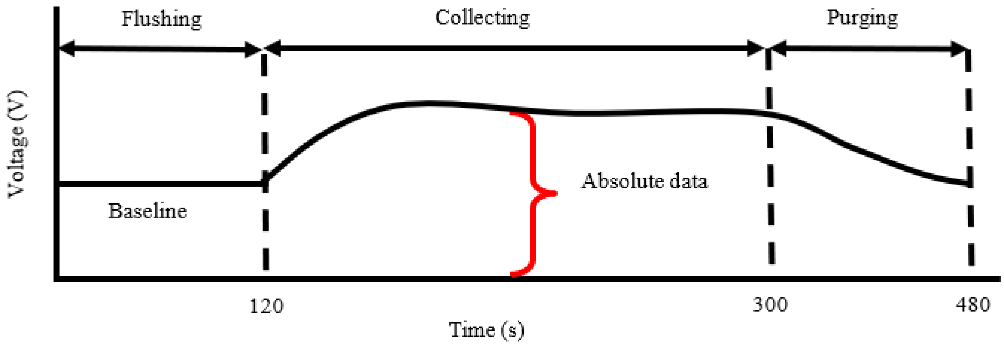
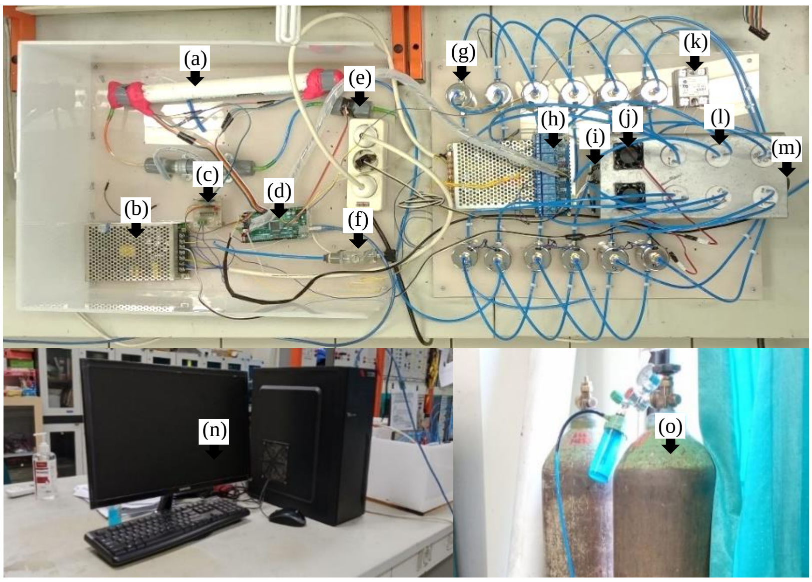


Figure 2. Pre-treatment data processing using absolute data method

3. RESULTS AND DISCUSSION

3.1. Design of electronic nose

Figure 3 showed the hardware of the e-nose, equipped with a controlled sample display system. A sample display system with six vials is installed in the e-nose, so it allows for a collection of 6 replicates data in one data collection process. The hardware is intended to be controlled by the software or data acquisition system. In Figure 4, the data acquisition system is displayed. A variety of gas sensors, temperature sensors, and RH sensors are used in the data collecting system. Moreover, the program is designed to activate the heater and fan, and adjust the opening of the 3-way solenoid valve that allows the sample of flavor in one vial not to mix with other samples of flavor in the other vial.



a) Gas sensors
b) Power supply
c) Resistors
d) Mikrokontroler ATMega 2560
e) Temperature and humidity sensor (DHT11)
f) Flow meter
g) Solenoid Valve 3-way
h) Relay 5 V
i) Heater
j) Fan
k) Solid-state relay
l) Sample chamber
m) Temperature sensor (LM35)
n) Computer
o) Oxygen tank

Figure 3. Hardware of electronic nose

The data acquisition system consists of some functions, such as setting the temperature of the sample room, cleaning duration, flushing duration, collecting duration, purging duration, and setting the number of vials. The temperature of the sample room, the position of the solenoid valve, and the responses of the temperature and relative humidity sensors are the data that are displayed during the data collection procedure. The e-nose operation is initiated by connecting the serial port to the Arduino. Then, it continued to set the sample room temperature. Data collection is carried out after the temperature has reached the set point. The sample room temperature will automatically maintain the set point during data collection. All data responses will automatically be saved in Microsoft excel after data collection is complete.

