Supervised Machine Learning Approach for Pork Meat Freshness Identification

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ABSTRACT

As the number of pork consumer increases in the meat industry, the demand for meat supplies also rises. Determining pork meat freshness, therefore, is the primary consideration of the pork meat customers. This smart study is mainly designed to assess and classify pork meat quality. Loin parts weighing 100 grams from various pigs in the wet market, were examined and became the data sets of the study, provided that a city veterinarian has inspected and approved it. Photos of pork meat are captured to undergo image processing. Simultaneously, electronic noses, specifically MQ-135 and MQ-136, evaluated Ammonia and Hydrogen Sulfide components of the pork meat, respectively. These parameters are then classified using the k-Nearest Neighbor Algorithm. Pork meat is distinguished from being fresh, half-fresh, and adulterated. By using the confusion matrix principle, functionality test and statistical analysis revealed that the system has a high accuracy rate of 93.33%.

CCS Concepts

• **Theory of computation→Nearest neighbor algorithms**

Keywords

Pork meat; Image Analysis; Electronic noses; K-Nearest neighbor; Meat quality

1. INTRODUCTION

For years, pork meat has been an essential part of the human diet, more so with the development of the economy and the improvement of people's living standard. Although there are religions that prohibit eating pork meat, it does not change the fact that this commodity still has an increasing call in the market. According to the report of Global Agricultural, over the past 50 years, global meat production has quadrupled from 84 million tons in 1965 to a current total of 330 million tons in 2017 [1]. This account proves that as the population increases, pork meat demand also increases. However, as the meat industry expands, there has also been an escalation in the demand of consumers for high quality and safe meat, which produced new threats to the meat industry. One existing challenge faced is to obtain reliable information on meat quality throughout its production process, which would provide a guaranteed quality of pork meat products. Based on the report given by the Department of Health: Public Health Surveillance Division, there was an increase of 4.96% cases of food-borne diseases nationwide with a total of 35, 158 affected individuals and 72 deaths from January 1 to September 2, 2017, compared to its previous year with a number of 33, 454 food-borne patients [2]. It would be a wild guess to tell whether the source of pork meat is within standards of any food bureau, nationally or internationally without any reliable information. Therefore, the discovery of a speedy instrument to detect adulterated pork meat is vital for the suppliers and consumers as a whole.

Throughout the manufacturing, delivery, and storage processes, meat products are significantly exposed to deterioration since bacteria are present everywhere. And it is well known that quality assessment must be done to all meat products supplied to the market to secure consumer safety [3]. This claim is the reason why it is essential to establish efficient, inexpensive, and rapid methodologies for examining or monitoring meat products to guarantee their sterile quality to be utilized both on the market and in consumer's household [4] [5]. "Food freshness sensing" is perceived as a collective unmet consumer need globally. The public well-being and the diminution of food waste are some of the great benefits if food freshness assessment is simply done [6]. It could be carried out with the participation of all kinds of indexes including sensory indexes, quantities, and character of decomposed matter, changes of color and luster, all types of physicochemical detection, sanitation (microorganism) detection, etc. [7]. This course is complex; hence, the single index cannot identify the degree of meat freshness correctly [8]. Meat purchasing decisions are influenced by color more than any other

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quality factor because consumers use discoloration as an indicator of freshness and wholesomeness [9]. The color and gloss, which are the first things to be considered, is determined by the quantity of muscle-red protein and off-springs decomposed. The color and luster of meat can well manifest its characters since it changes effortlessly with the corruption of meat. Fresh meat has a rosy appearance while hypo-fresh meat is gray. Degenerative meat is henna, has no luster and has asymmetric green marks in some area [10]. Another basic sensory index considered is the gas sensor. Interests of low-cost gas-sensors have augmented during the last decade for use in various applications [11], and one of these is for food quality control which performs a fast screening to identify any possible spoilage of the product [12]. When enzyme putrefies the meat, acid and volatility odor matters occur such as H_2S and NH_3 [10]. Hydrogen Sulfide, also known as H_2S, usually takes place when organic matter is corrupted in the absence of oxygen by bacteria. It has a characteristic smell of rotten egg [13]. It is also generated during the decomposition of several food stocks. On the other hand, NH_3, popularly known as Ammonia, is one of the chemical volatiles that is normally present during spoilage processes and contamination [14]. Therefore, a relationship happens between the meat freshness and the change in the concentration of these gases [15]. Furthermore, several researchers have released numerous studies in dealing with the assessment of pork meat quality. Some of them used Total Volatile Basic Nitrogen (TVB-N) content and Warner-Bratzler Shear Force in food products [16], Plaque Characteristics of the meat [17], and Color Region Ratio (CRR) [18], while others used Voltammetry Electronic Tongue [19] and Electronic Noses [20]. Whichever scholars want to utilize, the key point of these studies is to discover a speedy, effective, and economical way of evaluating pork meat quality.

