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Analysis of Odor and Color Parameters in the Meat Freshness Detection System Using Gas Sensor and Reaction Kinetics Methods

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Abstract

The degradation of beef is typically indicated by the presence of NH_3 as ammonia and H_2S as hydrogen sulfide. The NH_3 and H_2S level will increase in line with the meat spoilage. This research is aims to develop the new meat storage with NH_3 and H_2S level measurement to detect spoilage in beef. This measurement is needed to make sure the meat that are store is still in good condition or already spoil. Kinetic model of NH_3 and H_2S gas is used to determine the correlation between meat spoilage with time. This equipment has main parts that consist of sensor system microcontroller and computer. The MQ 137 works as detector of NH_3 gas which are emitted by sample of beefs during observation. The MQ – 136 sensor works as detector of H_2S gas. This research also analyzes the color change in beef spoilage. The data of meat storage develop in this research shows that it can properly measure NH_3 and H_2S gases that occur during the gas evolution process. The color of the meat also changes while the meat spoilage starts. The rate constants of change of H_2S and NH_3 follow the zero-order kinetics of H2S and NH3 with constant rates of 0.90 and 0.95, respectively. This result shows that time highly correlated with the spoilage meat.

INTRODUCTION

This study's primary equipment consists of a collection of gas detection devices that were self-designed. This equipment's primary components are the computer, microcontroller (Arduino), and sensor system [1]. Meat can provide satisfaction and enjoyment to people who eat it, therefore it is used as a diversification of food sources [2]. Meat has many nutrients so that it meets nutritional needs. Beef is one of the types of meat most consumed by humans [3]. The high demand for meat and limited availability of meat, the price of meat becomes more expensive. Currently, traditional methods are still used to determine the freshness and quality of meat, namely by using direct human contact through visual inspection and smell [4]. Therefore, it is natural to build a system that can detect the level of meat freshness quickly, accurately and non-destructively [5].

Meat is a commonly consumed dietary element, making the understanding of its spoilage crucial to ensure its health benefits and mitigate adverse effects on well-being [6]. The stages of rotting that occur in meat are the appearance of odors including hydrogen sulfide gas (H2S), ammonia (NH3), when the number of microorganism populations is ca. 107-8 cells / cm2, then followed by the appearance of

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mucus when the number of microorganism populations is ca. 108-9 cells/cm2, and the last is the color change caused by H2S oxidizing myoglobin to the metmyoglobin form, causing a green color [7].

Several cases in Banyumas and Purwokerto found the sale of rotten meat. Among others, hundreds of kilograms (kg) were found in several markets by the Banyumas Animal Husbandry and Fisheries Service. Classification of the level of meat rot is needed to find out what substances are contained in the meat and to make it easier for government agencies such as the Marine, Agriculture and Food Security Service (KPKP) and Kesmavet to separate meat that is suitable and unsuitable for marketing in order to create the suitability of food ingredients, especially meat in the community [8].

Meat rot can be seen from the appearance of gas caused by the metabolism of protein by Clostridium, Bacillus and Pseudomonas bacteria [9]. The gases generated comprise H2S and NH3. Bacteria in decomposing meat not only generate gas but also induce mucus development. Pseudomonas bacteria necessitate energy for growth during carbohydrate metabolism [10]. Meat becomes green because myoglobin is oxidized to metmyoglobin by H2S generated by bacterial activity [11]. The substances contained in rotten meat, the formation of mucus and changes in color cannot be detected by the sense of smell and sight alone.

In the field of chemistry to detect meat rot, laboratory tests are carried out to determine what substances are contained in the meat and how many bacteria are contained in it. To carry out laboratory tests takes a long time and can only be done using several laboratory equipment, so an objective tool is needed that can be used anywhere and does not require special skills to use it [12].

In this study, gas, color, and odor sensors were used to construct a meat rot classifier. The MQ-136, MQ-137, TCS 3200 color sensor, and PH sensor are the sensors utilized for gas sensor-based meat rot categorization. One kind of gas sensor designed especially to identify NH3 gas from decaying meat is the MQ-137 [13]. H2S gas produced in decaying meat is detected by the MQ-136. The purpose of TCS 3200 is to identify the color that decaying meat produces. The image of the meat must next be converted to RGB and finally to LAB.

