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Utilization of Electronic Nose to Detect Quality of Meat in the Beef Ribs section

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ABSTRACT

This study analyzes the use of Electronic Nose (E-Nose) in detecting the quality of beef on the ribs. This experiment used a variety of gas sensors, and found a significant pattern related to rib meat quality. There are three sensors, namely MQ137, MQ5, and MQ6, which show the value is inversely proportional to the other sensors. An increase in the value of this sensor indicates a decrease in the quality of the ribs. Furthermore, MQ8 gave the highest score in the "Good" and "Very Good" categories, while MQ5 and MQ6 gave the highest score in the "Eligible" and "Not Feasible" categories. The analysis revealed that E-Nose has the ability to recognize changes in aroma associated with changes in the quality of rib meat. These results show that E-Nose can provide objective and fast information about the quality of beef in the ribs, which can support the food industry in decision making and product quality control. Further research is needed to optimize the use of sensors and validate this technology in various storage conditions and types of beef.

Keywords: *Electronic Nose, Meat, Detection, Quality, Beef Ribs.*

Introduction

The food industry places product quality as a crucial factor in ensuring consumer satisfaction and meeting food safety standards. Especially in the context of beef products, quality has a central role that affects the taste, texture, and nutritional value of the product [1][2]. Highly demanded parts of beef, such as ribs, have significant commercial value in a variety of culinary dishes. Therefore, supervision of changes in beef quality in ribs is inevitable in order to maintain product quality, consumer satisfaction, and prevent potential negative impacts on human health [3][4]. Beef or buffalo is a food that has a high protein content, vitamin B, and several types of minerals such as iron and phosphorus which are important for body health. Based on a report by the Central Statistics Agency (BPS), the average consumption of beef/buffalo in Indonesia in 2022 is 0.010 kilograms (kg) per capita per week. This figure increased compared to the previous year which was 0.009 kg per capita per week, as well as being the highest record in the last decade [5]. The average national beef/buffalo consumption was static throughout 2017-2021 as shown in Figure 1 below.

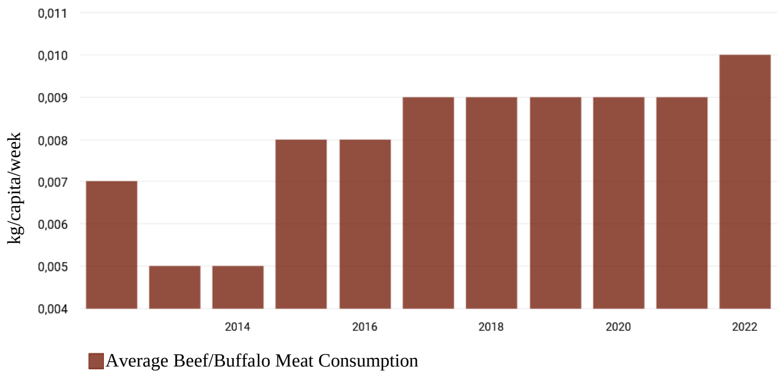


Figure 1. Average Beef Consumption in Indonesia

According to data from the Central Statistics Agency (BPS), throughout 2022 Indonesia imported 225.6 thousand tons of beef (cattle, buffalo, and the like). In 2022, Indonesia imports the most beef from India, with a volume of 105.8 thousand tons [5]. The portion accounts for almost half of the total national meat imports. There is also a lot of meat imported from Australia, Brazil, the United States, New Zealand, and Spain with details as shown in Figure 2 below.

