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Meat spoilage characterization via electronic nose

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ABSTRACT

Meat is one of the food varieties that spoils rapidly when not chilled. Meat spoilage in public markets has been one of the main contributors to food wastage and imposes health hazards when consumed. Although the meat vendors intend to sell fresh and good products, they cannot identify how much time meat will reach spoilage, much more the buyers. A system that can characterize meat samples to predict spoilage time will benefit not only the vendors and regulation authorities but moreover the consumers. This study aims to develop an electronic nose system for characterizing the gases emitted when meat is approaching spoilage. The system will look for patterns in the levels of methane (CH_4), ammonia (NH_3), and hydrogen sulfide (H_2S). An array of metal oxide semiconductor (MOS) sensors placed in an air-tight chamber measures the emitted gas particles by the meat samples. In each experiment, a meat sample is placed in the enclosure while monitoring the concentration of CH_4, NH_3, and H_2S at different time intervals. Several variables affect the rate of spoilage of meat. The meat samples' weight (or volume) and the time elapsed at room temperature are used as the independent variables. The level of the concentration of CH_4, NH_3, and H_2S at different time intervals becomes the feature vectors for training different classifiers. Four classifiers were considered for meat spoilage characterization but the weighted KNN performed best with an accuracy of 98.33%. The system has successfully detected spoilage in meat as well as the experts in the field do. Spoilage can be detected by taking into account the gas concentration levels of CH_4, NH_3, and H_2S. In future works, temperature effects can also be integrated with the system.

Keywords: electronic nose, MOS sensors, meat spoilage, KNN, pattern recognition

1. Introduction

The Food and Agriculture Organization of the United Nations and the World Health Organization proclaimed that 33% of the food made for human utilization is squandered every year [1]. Food spoiling is a metabolic process that results in food products that are unfit for human consumption [2]. Meat is just one of the various food varieties that will ruin rapidly if not chilled or put away appropriately [3]. Meat spoilage also has an economic impact. The health of customers is directly tied to the quality of meat [4]. Consumers have placed a greater emphasis on food quality and safety as human living standards have continued to rise [5]. Normal individuals can not figure out if or not artificially treated meats have transformed. These meats are unhealthy to eat [6]. The meat freshness is a huge mark of the quality and security of meat items, and it is something that meat makers, vendors, and consumers give close consideration to [7]. Sensory evaluations rely on human senses to provide data on color, odor, rubbery state, and overall meat quality [8]. However, sensory analysis has various imperfections, including the significant expense of the expert group, judgment errors attributable to exhaustion and subjectivity, and the way that it can not be utilized for online estimation [9]. Chemical methodologies are level-headed and exact, yet they are regularly applied in research facilities, which are both ruinous and tedious [10].

Meat deterioration prompts the advancement of off-flavors, off-scents, and frequent sludge development because of the breakdown of important substances fat, protein, and carbohydrates which make the item unwanted for human utilization [11]. items will be limited or moved into cooler stockpiling well before microbiological waste happens [12]. in creatures butchered in-country networks with next to no security measures, microorganisms present in the creatures' digestion tracts can undoubtedly taint the meat [13]. Stows away become polluted either because the outside of the away stow is messy, or because once eliminated from the creature, within the away stow is a decent reproducing place for microorganisms [14]. The presence of an awful scent or smell coming from food means that it very well might be hazardous. In any case, recall that not all hazardous food smells terrible [15].

There are many emerging technologies for electronic noses [16,17] the following are some of the sensors used for meat spoilage detection.

Spectroscopy is a high-level identification method that capacities on the association among tissue and electromagnetic radiation of different frequencies [17,18]. However, utilization is expensive and limited to the laboratory environment.

The conductive polymer has fundamental mechanical properties that consider the development of food deterioration sensors [19]. These sensors might be characterized into the

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method of transduction and application [20]. However, CP-based gas sensors are more sensitive to the detection of halogens, alcohols, and ethers.

Another one of these technologies is the electronic nose, [21-24] state in their study that the electronic nose was a device that simulates human olfaction to analyze, perceive, and research muddled gases. The MOS is the most ordinarily utilized in e-noses [25]. It is a type of gas sensor that can identify early indications of meat deterioration.