METHODS

Sample Preparation

This research location at The Control Laboratory, Telkom University Purwokerto, the specimen used in this investigation was beef. The meat was bought straight from an abattoir in Purwokerto, Indonesia. When the meat was delivered to the lab, it was fresh and sealed. 100 g of the corpse's flesh was removed for measurement [14].

Detection Equipment

Self-designed gas detection gadgets are working as main tools. Another part is the computer, Arduino microcontroller, ammonia sensor and hydrogen sulfide sensor. Both of these sensors are metal oxide semiconductors for gas sensing purposes [14].

This sensor exhibits a resistance value that varies with fluctuations in the concentration of the measured gas, leading to corresponding changes in the device's voltage. After being converted using a calibration equation, the serial monitor shows the concentration of NH3 and H2S in parts per million (ppm) and will be entered into a computer database [15]. A 20 cm × 20 cm × 20 cm acrylic box with a tight-fitting lid contains four sensors. During the test, the acrylic container is filled with the beef sample that is intended for gas emission detection. The manufacturer's datasheet shows the two gas sensors' selectivity [16].

The Arduino microcontroller uses serial communication with the attached computer to read sensor data.

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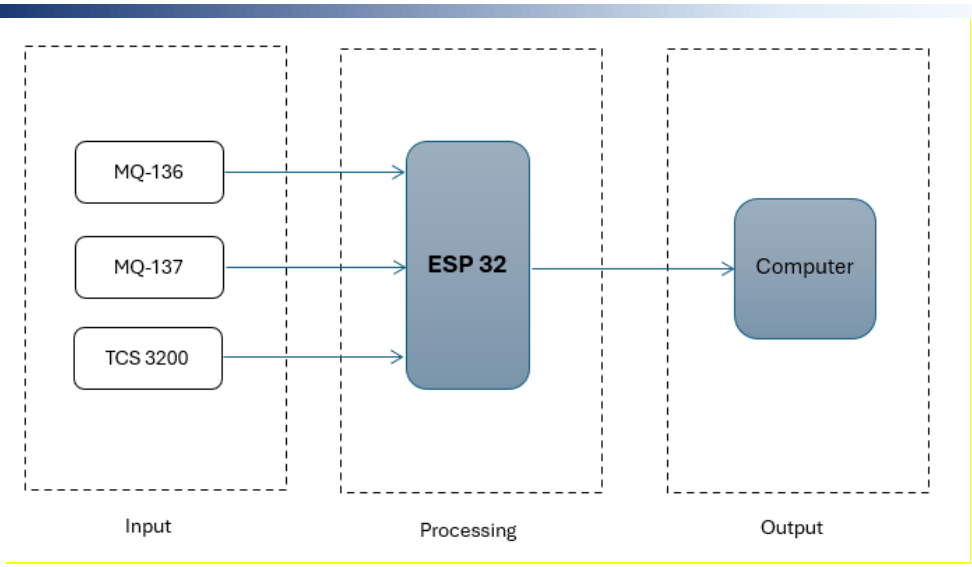
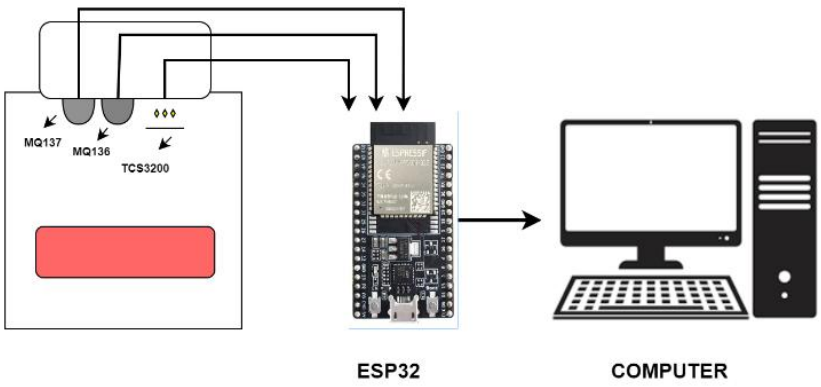