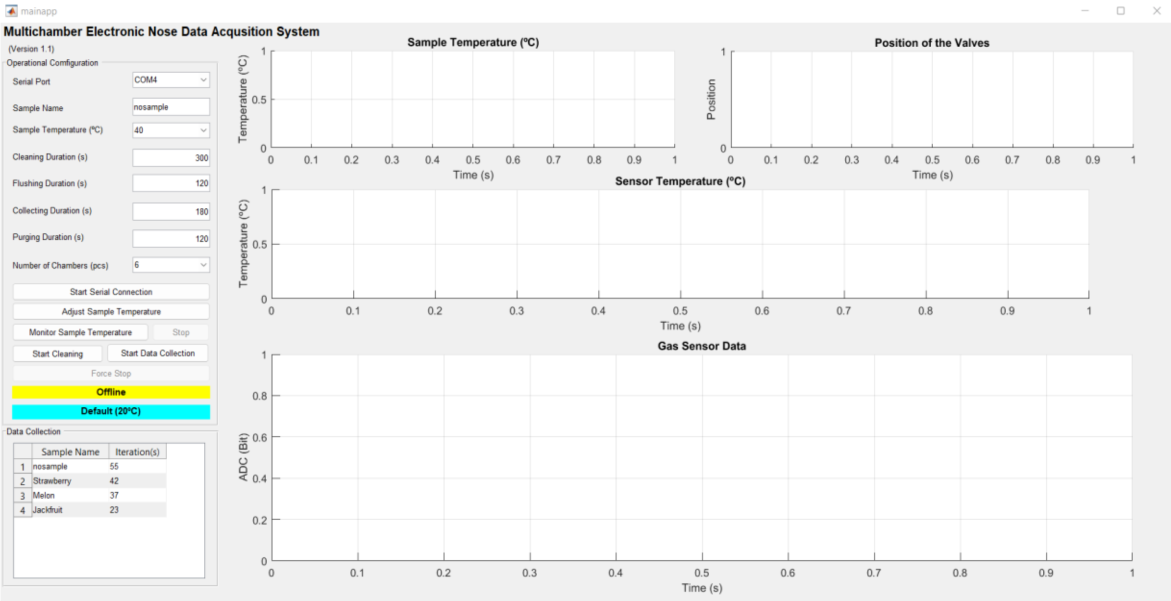


Figure 4. Data acquisition system

3.2. Results of designing test of electronic nose

Testing the design system of the e-nose is performed to determine its performance. The test begins by looking at each sensor's response to a random sample's flavor. Figure 5 showed the display of the data acquisition system after the data collection process. According on the sensor response graph, the sample display system can work according to the expected process. Furthermore, the test was carried out using 4 synthetic flavors: durian, mocca, orange, and strawberry. Each sample was tested 30 times. One process of data collection was carried out 6 times. So, one sample is carried out 5 times.

