Studying the effect of electrodes on the electrical impedance measurement of meat

Dang Thanh Trung[1], Nguyen Phan Kien[1*], Chu Duc Hoang[2], Nguyen Thanh Trung[3]

[1]Hanoi University of Science and Technology;
[2]VNU University of Engineering and Technology (VNU-UET), Hanoi, Vietnam;
[3]Dept. of Medical Equipment, 108 Military Central Hospital, Hanoi, Vietnam.
*Corresponding author: kien.nguyenphan@hust.edu.vn

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ABSTRACT

Several investigations contributed to developing the Electrical Resistivity Spectroscopy equipment used to evaluate meat standards. In the prior research, a method for effectively calculating the power resistance spectra of pork meat was devised. This method was successfully implemented. Electrodes fabricated from medical knitting needles and the term means syringes were used in this study to measure the energy-dispersive spectra of flesh. These two different transducers were constructed for the investigation and employed in the measurement process. In medicine, both types of electrodes are utilized; however, assessment findings acquired using the same equipment reveal a distinct disparity between the outcomes of the two measurements. This demonstrates that selecting an electrode for a specific measurement requires careful consideration and consideration overall. In the coming years, the investigation and advancement of weighing electrodes, which are utilized to assess the electronic input resistance of pork meat and over which the research group is concentrating, are further investigated to develop the measurement system electrodes the most appropriate and essential. Using data from knowledge grows.

Keywords: Pork meat; KNO_3; Bioelectrical impedance Spectroscopy.

1. INTRODUCTION

The peculiar bio-impedance wavelengths of a clinical specimen can provide crucial knowledge about the structure of the sample's cells, as well as infer useful advice about the model's conditions of exposure [1]. Elemental analysis spectroscopy is a powerful method that investigates the resistivity properties of a cell by employing an alternating current (AC) signal of low amplitude and variable frequency. To obtain an impedance spectrum for the electrochemical cell that is being evaluated, the AC signal is swept over several different frequencies. EIS is distinct from approaches involving direct current (DC) in that it makes it possible to investigate capacitive, resistive, and diffusion phenomena that occur within an electrochemical cell. Because the theory underpinning EIS is more complicated than that behind DC approaches, it is recommended that one have at least a fundamental comprehension of the fundamental principles before continuing. EIS can be utilized in a wide variety of fields, such as coverings, electrodes, fuel cells, solar cells, radar systems, and biotechnology.

[2] One of the most effective approaches for huge meat quality assessment is called near-infrared spectroscopy (NIRS), and it can forecast the drip leakage and pressure of pork specimens. The use of optical dispersion in conjunction with hyperspectral imagery has shown only a little effectiveness in determining the level of softness that currently exists in beef steak [3]. Changes in electrical characteristics could be used to determine biophysical metrics of the meat porous structure [4, 5]. These geophysical factors include the penetration of meat fiber membranes as well as the flow of micro-and macro fluids.

Electrodes can interfere with the impedance meter readings by creating stray current flows, thus giving inaccurate values for samples. When conducting tests on the electrical properties of biological materials, researchers sometimes add metal electrodes to tissues to induce currents through tissue cells. These induced currents provide important evidence regarding cellular physiology within cells under investigation.

Electrodes affect the electrical resistance of meat, and this affects the way we measure meat. The goal of measuring impedance in pork meat cattle remains limited to determining carcass composition, then the use of two electrodes placed parallel to the current path is recommended for obtaining accurate results.

Energy dispersive evaluation in biological materials, also known as bioimpedance unit of measure or high voltage impedance spectra, is a technique developed to research a range of variables relating to living creatures, trees, and even other types of organisms. In recent times, the assessment of electrodermal resistance has been applied to assessing various aspects of the good of fruits and pork meat. Electrical impedance spectrometry is utilized to investigate the association between shifts in the values of electrophysiological resistance and other parts of pork meat, such as the length of time the flesh was aged, the volume of liquid it contained, and its saltiness. To assess the quality of pork meat methods for the detection of bruising, a new technique that uses visible (VIS) and near-infrared (NIR) light transmission has been developed. It has been illustrated that by employing NIR light in transmission schemes, it is essential to catch the saggy skin not only on the ground, as is the case with conventional methods, but also underneath the surface [7]. To quantify the spectrum strength fluctuations of chicken muscles brought on by either the preservation moment domain or the shear force values, a comprehensive 2 different (2D) coefficient of determination of visible/near-infrared (NIR) spectra was carried out [8]. The application of spectrophotometric analysis to the perseverance of the reliability of living creatures (such as milk, ground beef, tuna, and egg) and vegetable (such as olive oil, frosted flakes, sugar, strawberries, and vegetable) goods and the proof of identity of pathogens of agricultural production enthusiasm is the primary focus of fluorescence spectrophotometric quantification.