This paper proposes a system that can characterize meat samples to predict the spoilage time that will benefit not only the vendors and regulation authorities but moreover the consumers.

This study aims to develop an electronic nose system for characterizing the gases emitted when meat is approaching spoilage. The system will look for patterns in the levels of methane, ammonia, and hydrogen sulfide.

2. Materials and methods

The development of the electronic nose for meat spoilage characterization adopts the CDIO framework as in Figure 1. The study started with a needs assessment based on interviews and dialogues with meat inspectors in the locality of Batangas City. The consultation with experts in meat spoilage characterization identified the problems they face in evaluating meat products in the public market i.e., sensory-based evaluation is quite a subjective and tedious process. From these concerns, the use of electronic noses has been conceptualized.

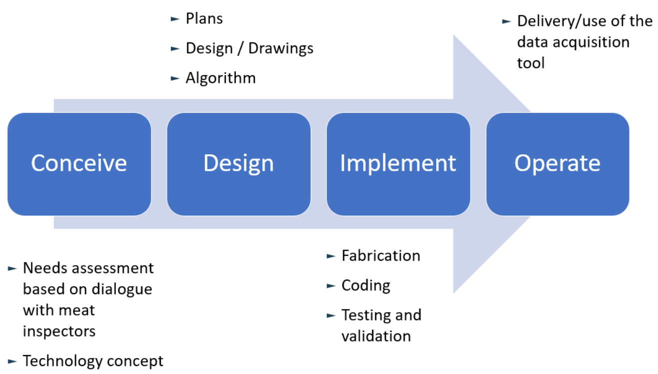

Figure 1. CDIO framework adopted in the study.

The design of the electronic nose considered the size of meat samples, the type of gases emitted by spoiling meat, the sensors to measure levels of those gases, and the electronic system that will process the sensor measurements. Upon doing a comparative study on available sensors, we have selected the following MOS sensors: MQ 05, MQ 135, and MQ 136, namely CH_4, NH_3, and H_2S sensor modules, respectively. The sensor array consists of three modules for each gas for a total of 9 sensors. The sensor array is installed inside an acrylic chamber with wooden support. The sensors are directly connected to an Arduino ATMega controller which serves as the data acquisition board for the computer (Figure 2).

Figure 2. Actual data acquisition set-up for meat spoilage characterization.

2.1. Data collection set-up training and testing dataset

In the experimentation, a total of 60 meat samples were used. Fifty-one samples were used for training while the other 9 were used for testing the system. Each of these samples followed the strict meat handling procedures recommended by the experts from the Office of the City Veterinary and Agricultural Services (OCVAS) of Batangas City. There are 20 meat samples for every weight category, 50 g, 100 g, and 200 g.

The initiation of the system requires turning on the fans and pre-heating the sensors which are automatically handled by the controller. Next is the placement of the meat sample. After 30 min, the system records the level of concentration of the three gases and signals the removal of the sample. Once removed, the sample is subjected to expert inspections to make appropriate annotations for the sensor measurements. Two experts were invited to label the meat samples as “spoiled” or “not spoiled”. Also, the system automatically flushes the chamber with fresh air and waits until the sensor's reading returns to zero as summarized in Figure 3.

Nine meat samples were used to generate a time-based measurement of gas concentration. Fresh meat is placed in the chamber at room temperature for 8 h. For every 30 min, the gas concentration levels were measured without flushing air during intervals as in Figure 4.

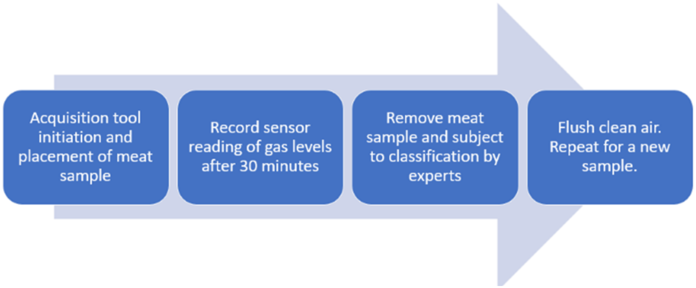

Figure 3. Workflow for gas concentration level measurements.