Determining edible meat from adulterated meat is a necessity because, primarily, contaminated pork meat can lead to health problems, which can be fatal – thus motivating this study to develop a modernized system which examines the quality of pork meat and differentiates edible meat from inedible. This study particularly aims to develop a software system and hardware setup that will set parameters for digital image processing to assess the quality of pork meat mainly through color, texture, and odor, and conduct a functionality test of the quality assessment system.

With this new system, it is believed that this is one of the best ways to aid meat quality inspections, especially in public markets where selling of “botcha” or “double dead” pig is usually found. It will be easier to determine whether the quality of the examined pork meat is fresh and is acceptable for human consumption or not. This innovation would also be a help to lessen the cases of food poisoning due to the intake of spoiled pork meat.

The discovery of a non-destructive, convenient, and rapid method to evaluate meat freshness is the primary purpose of this study. Its goal is to minimize or eliminate, if possible, the cases in which numerous individuals were poisoned with contaminated pork meat they had ingested. Additionally, this will promote public awareness involving pork meat’s quality. By this, the intention of keeping the consumers’ health and safety from the spoiled meat products will be taken into account as well.

The results of this study shall benefit various people in society. This study can be the key to the development of efficient pork quality inspection in the local government of Davao. Pork consumers and suppliers will have the assurance that the pork meat they produce, buy, and consume is in good quality. Lastly, this study may have the privilege to belong in the largest abstract and citation database, the Scopus.

Importantly, this study limits to the development of pork meat assessment system that users can identify the freshness of pork meat through image analysis and electronic nose with the aid of the software system. It is also restricted to determine the qualities of unprocessed pork meat only. Meat of the hybrid pigs, which grow in slaughterhouses, will be utilized. Freshness classification of chicken, beef, and other kinds of meat are not included in this study, hence making its data “unknown” to the system.

2. MATERIALS AND METHODS

Applied research was exploited as the outline of this study. This applied research intends to aid the existing problem on efficient pork quality inspection, fill important information, develop a new method of the system via digital image processing and electronic noses, and analyze the results.

Several related kinds of literature have been considered to begin this study. The works about the Total Volatile Basic Nitrogen (TVB-N) influences this research the most, yet, a low-cost and facile alternative system is initiated for this study to be more economical as it is one of the design constraints taken into consideration.

2.1 Conceptual Framework

Figure 1 illustrates the conceptual framework of this study. It shows the relationship between the three components which stands as a guide throughout the study duration. Pork meat image and odor are the two essential inputs of this system. The skin texture and color of the meat are derived from the photograph of the pork, while chemical volatile is emitted together with the pork meat odor. The pork meat image is then processed using an image extraction technique which uses some of the gradient procedures, background creation and unknown masking for labeling and masks clean-up. Gas sensors such as MQ-135 and MQ-136 are operated for Ammonia and Hydrogen Sulfide detection, respectively, since they have high-sensitivity of the mentioned gases.

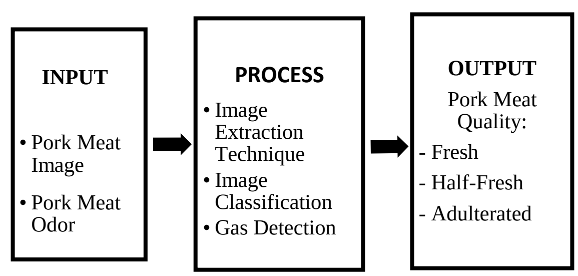

Figure 1. Conceptual framework

Once the image extraction technique and gas detection are done, classification using the k-NN algorithm takes place whether the sample is fresh, hypo-fresh, or adulterated. These procedures are thoroughly discussed in the “Software Analysis and Design” section. Finally, the 7-inch monitor displays the quality of the assessed pork meat being and the values extracted from the image and odor of the pork meat.