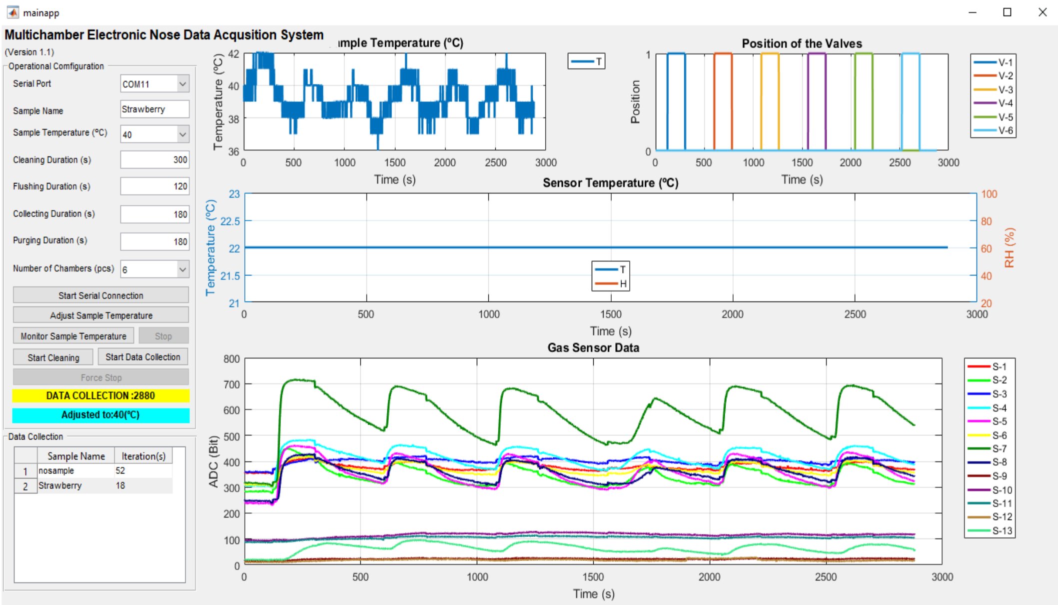


Figure 5. Display of the data collection process

3.2.1. Response of gas sensor

The data collection process is carried out for 480 seconds, which includes the process of flushing, collecting, and purging. The thirteen gas sensors can respond to the synthetic flavors. Figure 6 showed an example of the gas sensor response for each synthetic flavor sample. Figure 6(a) to Figure 6(d) is the response of the aroma sensor sequentially for durian, mocca, orange and strawberry. The graphic pattern between the samples is different. So, that the gas sensor circuit can respond to the taste of each sample well which is marked by changes in the increase in the collceting process.

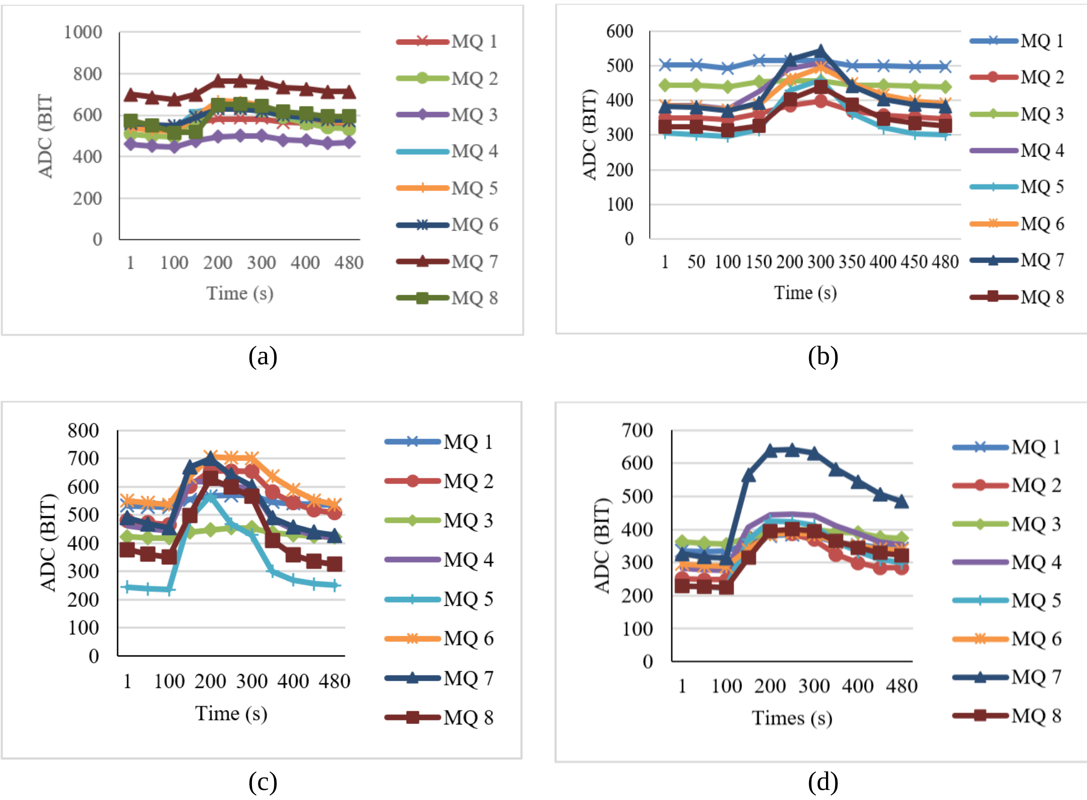


Figure 6. Response of gas sensor (a) durian, (b) mocca, (c) orange, and (d) strawberry

3.2.2. Pre-treatment data processing

Data analysis begins with pre-treatment of data processing. Pre-treatment data processing is represented in a radar graph, presented in Figure 7. The absolute data used is the gas sensor response data from 291 to 300. The data was chosen because the gas response is stable. The pattern of each sample visually looks similar, so further analysis is needed to determine the distribution of the sample pattern for each replication.