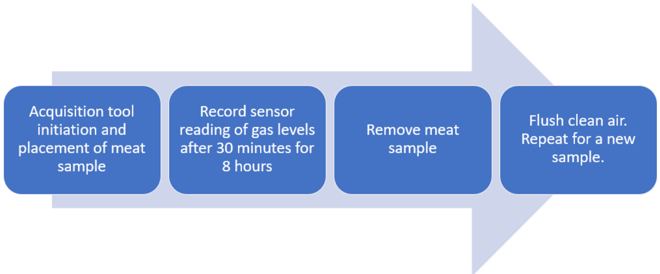

Figure 4. Workflow for the time-based measurement of the gas concentration levels and their rate of increase.

2.2. Classifier model selection, training, and evaluation

There are 4 classifier models considered in this study. First, we considered K-Means Clustering because of its low complexity in terms of implementation. The clustering algorithm aims to group the gas concentration level measurements into two categories: 'spoiled' and 'non-spoiled'. The second model considered is the Logistic Regression due to the logarithmic nature of the gas concentration levels over time. The third model considered is the Support Vector Machine due to its known robustness and good generalization capability for small data sets. Lastly, K-Nearest Neighbour due to its capability to cluster highly non-linear data.

The evaluation metrics used to measure the performance of the classifiers are as follows: accuracy, precision, recall, and F1-score. The classification model with the highest accuracy and F1 score is selected for the electronic nose.

3. Results and discussion

3.1. Data acquisition tool

The data acquisition tool is composed of an array of nine gas concentration sensors distributed evenly in the ceiling of the data acquisition chamber. These sensors feed readings to a microcontroller which then translates sensor readings into gas concentration levels and records the measurements into a *.csv file. The microcontroller also actuates the fan for flushing clean air and the LED indicators (Figure 5).

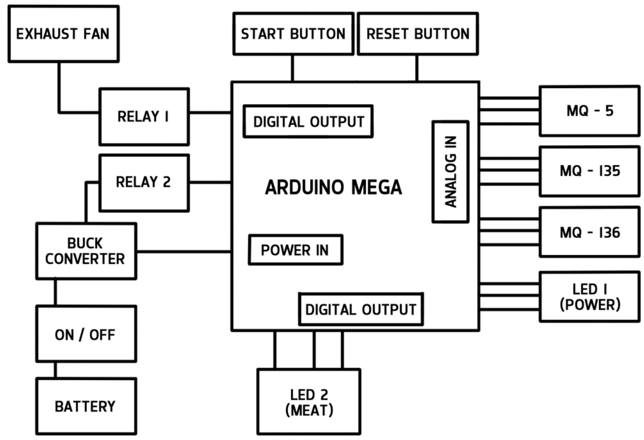

Figure 5. Block diagram of the electronic nose.

3.2. Gas concentration levels of the random meat samples

To explore the possible correlations between the gas concentration levels in both the spoiled and non-spoiled meat samples, we plot the sensor readings with the classification labels identified by the meat inspectors in Figure 6. The measurements of gas concentration levels of meat samples have no clear linear boundary for the spoiled and not-spoiled categories.

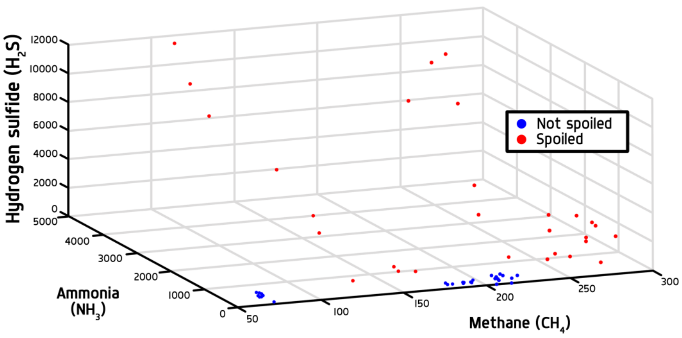

Figure 6. Gas concentration levels of random meat samples.

3.3. Performances of the classification models

There are four classification models considered for identifying spoiled meat samples. The evaluation results suggest that K-NN would be the most appropriate model for classification between spoiled and not spoiled due to its balance between precision (positive predictive value) and recall (sensitivity) as in Table 1. Since both, the positive prediction and sensitivity are equally important in this classification task, the F1-score is used to choose the most appropriate model.