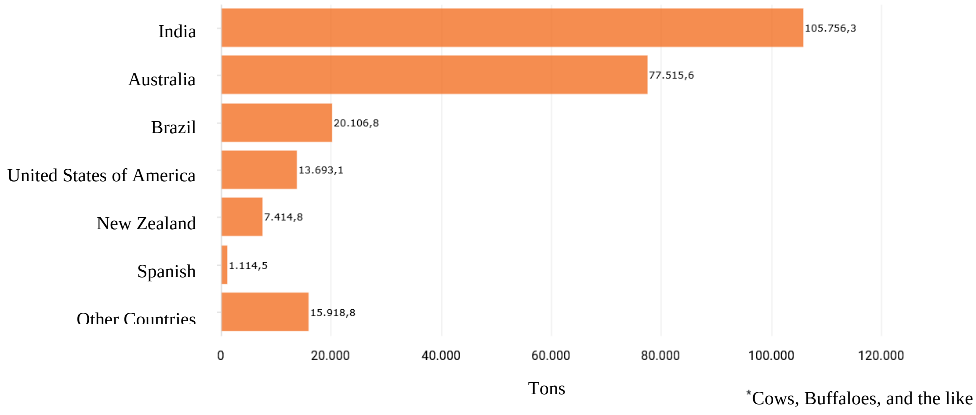


Figure 2. Import Volume of Indonesian Beef by Country of Origin (2022)*

Although testing traditionally through direct evaluation of meat texture and color is still commonly used, such methods have limitations due to their subjective nature and susceptibility to variations in results between tests. However, the use of technology has resulted in a more objective and efficient alternative method of detecting beef quality [6][7]. In this regard, Electronic Nose (E-Nose) can be used as one of the promising solutions for early detection [8][9].

Electronic Nose has progressed significantly in recent years as a tool that can detect and identify scents and odors. With a principle like the human sense of smell [10][11][12], the E-Nose is an electronic device that can simulate the ability of humans to recognize diverse smells and distinctive odors [13][14][15][16]. The use of E-Nose itself in the food industry, especially in beef products, has the potential to improve the accuracy and effectiveness in assessing product quality, as well as overcome the limitations of traditional methods that are more subjective and manual.

Research Methods

In this research method, it will explain the stages of obtaining data by utilizing beef ribs as a test sample, as well as the use of sensor arrays used as Electronic Nose (E-Nose) to detect aromas, then there is Arduino acting as a Microcontroller that functions as a medium for converting analog signals into digital, and laptops as media for data processing and analysis[17].

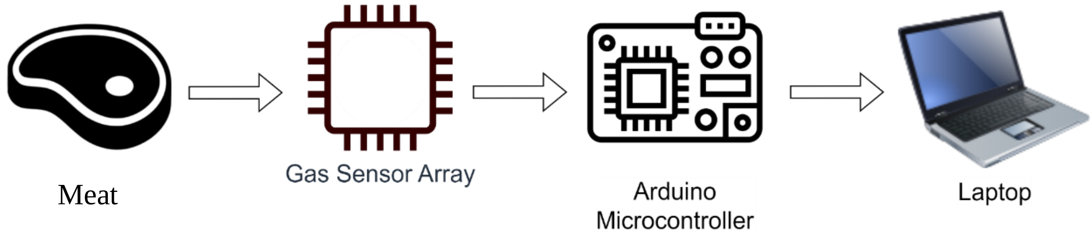


Figure 3. Research Methods

First, samples of beef ribs with various quality conditions will be prepared. Furthermore, the beef rib sample will be identified by Sensor array, with the characteristics of each sensor different. The analog signal generated by the sensor array will be captured by the Arduino which acts as a Microcontroller, which will then convert it into a digital signal by using an ADC (Analog Digital Converter). Scent data in the form of digital signals will be stored in a laptop for further analysis.

Results and Analysis

Results and Analysis display the sensors used and show sensor response patterns related to various conditions of beef quality.

Sensors Used.

Sensor selection is based on detecting gases such as ammonia, NOx, LPG, methane, alcohol, CO, and volatile organic compounds related to storage conditions and meat processing processes and providing objective information regarding the aroma and odor profile of meat. Here are the sensors used and their descriptions:

Table 1. Sensors Used.