2.2 Hardware Development

Guidance was asked from experts and related literature regarding the standard materials for meat storage were also gathered. Trade-off analysis was practiced to come up with a better output. The materials used in making the hardware component of this system are within the standards of the Meat Inspection Code of the Philippines [21]. These standards guarantee the health and safety procedures, which is the first design constraints of the study.

Shown in Figure 2 below is the studio-type chamber for capturing images and detecting gases. The box is made up of glass with two fixed Light Emitting Diode (LED) on both sides for proper lighting and ray distribution. Found in the center of the chamber ceiling is the mounted Raspberry Pi Camera which captures the sample pork meat placed on the raised flooring or platform below it. On the left wall of the case are the gas sensors, MQ-135 and MQ-136. Beside the studio-type chamber is the circuitry box, which rooms the Arduino Uno, Raspberry Pi 3, exhaust fan, and the 7-inch LCD monitor.

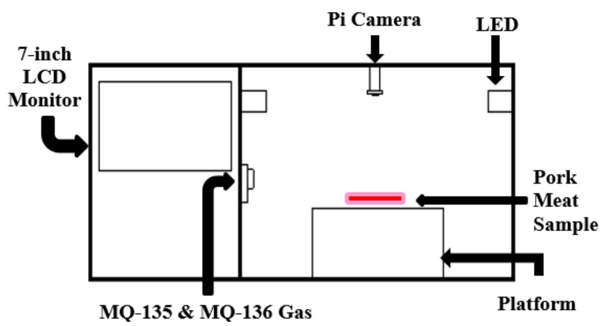

Figure 2. Studio-type chamber

To effectively visualize the procedure which the system does from one hardware component to the other, a block diagram in Figure 3 is presented. The central processing unit for this system is the Raspberry Pi (R-Pi). Every element of the system passes through it. The Pi camera and the gas sensors feed inputs to the Raspberry Pi, whereas the R-Pi processes it. The R-Pi, on the other hand, requires a 5-Volt power supply to operate well. An SD card is also essential for storing & handling data and for image and odor breakdown. Lastly, the LCD monitor displays the pork meat quality with the corresponding values of the image and odor analysis.

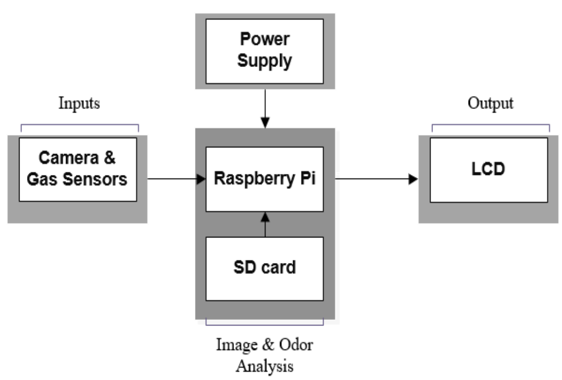

Figure 3. Block diagram

2.3 Software Analysis and Design

Python programming language is used for the implementation of this study, as well as for the application of the algorithm technique like k-NN, and for extending the reliability of performing classification processes. Also, some libraries in Python are applied for image extraction and analysis. OpenCV library, which is well-known for real-time computer vision, is also executed for efficient results. Revealed in Figure 4 is the flow chart of the system which demonstrates the step-by-step process on acquiring the desired output of this study.

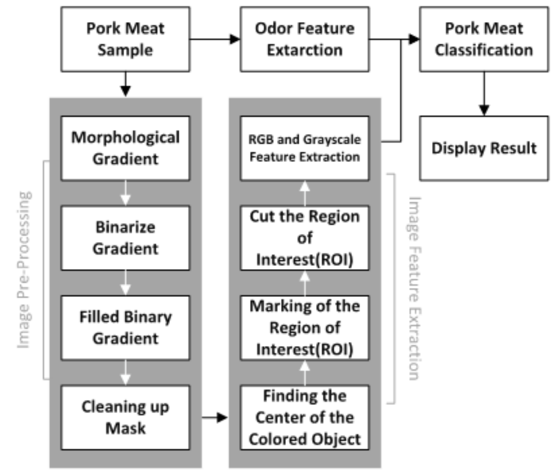

Figure 4. Flow chart

The process of image analysis begins after capturing the image of the sample. This captured sample is acquired by the use of a camera which is programmed in Java Integrated Development Environment (IDE). After the sample image has taken, the image transforms into various formats which include the application of different gradient and background removing techniques.