Table 1. Model comparison results in percentage (%).

Model	Accuracy	Precision	Recall	F1-scores
K-Means	63.33	57.69	100.00	73.17
Logistic Regression	96.67	100.00	93.33	96.55
Support Vector	93.33	100.00	86.67	92.86
K-NN	98.33	100.00	96.67	98.31

3.4. Evaluation of the electronic nose

Again, the goal of the electronic nose was to identify when the meat sample is about to spoil. To do this, we measured the time it took before the electronic nose categorized the meat sample as spoiled or not. From Table 2, the 50 g meat sample spoiled the fastest. This also showed that the bigger the meat sample, the slower it can reach spoilage. The meat samples used in this test were certified fresh by the invited experts from the OCVAS of Batangas City. The rate of increase in levels of gas concentrations presented in Table 2 includes only the change in levels from the start to the time when the sample is detected or classified as spoiled.

Table 2. Time before meat samples spoiled.

Weight (g)	Time before spoilage	Increase in CH_4, NH_3, H_2S concentrations (%)
50	30	34.96, 41.25, 40.05
100	150	32.96, 30.07, 35.67
200	180	32.09, 28.68, 24.28

4. Conclusions

The system has successfully detected spoilage in meat, similar to the research conducted by experts in the field. Spoilage can be detected by taking into account the gas concentration levels of CH_4, NH_3, and H_2S. The temperature effect on the system warrants further investigation.

References

[1]Meybeck A, Cederberg C, Gustavsson J, van Otterdijk R, Sonesson U. Global food losses and food waste. Rome, Italy: Food and Agriculture Organization of the United Nations (FAO); 2011. Available from: https://www.fao.org/publications/card/en/c/I2697E

[2] Rawat S. Food spoilage: microorganisms and their prevention. Asian Journal of Plant Science and Research. 2015;5(4):47-56.

[3] Sarioglu OF, Celebioglu A, Tekinay T, Uyar T. Bacteria-immobilized electrospun fibrous polymeric webs for hexavalent chromium remediation in water. International Journal of Environmental Science and Technology. 2016 Jun 2;13(8):2057-66. Available from: https://doi.org/10.1007/s13762-016-1033-0

[4] Xiao Y, Jiaojiao J, Guohua H, Fangyuan Y, Minmin W, Jie H, Xiaoguo Y, Shanggui D. Determination of the freshness of beef strip loins (M. longissimus lumborum) using electronic nose. Food Analytical Methods. 2014 Jan 28;7(8):1612-8. Available from: https://doi.org/10.1007/s12161-014-9796-8

[5] Chen YN, Sun DW, Cheng JH, Gao WH. Recent advances for rapid identification of chemical information of muscle foods by hyperspectral imaging analysis. Food Engineering Reviews. 2016 Apr 4;8(3):336-50. Available from: https://doi.org/10.1007/s12393-016-9139-1

[6] Weng X, Luan X, Kong C, Chang Z, Li Y, Zhang S, Al-Majeed S, Xiao Y. A comprehensive method for assessing meat freshness using fusing electronic nose, computer vision, and artificial tactile technologies. Journal of Sensors. 2020 Sep 21;2020:1-14. Available from: https://doi.org/10.1155/2020/8838535

[7] Qiao L, Tang X, Dong J. A feasibility quantification study of total volatile basic nitrogen (TVB-N) content in duck meat for freshness evaluation. Food Chemistry. 2017 Dec;237:1179-85. Available from: https://doi.org/10.1016/j.foodchem.2017.06.031

[8] Papadopoulou OS, Panagou EZ, Mohareb FR, Nychas GJ. Sensory and microbiological quality assessment of beef fillets using a portable electronic nose in tandem with support vector machine analysis. Food Research International. 2013 Jan;50(1):241-9. Available from: https://doi.org/10.1016/j.foodres.2012.10.020

[9] Kiani S, Minaei S, Ghasemi-Varnamkhasti M. Fusion of artificial senses as a robust approach to food quality assessment. Journal of Food Engineering. 2016 Feb;171:230-9. Available from: https://doi.org/10.1016/j.jfoodeng.2015.10.007