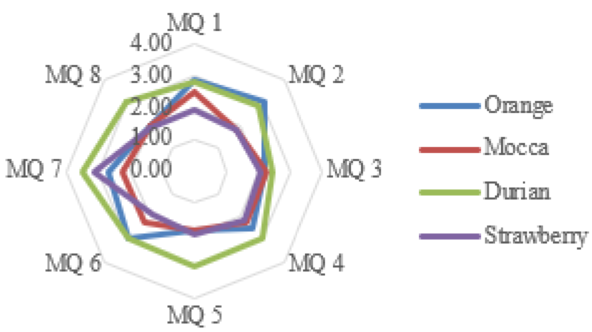


Figure 7. Comparison of gas array sensor pattern synthetic flavor

3.2.3. Principal component analysis

PCA was used to further analyze the pre-treatment data analysis results. It aims to determine how each sample's flavor pattern is distributed. PCA is an orthogonal linear transformation that transforms data into the first principal component coordinates, the second most variation in the second main priority coordinates, and so on. The main purpose of PCA is data analysis to identify patterns and find patterns to reduce the dimensions of the dataset with minimal information loss [29], [30]. The graph of the score plot in Figure 8 showed the four samples classified well into four groups according to the flavor type. The score of PC-1 is 68.10%, PC-2 is 23.61%, and PC-3 is 6.57%. The cumulative score of the three PC is 98.28%. In short, the controlled sample display system on the e-nose is applied properly to classify some synthetic flavors.

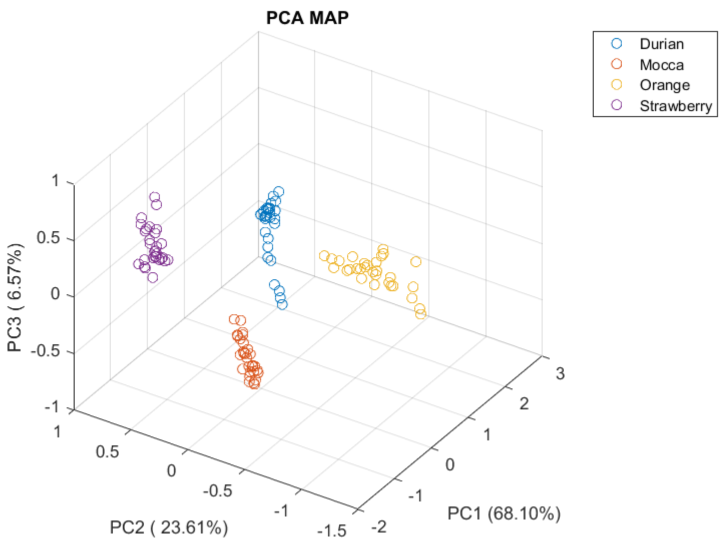


Figure 8. Score plot of synthetic flavor classification with absolute data method

4. CONCLUSION

The design of the controlled sample display system on the e-nose can work properly. Meanwhile, the e-nose's work system can be operated according to the data acquisition system's design. The flavor of the samples in each vial did not mix during the data collection process. The e-nose system performance test was carried out on four synthetic flavoring samples. The pattern recognition method uses a principal component analysis and can classify the four samples according to the flavor type. The results of the cumulative variance of PC-1, PC-2, and PC-3 were 98.28%.

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REFERENCES

[1] M. Weerawatanakorn, J. C. Wu, M. H. Pan, and C. T. Ho, "Reactivity and stability of selected flavor compounds," *Journal of Food and Drug Analysis*, vol. 23, no. 2, pp. 176–190, Jun. 2015, doi: 10.1016/j.jfda.2015.02.001.