Picture 1. Block diagram of the gas detector device



Picture 2. Diagrammatic representation of the sensor chamber, sample chamber, and sensor system

Measurement Procedure

The beef sample is kept in a DIY-box with a gas sensor installed. The released gas of beef being evaluated will be applied to both gas sensors (MQ-136 and MQ-137). The voltage reading on the device will then fluctuate as a result of the sensor's reaction to the gas releases from the meat. The amount of gas that the flesh emits determines how much of this voltage change occurs. On the other hand, the meat freshness being examined by concentration of these gases. After converting the voltage value, the resistance ratio (Rs) to the resistance in clean air (Ro) is calculated. The calibration equation will then use the Rs/Ro ratio to determine the gas concentration value in parts per million. During a 24-hour period of room temperature storage, gas measurements were made hourly with three replications [17].

RESULT AND DISCUSSION

Classification of Sample Freshness

Important things that affect the deliciousness and quality of meat are its smell, color, texture, and taste. Many people argue that fresh meat has no smell at all. Meat damage can be caused by the action of microorganisms in the meat or the distribution of microbial enzymes inside and outside the cells in the meat. Factors that indicate meat has rotted include changes in color and odor, different textures, mucus, and the release of gas.

The system groups meat based on the amount of TVB-N in it to determine how fresh the meat is. TVB-N is the amount of nitrite removed from meat vapor or gas when in a basic state. This TVB-N

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stores all nitrogen content that can be ammonia at that time. Fresh meat is considered meat that has a TVB-N compound of less than 15 mg per 100 grams of meat. Slightly cooked starter has a value of between 15-30 mg of potassium per 100g of meat, while stale starter has a value above 30 mg per 100g of meat [18].

The meaning of meat decay content based on TVB-N value. Until now, there have been several types of devices that can detect gas that have been made. Gas sensors can be distinguished based on the materials used, such as conductive metal oxides, conductive polymers, and piezoelectric sensors such as quartz crystals. The MOS gas sensor is one type of sensor that is often used to make electronic smelling devices. This is because the sensor is very sensitive and affordable. The first gas sensor used a material called SnO2 in the form of a thick layer and was created by Taguchi in 1960. The MOS gas sensor, its type, is small, energy efficient, and has a good design.

Depending on the settings, the amount of time beef is stored changes in response to changes in NH3 and H2S gas levels. Based on the length of the inspection, meat can be divided into three groups: 0–9 hours, 10–20 hours, and 21–24 hours. Fresh meat makes up the first group (0–6 hours), non-fresh meat makes up the second group (7–13 hours), and rotten meat makes up the last group (14–20 hours). A study conducted in 2022 revealed that beef experiences changes in Total Volatile Base (TVB) levels of 0. 021% N, texture, pH, and Total Plate Count (TPC) after being stored at room temperature for 10 hours. This research was carried out in Asmara and surrounding areas. According to a statement from 2019, meat can be categorized as fresh (within 0-7 hours post-slaughter), medium fresh (8-13 hours post-slaughter), or non-fresh (beyond 13 hours post-slaughter), based on its color and texture. [19], [20].

At that temperature, beef held at 24 °C became unfit for consumption after 13 hours. Beef breast flesh held at 21 °C begins to exhibit significant spoilage after approximately 12 hours, characterized by sediment formation and the creation of sulfide chemicals. This study indicates that beef remains fresh for 7 hours, aligning with the median findings of other research. The difference may be due to the sample, basic assessment criteria, and storage temperature.

From this study it can be stated that the detection device that has been made can properly detect NH3 and H2S gases that occur during the gas evolution process. TC Color Analysis can distinctly categorize the brightness levels of meat into three groups within 24 hours of sampling. Changes in NH3 and H2S gases from stored beef can be a sign of how fresh the meat is [21].

Color Sensor Testing

Color sensor testing is done to see whether this sensor can measure the color of an object accurately or not. The TCS 3200 sensor will produce RGB values from objects placed nearby.