The technique of image pre-processing is presented in Figure 5. To start the method, the Morphological Gradient is first utilized to identify the irregular shape of the pork meat sample. After detecting the edges of the image sample, the next process is the Binarized Gradient. This technique transforms the altered image into the global threshold with 1s and 0s, wherein the colors you can only see are black and white. This technique is useful to detect and track the object accurately. Afterward, the system removes the background of the image. The removing procedure is what we call Filled Binary Gradient, which converts its threshold into its adjacent values. The last process in image processing is cleaning up the mask, which smoothens the sample image edges so that locating the center of the object becomes easily attainable. After detecting the center of the object, the program can now mark the region of interest (ROI). The ROI is then cropped from the enhanced image and subsequently undergoes feature extraction. From this cropped ROI, the average RGB (Red, Green, Blue) value is extracted. It later transforms into a grayscale image to initialize another value. These values are now the parameters of performing image analysis.

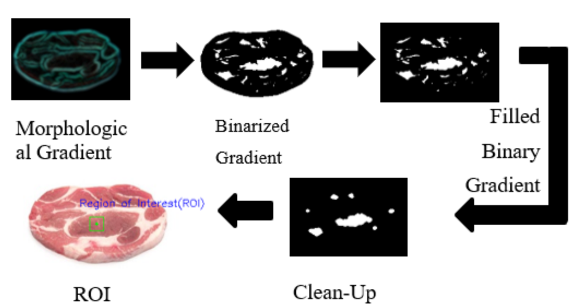

Figure 5. Image pre-processing technique

This study will not be that viable without the extracted values of meat odor from the gas sensors. The system is set to wait for 30 seconds for the electronic nose to settle and read the gas values which the pork meat emitted. While all necessary parameters are on hand, it will then be classified through the k-NN algorithm. The classification lasts for about 15 seconds to display all the values extracted from the pork meat and the analysis as well if it is "Fresh," "Half-Fresh," or "Adulterated." The k-NN technique is suited for image and data analysis application.

2.4 Sampling and Testing Procedure

The first consideration when doing this project was the health and safety quality of the pork meat. Hence, before taking samples, a city veterinarian evaluated the pork meat using traditional standards. The samples taken into consideration are the meat from the loin part of the pork, which weighs 100 grams each. For the basis of fresh meat, the collection of sample pork meat images and odor was done after a 100-gram loin part has been sliced from the newly slaughtered pork. Two to 12 hours later, samples for half-fresh meat were gathered. Adulterated pork meat samples were also collected after 24 hours onwards. These meat samples were not refrigerated nor cured. These were merely unprocessed meat. Personal Protective Equipment (PPE) were used so that pork meat samples will not be contaminated unnaturally.

Also, the pork meat samples gathered, with the assistance of the veterinarian, were considered as the data sets of the system. These data sets contained six parameters, including Blue, Green, Red, Ammonia, Hydrogen Sulfide, and Grayscale characteristics of the pork meat, which were added to the data bank of the classifier. The meat of fish, chicken, and beef are not included in this research. They are "unknown" to the system.

2.5 Statistical Analysis

With regards to the statistical treatment of this study, it must be determined whether the machine successfully classifies the pork meat quality or not. Pork meat quality for this study is determined by sensory indices for its color and odor. The principle of the confusion matrix is applied to obtain the accuracy of the algorithm used in this research. The accuracy of the system will be calculated by summing up all the true values and then divided by the total value of both true and false prediction. The calculation is shown in equation 1:

$$\text{Accuracy} = \frac{(F, F) + (HF, HF) + (A, A)}{\text{TOTAL NO. OF SAMPLES}}$$

Where:

Accuracy = is the ratio between the sum of the true value and the total number of predictions made by the classifier

F = Fresh
HF = Half-Fresh
A = Adulterated

3. RESULTS AND DISCUSSIONS

The fundamental goal of this research is to develop a modernized system which will aid the meat industry in dealing with the pork meat sold in the market. Pork meat quality has been a continuing problem since pork meat is one of the primary commodities which people consume every day. Thus, this section illustrates the software system and hardware setup of the developed device, and the accuracy of the algorithm used.