[10] Sallam KI, Samejima K. Microbiological and chemical quality of ground beef treated with sodium lactate and sodium chloride during refrigerated storage. LWT - Food Science and Technology. 2004Dec;37(8):865-71. Available from: https://doi.org/10.1016/j.lwt.2004.04.003

[11] Singh R. Economic impact of meat spoilage and preservation. Pashudhan Praharee. 2020Sep14. Available

from: https://www.pashudhanpraharee.com/economic-impact-of-meat-spoilage-and-preservation/.
[12] Breidenstein BB. Economic impact of meat spoilage organisms. InProceedings-Annual Reciprocal Meat Conference of the American Meat Science Association (USA) 1986.
[13] Weiler GA, Fernandez JL. Food safety is everybody's responsibility. World Health Organization-Philippines. 2019Jun5. Available from: https://www.who.int/philippines/news/commentaries/detail/food-safety-is-everybody-s-responsibility
[14] Hygiene and Environmental Health Module: 8. Food Contamination and Spoilage. UK: The Open University; 2011. Available from: https://www.open.edu/openlearncreate/mod/oucontent/view.php?id=194
[15] Casalinuovo I, Di Pierro D, Coletta M, Di Francesco P. Application of electronic noses for disease diagnosis and food spoilage detection. Sensors. 2006Nov1;6(11):1428-39. Available from: https://doi.org/10.3390/s6111428
[16] Lohumi S, Lee S, Lee H, Cho BK. A review of vibrational spectroscopic techniques for the detection of food authenticity and adulteration. Trends in Food Science & Technology. 2015 Nov;46(1):85-98. Available from: https://doi.org/10.1016/j.tifs.2015.08.003
[17] Pu Y, Wang W, Alfano RR. Optical detection of meat spoilage using fluorescence spectroscopy with selective excitation wavelength. Applied Spectroscopy. 2013 Feb;67(2):210-3. Available from: https://doi.org/10.1366/12-06653
[18] Nuernberger P, Ruetzel S, Brixner T. Multidimensional electronic spectroscopy of photochemical reactions. Angewandte Chemie International Edition. 2015 Aug 26;54(39):11368-86. Available from: https://doi.org/10.1002/anie.201502974
[19] Bai H, Shi G. Gas sensors based on conducting polymers. Sensors. 2007 Mar 7 ;7(3):267-307. Available from: https://doi.org/10.3390/s7030267
[20] Gupta N, Sharma S, Mir IA, Kumar D. Advances in sensors based on conducting polymers. Journal of Scientific & Industrial Research. 2006 Jul;65:549-57.
[21] Ghasemi-Varnamkhasti M, Mohtasebi SS, Siadat M, Balasubramanian S. Meat quality assessment by electronic nose (machine olfaction technology). Sensors. 2009 Jul 30 ;9(8):6058-83. Available from: https://doi.org/10.3390/s90806058
[22] Majchrzak T, Wojnowski W, Dymerski T, Gębicki J, Namieśnik J. Electronic noses in classification and quality control of edible oils: a review. Food Chemistry. 2018 Apr;246:192-201. Available from: https://doi.org/10.1016/j.foodchem.2017.11.013
[23] Timsorn K, Thoopboochagorn T, Lertwattanasakul N, Wongchoosuk C. Evaluation of bacterial population on chicken meats using a briefcase electronic nose. Biosystems Engineering. 2016Nov;151:116-25. Available from: https://doi.org/10.1016/j.biosystemseng.2016.09.005
[24] Sun QX, Dong FJ, Chen Q, Kong BH. China National Knowledge Infrastructure --- Download Paper. Application of electronic nose technique detect the flavor and quality of meat and meat products--《food research and development》2015年12期.Available from: https://en.cnki.com.cn/Article_en/CJFDTotal-SPYK201512034.htm?fbclid=IwAR3nsViFiovwuPcZGrIMb9MnWIps2IlOV0Y9NEjEmc0Q6XZaQPv9RBbFbzE
[25] Estakhroyeh HR, Rashedi E, Mehran M. Design and construction of electronic nose for multi-purpose applications by sensor array arrangement using IBGSA. Journal of Intelligent & Robotic Systems. 2017 Dec 18;92(2):205-21. Available from: https://doi.org/10.1007/s10846-017-0759-3

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