Table 1. Color Sensor Test Result Data on Fresh Meat for 45 hours

Time	Red	Green	Blue	Hour to-	Colour
2024-08-23T16:00:31	97	0	10	0	
2024-08-23T16:05:31	101	0	13	1	
2024-08-23T17:00:31	113	11	33	2	
2024-08-23T18:00:31	118	12	34	3	
2024-08-23T19:00:31	102	0	18	4	
2024-08-23T20:00:31	93	0	8	5	
2024-08-23T21:00:31	78	0	0	6	
2024-08-23T22:00:31	66	0	0	7	
2024-08-23T23:00:31	59	0	0	8	
2024-08-24T00:00:31	52	0	0	9	
2024-08-24T01:00:31	45	0	0	10	
2024-08-24T02:00:31	39	0	0	11	
2024-08-24T03:00:31	34	0	0	12	
2024-08-24T04:00:31	31	0	0	13	

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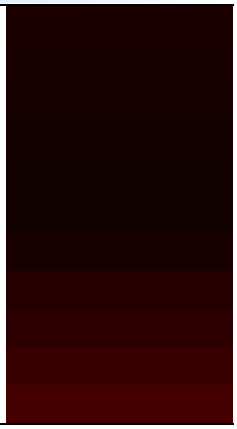
2024-08-24T05:00:31	27	0	0	14	
2024-08-24T06:00:31	24	0	0	15	
2024-08-24T07:00:31	22	0	0	16	
2024-08-24T08:00:31	19	0	0	17	
2024-08-24T09:00:31	17	0	0	18	
2024-08-24T10:00:31	16	0	0	19	
2024-08-24T11:00:31	25	0	0	20	
2024-08-24T12:00:31	37	0	0	21	
2024-08-24T13:00:31	44	0	0	22	
2024-08-24T14:00:31	57	0	0	23	
2024-08-24T15:00:31	68	0	0	24	

From table 1, it is found that the Red-Green-Blue (RGB) color of fresh meat changes significantly from 1 hour to 7 hours of testing. Fresh meat changes when the rotting process occurs. The color of fresh meat that we often see in the market is bright red. Unhealthy meat will have a dark red color approaching dark.

In the fresh meat color sensor test data, the RGB value shows the R value that appears most often compared to G and B. The average R value is 90, G is 0, and B is 10. Based on figure 1, the results of the color display can be seen. This fresh meat was tested from 11.30 am to 6.30 pm at room temperature. During this test, not too many changes occurred in fresh meat. From table 2, the average color number (RGB) of semi-fresh meat is much different from the fresh meat image in the time span of 12 hours to 18 hours.

In the results of the semi-fresh meat test, the RGB on the graph obtained is very different from the RGB results on fresh meat. The average value of red (R) is 59, while for green (G) is 0 and blue (B) is 0. It can be seen in Table 1. This semi-fresh meat was tested at 18.00 - 24.00. In the change in the shape of raw meat. The semi-fresh meat looks faded because it is affected by room temperature for 14 hours. From table 1, it was found that the color of the semi-fresh meat and the fresh meat image were not the same for 14 hours.

In the rotten meat test, the RGB value decreased from fresh and semi-fresh meat. In figure 1, the average frequency value for red is 31, for green is 0, and for blue is also 0. This unpleasant meat was investigated from 01.30 to 06.30 in the morning in a room with normal temperature. In the image changes, we can see the difference between fresh, semi-fresh, and rotten meat. Meat that is not fresh looks dark, rotten, and moldy because it has been stored at room temperature for too long for approximately 2 days [22], [23]. [24]. [25].

Color Sensor Test Analysis

From the information obtained, we can see the pattern and relationship between freshness level of the meat and its color. Fresh meat has the freshest color compared to the other two meats. The following is a comparison between fresh meat, semi-fresh meat, and rotten meat according to the number image. Color data is important to see the difference in meat color levels clearly [26].

The installed color sensor functions by changing its resistance value when detecting different colors. The results of this color sensor depend on the frequency changed by the detected color, the incoming Light, and distance between the sensor and the object to be measured. To get accurate results, the sensor should be used in a dark place. Based on the data sheet, the sensor should be read at a distance of 1.5 cm from the object in front of it on the sensor circuit board.