Sensor	Description
MQ135	ammonia (NH_3), NOx, alcohol, benzene, smoke, carbon dioxide (CO_2)
MQ136	hydrogen sulfide (H_2S)
MQ137	ammonia (NH_3)
MQ138	toluene, acetone, ethanol and formaldehyde
MQ2	LPG, i-butane, propane, methane, alcohol, hydrogen, smoke
MQ3	alcohol, benzene, methane (CH_4), hexane, LPG, CO
MQ4	methane (CH_4), natural gas
MQ5	LPG, natural gas, town gas
MQ6	LPG, iso-butane, propane
MQ8	hydrogen (H_2)
MQ9	methane, propane, dan CO

Sensor Response

Sensor response is the result of the response of the sensor array in Electronic Nose to aromas or volatile compounds in beef samples. Each sensor in the array provides a specific response that forms an aroma pattern containing information about the quality of the beef ribs. This pattern is analyzed to identify changes in aroma related to changes in quality. The data collection process was conducted for 2220 minutes, then the results obtained in sampling were divided into 4 categories, namely:

1. Very Good: 300,
2. Good: 360,
3. Eligible: 240,
4. Not Feasible: 1320.

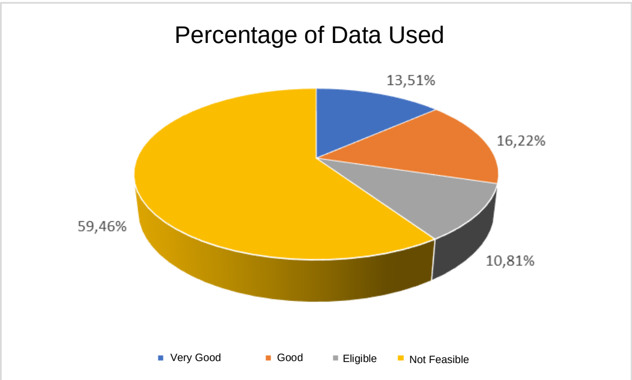


Figure 3. Percentage of Data Used

Figure 4. Is the result of the percentage of data obtained at the time of data retrieval. From the results obtained, the Very Good Category has a percentage of 13.51%, followed sequentially for the Good Category of 16.22%, Eligible 10.81%, and Not Feasible of 59.46%.

Analysis of Sensor Response

Analysis of the sensor response on the Electronic Nose (E-Nose) involves mapping the sensitivity of each sensor in the array to aroma compounds in the beef sample. By comparing changes in sensor output when exposed to aroma, distinctive sensor response patterns can be identified. Statistical techniques and signal processing were used to classify samples based on sensor response patterns, providing insight into aroma characteristics associated with changes in meat quality.

From the data that has been obtained, the next step is to analyze the data. The following is the result of an analysis of the sensor response obtained in each category.