[2] Radi, E. Wahyudi, M. D. Adhityamurti, J. P. L. Y. Putro, Barokah, and D. N. Rohmah, "Freshness assessment of tilapia fish in traditional market based on an electronic nose," *Bulletin of Electrical Engineering and Informatics*, vol. 10, no. 5, pp. 2466–2476, Oct. 2021, doi: 10.11591/eei.v10i5.3111.

[3] R. Radi, B. Barokah, D. N. Rohmah, E. Wahyudi, M. D. Adhityamurti, and J. P. L. Yuroto Putro, "Implementation of an electronic nose for classification of synthetic flavors," *Bulletin of Electrical Engineering and Informatics*, vol. 10, no. 3, pp. 1283–1290, Jun. 2021, doi: 10.11591/eei.v10i3.3018.

[4] A. J. Taylor and R. S. T. Linforth, *Food Flavour Technology*, 2nd ed. Chichester, U.K. ; Ames, Iowa: Wiley-Blackwell, 2010.

[5] L. Viana and M. English, "The application of chromatography in the study of off-flavour compounds in pulses and pulse by-products," *LWT*, vol. 150, p. 111981, Oct. 2021, doi: 10.1016/j.lwt.2021.111981.

[6] H. Guohua, W. Yuling, Y. Dandan, and D. Wenwen, "Fuji apple storage time predictive method using electronic nose," *Food Analytical Methods*, vol. 6, no. 1, pp. 82–88, 2013, doi: 10.1007/s12161-012-9414-6.

[7] A. T. John, K. Murugappan, D. R. Nisbet, and A. Tricoli, "An outlook of recent advances in chemiresistive sensor-based electronic nose systems for food quality and environmental monitoring," *Sensors*, vol. 21, no. 7, 2021, doi: 10.3390/s21072271.

[8] S. Cervellieri, V. Lippolis, E. Mancini, M. Pascale, A. F. Logrieco, and A. De Girolamo, "Mass spectrometry-based electronic nose to authenticate 100% Italian durum wheat pasta and characterization of volatile compounds," *Food Chemistry*, vol. 383, 2022, doi: 10.1016/j.foodchem.2022.132548.

[9] C. Machungo, A. Z. Berna, D. McNevin, R. Wang, and S. Trowell, "Comparison of the performance of metal oxide and conducting polymer electronic noses for detection of aflatoxin using artificially contaminated maize," *Sensors and Actuators B: Chemical*, vol. 360, p. 131681, Jun. 2022, doi: 10.1016/j.snb.2022.131681.

[10] Y. Huang, I.-J. Doh, and E. Bae, "Design and validation of a portable machine learning-based electronic nose," *Sensors*, vol. 21, no. 11, p. 3923, Jun. 2021, doi: 10.3390/s21113923.

[11] Y. Cao, Y. Zhang, M. Lin, D. Wu, and K. Chen, "Non-destructive detection of damaged strawberries after impact based on analyzing volatile organic compounds," *Sensors*, vol. 22, no. 2, 2022, doi: 10.3390/s22020427.

[12] W. Jia, G. Liang, H. Tian, J. Sun, and C. Wan, "Electronic nose-based technique for rapid detection and recognition of moldy apples," *Sensors (Switzerland)*, vol. 19, no. 7, 2019, doi: 10.3390/s19071526.

[13] R. Calvini and L. Pigani, "Toward the development of combined artificial sensing systems for food quality evaluation: A review on the application of data fusion of electronic noses, electronic tongues and electronic eyes," *Sensors*, vol. 22, no. 2, p. 577, Jan. 2022, doi: 10.3390/s22020577.

[14] P. Boeker, "On 'Electronic Nose' methodology," *Sensors and Actuators B: Chemical*, vol. 204, pp. 2–17, Dec. 2014, doi: 10.1016/j.snb.2014.07.087.

[15] C. Qu, C. Liu, Y. Gu, S. Chai, C. Feng, and B. Chen, "Open-set gas recognition: A case-study based on an electronic nose dataset," *Sensors and Actuators B: Chemical*, vol. 360, p. 131652, Jun. 2022, doi: 10.1016/j.snb.2022.131652.

[16] R. Rusinek *et al.*, "Effect of supplementation of flour with fruit fiber on the volatile compound profile in bread," *Sensors*, vol. 21, no. 8, p. 2812, Apr. 2021, doi: 10.3390/s21082812.