The area where the sensor has a viewing power of 4 mm x 4 mm. The sensor works sequentially starting from the red photodiode filter, then the green photodiode filter, and finally the blue photodiode filter. The first process starts from the red photodiode capturing the reflected light from the LED that hits the meat in the form of a current and is converted by the oscillator into a square signal whose

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frequency is determined by the intensity of the light captured by the red photodiode. The next process for the green and blue filters is the same as the red filter. From the frequency results obtained by red, green, and blue, the reading range is obtained when the meat is fresh, half fresh, and rotten meat. The reading range for the color sensor on the microcontroller is as follows:

1. Fresh meat (R<113 & R>66 & G<13 & G>0 & B<34 &B>0).
2. Semi-fresh meat (R<59 &R>31 & G<0&G>0&B<0&B>0)
3. Rotten meat (R<31&R>16&G<0&G>0&B<0&B>0)

The frequency reading of the freshness level of the meat will be displayed on the computer according to the basic order of the meat color, namely red, green, and blue in sequence and the buzzer will sound [27]. Then the data results that have been obtained will be analyzed by the microcontroller by arranging the RGB range and limits of each meat reading entered into the device.

Odor Sensor Testing

The MQ 136 and MQ 137 odor sensor tests were conducted to see how these sensors react to changes in meat quality. To test how the sensor reacts to the odor of the meat being tested, we will use several rules that we will always follow in every test.

The odor sensor is installed above the test chamber, while the meat sample is placed below it when the test is carried out. The collection of gas sensor voltage data runs for 5 minutes since the meat entered the sensor test chamber. The odor sensor test on meat begins by using fresh meat as a sample. Data is taken in the manner specified in the data collection procedure [28].

Kinetic Analysis of NH_3 and H_2S Changes

Under aerobic conditions, beef undergoes spontaneous deterioration at room temperature through two distinct processes: glycolysis and proteolysis. These processes occur simultaneously, albeit at different rates.. The breakdown of glucose and lactate by microorganisms that break down meat results in the production of ethanol and fatty acids [29]. Sulfides are produced by the processes known as secondary metabolism, which break down nitrogen molecules and amino acids. The elevation of ammonia levels in meat, along with prolonged storage duration, indicates the onset of spoilage. This is related to the increasing number of microbes. The production of NH_3 and H_2S gases occurs when bacteria such as Bacillus, Clostridium, and Pseudomonas break down proteins. Figure 1 and Figure 2 show how the concentrations of H_2S and NH_3 gases change in the beef being tested in this study [29]. [30].