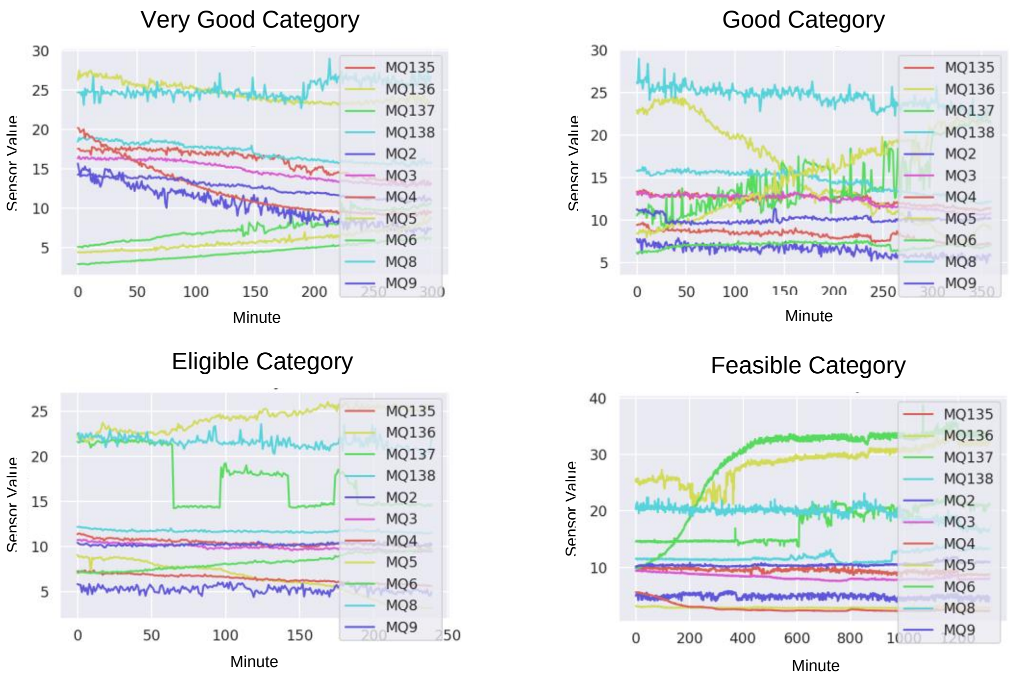


Figure 4. Results of Sensor Response Array by Category

Figure 5 is the result obtained from the sensor array. The analog data is then converted into digital form, to facilitate the analysis stage. The following is a summary of the response of all sensors. Tables 2 and 3 are a summary of the Response Array by category. Tables 2 and 3 take data for the minimum and maximum values of each category and each sensor.

Table 2. Summary of Sensor Response Array by Category

Category	MQ135	MQ136	MQ137	MQ138	MQ2
(1)	(2)	(3)	(4)	(5)	(6)
Very good	12,62 - 17,78	23,01 - 27,5	4,98 - 10,83	15,26 - 19,03	6,72 - 15,66
Good	11,13 - 13,56	7,31 - 24,46	8,8 - 22,09	11,9 - 16,26	4,77 - 7,89
Eligible	9,7 - 11,44	3,14 - 9,05	14,24 - 21,89	11,39 - 12,19	4,38 - 6,09
Not Feasible	8,26 - 10,21	2,7 - 3,39	13,63 - 22,61	10,41 - 14,28	3,85 - 5,84

Table 3. Advanced Summary of Sensor Response Array by Category

Category	MQ3	MQ4	MQ5	MQ6	MQ8	MQ9
(1)	(7)	(8)	(9)	(10)	(11)	(12)
Very good	12,68 -16,58	8,98 - 20,19	4,31 - 8,88	2,81 - 6,42	22,69 - 29	10,7 - 14,34
Good	10,54 -13,35	6,88 - 9,71	7,99 - 22,7	6 - 7,65	21,67 - 29	9,44 - 11,34
Eligible	9,37 -10,74	5,59 - 7,35	21,57 - 26	7 - 9,77	19,63 - 23,56	9,89 - 10,53
Not Feasible	7,54 -9,48	2,23 - 5,59	20,15 - 33,92	9,77 - 38,73	15,99 - 23,12	9,78 - 11,8