[17] Grassi, Benedetti, Opizzio, Nardo, and Buratti, "Meat and fish freshness assessment by a portable and simplified electronic nose system (Mastersense)," *Sensors*, vol. 19, no. 14, p. 3225, Jul. 2019, doi: 10.3390/s19143225.

[18] Radi, M. Rivai, and M. H. Purnomo, "Study on electronic-nose-based quality monitoring system for coffee under roasting," *Journal of Circuits, Systems and Computers*, vol. 25, no. 10, p. 1650116, Oct. 2016, doi: 10.1142/S0218126616501164.

[19] D. Lelono, K. Triyana, S. Hartati, and J. E. Istiyanto, "Classification of Indonesia black teas based on quality by using electronic nose and principal component analysis," in *AIP Conference Proceedings*, 2016, vol. 1755, p. 020003, doi: 10.1063/1.4958468.

[20] B. Tudu *et al.*, "Towards versatile electronic nose pattern classifier for black tea quality evaluation: an incremental fuzzy approach," *IEEE Transactions on Instrumentation and Measurement*, vol. 58, no. 9, pp. 3069–3078, Sep. 2009, doi: 10.1109/TIM.2009.2016874.

[21] D. Lelono, H. Nuradi, M. R. Satriyo, T. W. Widodo, A. Dharmawan, and J. E. Istiyanto, "Comparison of difference, relative and fractional methods for classification of the black tea based on electronic nose," in *2019 International Conference on Computer Engineering, Network, and Intelligent Multimedia (CENIM)*, Nov. 2019, vol. 2019-Novem, pp. 1–7, doi: 10.1109/CENIM48368.2019.8973308.

[22] S. N. Hidayat *et al.*, "The electronic nose coupled with chemometric tools for discriminating the quality of black tea samples in Situ," *Chemosensors*, vol. 7, no. 3, p. 29, Jul. 2019, doi: 10.3390/chemosensors7030029.

[23] P. C. Marchal, C. Sanmartin, S. S. Martínez, J. G. Ortega, F. Mencarelli, and J. G. García, "Prediction of fruity aroma intensity and defect presence in virgin olive oil using an electronic nose," *Sensors*, vol. 21, no. 7, p. 2298, Mar. 2021, doi: 10.3390/s21072298.

[24] S. Xu *et al.*, "Detecting and monitoring the flavor of Tomato (Solanum lycopersicum) under the impact of postharvest handlings by physicochemical parameters and electronic nose," *Sensors*, vol. 18, no. 6, p. 1847, Jun. 2018, doi: 10.3390/s18061847.

[25] J. Li, S. Zhu, S. Jiang, and J. Wang, "Prediction of egg storage time and yolk index based on electronic nose combined with chemometric methods," *LWT - Food Science and Technology*, vol. 82, pp. 369–376, Sep. 2017, doi: 10.1016/j.lwt.2017.04.070.

[26] P. Handa and B. Singh, "Electronic nose and their application in food industries," *FOOD SCIENCE RESEARCH JOURNAL*, vol. 7, no. 2, pp. 314–318, Oct. 2016, doi: 10.15740/HAS/FSRJ/7.2/314-318.

[27] A. Loutfi, S. Coradeschi, G. K. Mani, P. Shankar, and J. B. B. Rayappan, "Electronic noses for food quality: A review," *Journal of Food Engineering*, vol. 144, pp. 103–111, Jan. 2015, doi: 10.1016/j.jfoodeng.2014.07.019.

[28] H. Alam and S. H. Saeed, "Modern applications of electronic nose: a review," *International Journal of Electrical and Computer Engineering (IJECE)*, vol. 3, no. 1, Feb. 2013, doi: 10.11591/ijece.v3i1.1226.

[29] J. Zhang *et al.*, "Identification of mouldy rice using an electronic nose combined with SPME-GC/MS," *Journal of Stored Products Research*, vol. 95, p. 101921, Jan. 2022, doi: 10.1016/j.jspr.2021.101921.

[30] X. Zhan, X. Guan, R. Wu, Z. Wang, Y. Wang, and G. Li, "Discrimination between alternative herbal medicines from different categories with the electronic nose," *Sensors*, vol. 18, no. 9, p. 2936, Sep. 2018, doi: 10.3390/s18092936.

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