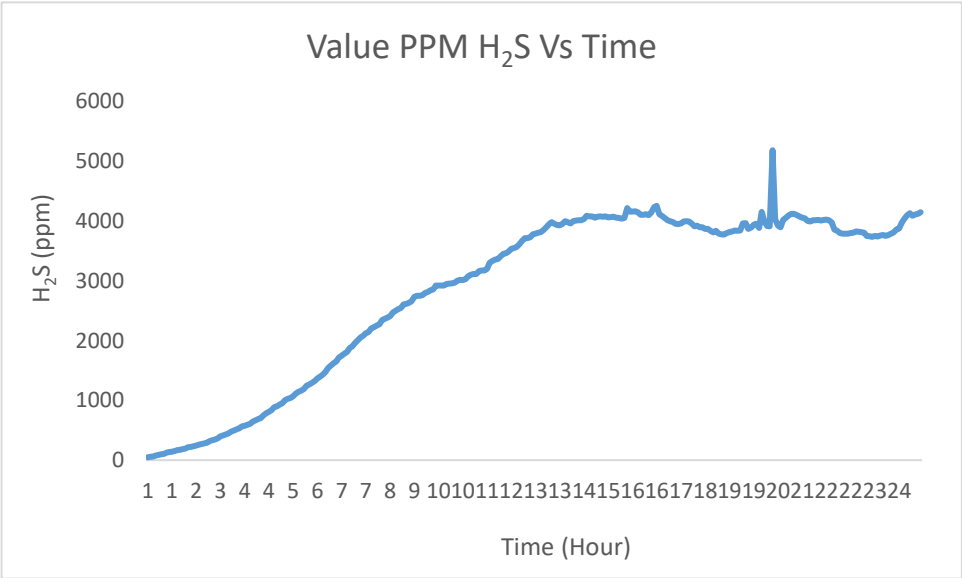

Figure 1. Change in the concentration of H_2S in meat stored at room temperature

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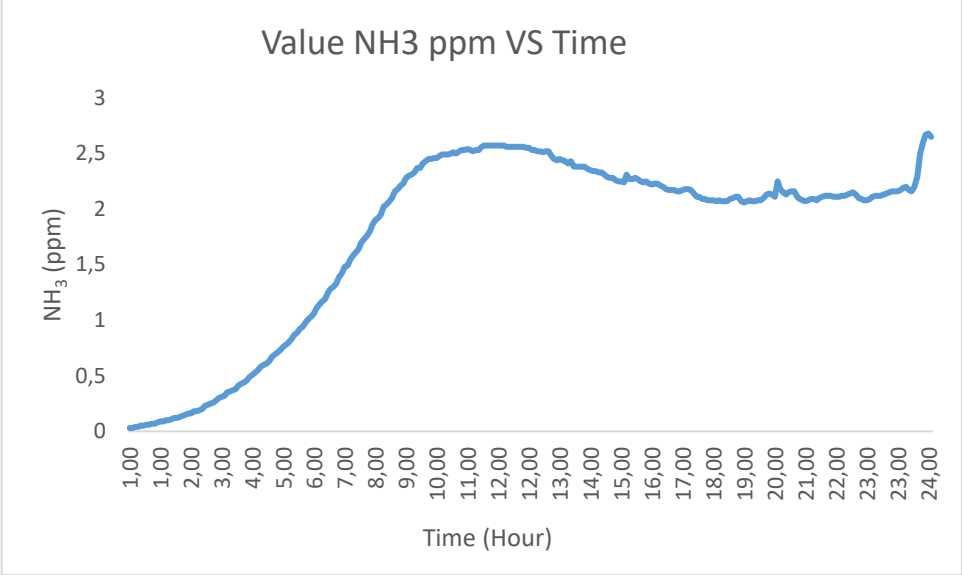

Figure 2. Change in the concentration of NH_3 in meat stored at room temperature

By the tenth hour, the increase in H2S gas was significant, with its concentration reaching 3000 ppm, while NH3 levels remained relatively low at just 2. 5 ppm.. Nonetheless, when reaching the 19th hour, the concentration of H2S gas exhibited a marked escalation, persisting until the 24th hour. At the 25th hour, the concentration of H2S gas rose by almost 30%, whereas the NH3 gas exhibited no increase relative to the 10th hour. The SPME (Solid Phase Micro Extraction) method is used to evaluate the deterioration of Irish free-range beef stored at 4 °C based on the production of hydrogen sulfide (H2S), dimethyl sulfide, and ethanol chemicals.

Meat rots with an unpleasant stench and an elevated pH as a result of the byproducts of sulfides, indoles, and amines produced by the microorganisms' consumption of amino acids, which raises ammonia levels. Amino acid and sulfur compounds's vapour are applicable as biomarkers of beef freshness.