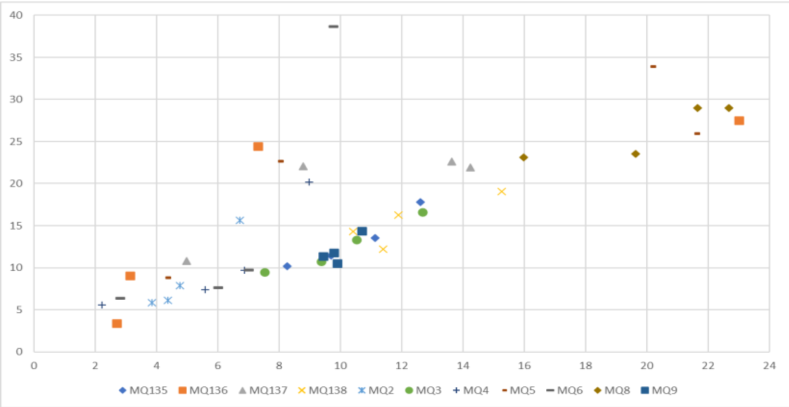
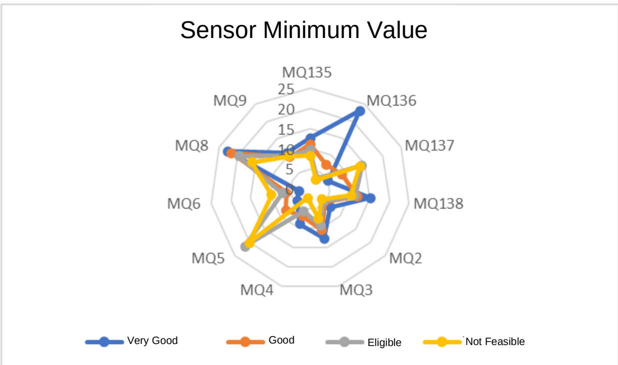
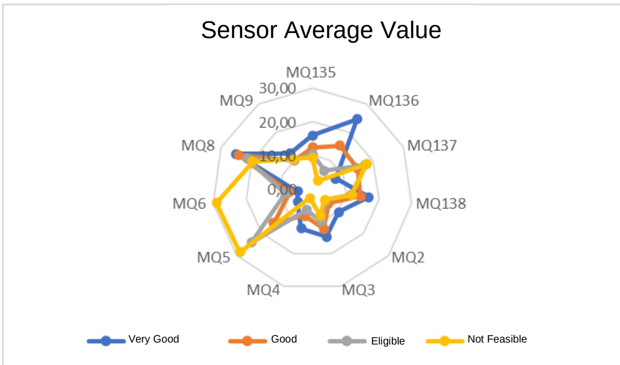


Figure 6. Scatter Plot of Sensor Array Response Summary Results

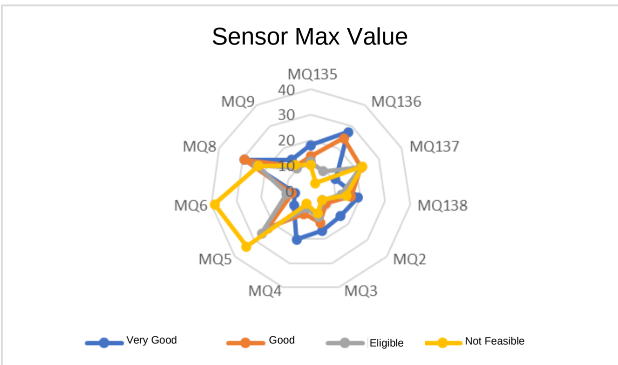
Figure 6 is a visualization using a scatter plot. Where the x-axis displays the minimum data from each sensor, while the y-axis is taken from the maximum value of each sensor. Figure 6 provides information on the position of the Beef Ribs meat category in 2 (two) dimensions of each sensor.



(a) Sensor Minimum Value



(b) Sensor Average Value



(c) Sensor Max Value

Figure 5. Radar Chart Pattern of Sensor Response

Figure 7 is a Radar Chart or Spider Chart to determine the pattern produced from all sensors. There are 3 (three) values shown in Figure 7. For (a) the minimum value of each sensor, (b) the average value of each sensor, (c) the maximum value of each sensor. This visualization can make it easier to make decisions later.

Conclusion

There are three sensors, namely MQ137 (ammonia (NH3)), MQ5 (LPG, natural gas, town gas), and MQ6 (LPG, iso-butane, propane). which shows the value inversely proportional to the value of other sensors. This indicates that the higher the value of the MQ137, MQ5, and MQ6 sensors, the quality of the rib meat is not feasible. MQ9 sensors (methane, propane and CO) have a high sensor value density compared to other sensors. MQ8 (hydrogen (H2)) gives the highest sensor value for the Good and Very Good Categories. and MQ5 and MQ6 gave the highest sensor scores for the Eligible and Not Feasible Categories. In-depth analysis of these patterns revealed that the E-Nose was able to recognize scent changes related to quality changes.

Further research can perform classification analysis using Machine Learning. Efforts to improve accuracy can use feature selection and signal data transformation methods. In order to develop a computerized system that is able to detect accurately, in order to determine the quality of meat in the beef ribs.

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