3.1 Graphical User Interface

This study intends to create a user-friendly device which can be operated easily by users who are not exposed to these kinds of interface. Therefore, the Graphical User Interface of the "Home Menu" shown in Figure 6 is so simple yet consistent and understandable. Each image icon of this interface corresponds to the function it has. There are three buttons on the left side of the interface. The "home" button, which is on the uppermost part, displays the home menu of the application. The "play" button, when pressed, goes directly to camera mode to capture the pork meat image and at the same time gathers the released gas of the meat using the gas sensors. Lastly, the "refresh" button reveals the values of the data extracted from the sample, which is presented in Figure 7.

Figure 6. Home menu graphical user interface

Figure 7 shows the GUI for the "Results" of the classified raw pork meat data. Values for the Ammonia and Hydrogen Sulfide are displayed on their corresponding places. Same goes with the values of the Blue, Green, Red, and Grayscale characteristics of the captured image. Importantly, the classification of the pork meat quality, whether it is "Fresh," "Half-Fresh," or "Adulterated" is also shown.

Figure 7. Results graphical user interface

3.2 Hardware Setup Installation

The hardware component of the system illustrated in Figure 8 is made up of a tinted glass which does not allow external lights to enter the chamber. Inside this chamber is the camera for capturing pork meat images, the two fixed LEDs for proper lighting, and the electronic noses for detecting volatile gases. The left-side box, where the 7-inch LCD is mounted, is where the circuitry is situated. The circuitry is composed of the microcomputer, microcontroller, electronic noses, exhaust fan, and the two LEDs. The camera is connected to the microcomputer while the electronic noses are directly linked to the microprocessor. An exhaust fan is needed for the circuitry box to avoid both the microcomputer and microcontroller from overheating.

Figure 8. Actual studio-type chamber

3.3 Data Analysis

Several functionality tests have been done to verify the system's feasibility and efficiency. Simultaneously, accuracy has also been validated every conducted test. The accuracy is calculated using the confusion matrix. Presented in Table 1 are the results of the pork meat analysis which were classified through the k-NN algorithm. This accuracy-test can confirm if the algorithm used in this study is efficient and applicable or not.

Basically, there were seventy-five (75) raw data that were predicted. By the confusion matrix accuracy formula in eqn. 1, it is revealed that the accuracy for identifying fresh pork meat is 93.10% wherein 27 out of 29 fresh meat samples are read correctly. On the other hand, there is an accuracy of 87.50% for detecting half-fresh pork meat which can acceptably verify 14 samples out of 16. Lastly, 29 out of 30 pork meat tested are appropriately detected as adulterated ones. As a result, there is an accuracy rate of 96.67% for distinguishing contaminated pork meat. In general, from the 75 sample pork meat tested, 70 of it have been reasonably validated, resulting in an accuracy of 93.33% of the whole system.

Table 1. Data analysis report

		Predicted Data		
Actual Data		Fresh	Half-Fresh	Adulterated
	Fresh	27	1	0
	Hal-Fresh	2	14	1
	Adulterated	0	1	29
TOTAL		29	16	30
ACCURACY		93.10%	87.50%	96.67%
TOTAL NO. OF SAMPLES		**75**		
OVERALL ACCURACY		**93.33%**		

4. CONCLUSIONS AND FUTURE WORKS

By and large, the research conducted was successful in developing a system that is suitable for classifying pork meat quality. The methodology done was able to distinguish and categorize pork meat into fresh, half-fresh, and adulterated, by means of extracting BGR features, Ammonia level, Hydrogen Sulfide value, and Grayscale characteristics from the pork meat. These values were then classified with the aid of the k-NN classifier. The k-Nearest Neighbor algorithm has performed an exceptional classification procedure for the adulterated pork meat with 96.67% accuracy. All in all, a precise classification of 70 pork meat has been completed out of 75 meat samples generating a high accuracy rate. Thus, making this research achieved its specific objectives.

To further improve this study, other researchers with related studies may add a meat classification feature from this research since pork meat is not the only commodity that people consume. Additionally, it is suggested that other classification algorithms, other than the k-NN, may be used to increase its accuracy. Parameters utilized in this research may also not be used and may vary from study to study. It may depend on the other scholars on what constraints should be used in this classification technique. As a final point, it is highly recommended to produce an online analysis of the study to accommodate a wide scope of recipients.

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