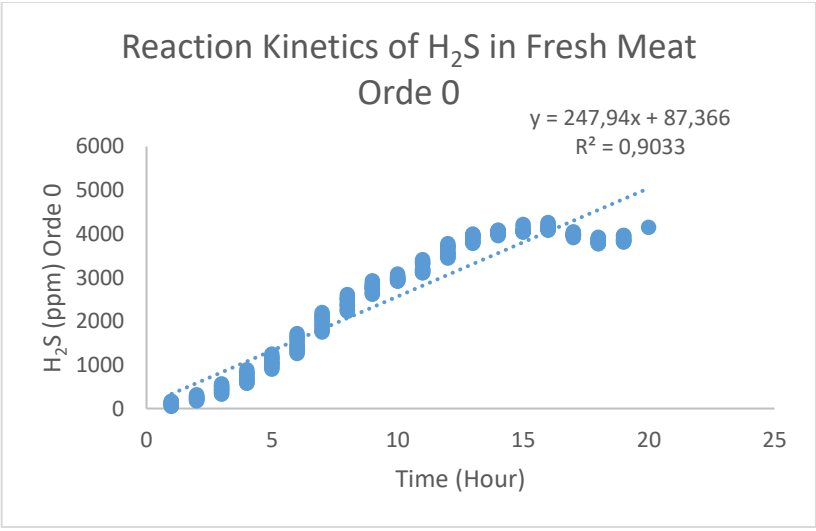

Figure 3. Reaction Kinetics of H_2S in Fresh Meat Order 0

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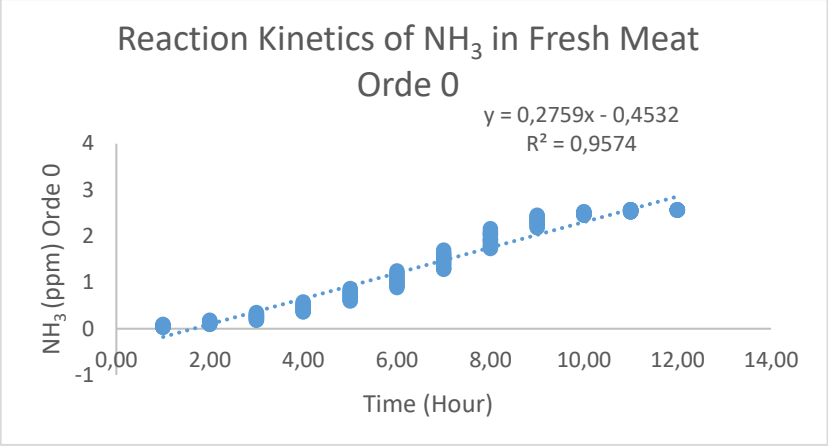

Figure 4. Reaction Kinetics of NH_3 in Fresh Meat Orde 0

Discussion

The rate constant (k) of NH_3 and H_2S formation is obtained from the zero-order kinetic equation. The relationship between the concentration of H_2S and NH_3 gases (C) and time (t) can be seen in Figures 3 and 4. Thus, it can be concluded that changes in the concentration of NH_3 and H_2S gases follow the zero-order kinetic equation [31], [32]. [33]. The investigation into the changes in quality of meat and processed beef products during heating follows zero-order kinetics. This same principle is observed in studies examining the texture changes and kinetics of color in beef.. The findings suggest that this study's results can forecast the development of H2S and NH3 gases from beef during storage at ambient temperature [34], [35].

Damage reactions occurring throughout the food chain encompass harm to meat. To generate superior food, it is essential to examine and regulate alterations in critical factors and establish optimal conditions throughout manufacturing, distribution, and storage to mitigate chemical, microbiological, or physical reactions [36].

Even if microbial activity is successfully managed by the use of certain preservation techniques, meat quality will unavoidably deteriorate over the course of the product's life cycle as a result of all these interactions. Therefore, to minimize such degradation, understanding of measurement through precise mathematical equations is necessary, including the influence of the main parameters, intrinsic and/or extrinsic to food, which influence product deterioration gradually [37].

Food modeling is currently centered on understanding quality degradation. By exploring alternative methodologies that incorporate kinetics, we can develop reliable mathematical models to predict how food attributes change during processing and throughout its shelf life during handling and storage. Utilizing these models can help mitigate food spoilage. [38].

CONCLUSION

The investigation concluded that the device, which utilizes MQ-136 and MQ-137 gas sensors, is capable of detecting the release of ammonia (NH3) and hydrogen sulfide (H2S) gases emitted by beef during its storage in ambient air. TCA Color can be used to classify meat quality, producing three different color groups: rotten meat (14–20 hours), non-fresh meat (8–13 hours), and fresh meat group (0–7 hours). The kinetic study results indicate that the evolution of NH3 and H2S gases adheres to the zero-order reaction kinetic equation with considerable precision. This meat freshness tool may serve as a research development instrument in the domain of food technology in the future. The utilization of this instrument significantly facilitates the testing process within the food business.

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