Because the problem has distinct electrical behavior like resistance and conductance, which fluctuate according to thread time, the assessment of material electrochemical characteristics can indicate the quality of the meat due to this new problem's particular electrical parameters. The preliminary results show that the impedance of pork is reduced by time and increased by measurement frequency [10]. On the other hand, the old method is still restricted in that it can only gather information with correctness that has not yet been validated and can only be carried out on a specific subset at a moment [11]. Investigations for electrically electrochemical impedance were carried out in this investigation with the assistance of bipolar efficiency. The acupressure piercing conductor and the general medical syringe sensor were used to analyze the equivalent resistance spectra in the same testing instruments provided in the earlier findings. This was done to ensure that the measurements were accurate. The significance of the sensor recruitment process in determining equivalent resistance can be deduced from an investigation into the effects of the particular conductors used in the analysis. Applying alternating high slightest approaches with a modest change to simultaneously fit naturalistic and fictitious forms with much the same set of uncertain variables to complicated data is presented in depth [12].

For the sake of gaining an understanding of how we may represent an electrochemical process, let us suppose a three-electrode arrangement in which a conducting energy transformation is immersed in an electrolyte solution, and an oxidative molecule serves as the analyte (Fig 1). Although not explicitly depicted in figure 1, the device is presumed to include both a reverse (auxiliary) electrode to preserve electro neutrality and a positive terminal to serve as a constant point of comparison. All three of the electrodes - the working, the monitor, and the reference - are linked to a potentiated. Please read our article in the Knowledgebase that explains how an up-regulated works so that you can gain a better understanding of how an excitotoxic performs in such a setting.

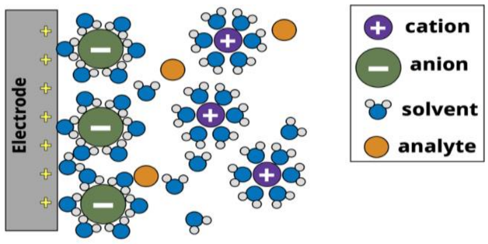

***Figure 1**. Shows modeling of the working electrode in an aqueous system with multiple conductors. The galvanic double surface is formed when the reference electrode, which is gray and offers promising aspects, draws anions, which are poorly absorbed and attracted to the interface.*

The EIS is a straightforward way of transforming intricate chemical responses into an electrical version that can be evaluated and applied to forthcoming research endeavors. These reactions can be reproduced more accurately by an analogous electrical circuit that takes into consideration inductance and capacitance, as demonstrated by the Randles Cell [13]. Because of this, we will need to use an analogous electrical current, such as the Randles transmission line [14], to describe the remedy, the electrodes, and the contact between the two stages based on the circuit boards of the solvent and the electric current. As a result, the resistance that was formed during an electrolytic investigation can be assessed using one or more courses that are comparable to it. Developing an appropriate prediction can lead to the confirmation of physiological modes that occur in a given unit, even though defining analogous circuits might be challenging. These methods have many promising utilities and can be utilized in a wide variety of study fields.

2. METHODS

2.1. Bioelectrical Impedance Measurement Probe

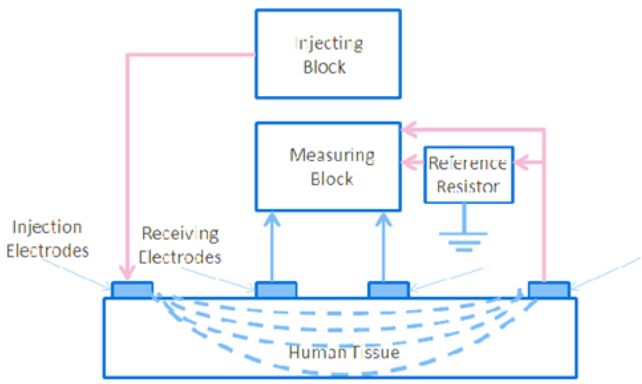

***Figure 2.** Electrical Impedance Spectroscopy (EIS) measurement.*

For Electrical conduction Spectral Analysis To have a better tradeoff between the effectiveness of the official outcome and the quality of healthcare services, the investigation assessment needs to have the layout of a wattage power supply. A wattage input current ought to have both a substantial emission electrodermal resistance and a broad bandwidth concurrently. One of the most important concerns of modern medicine is finding ways to gather knowledge about a person's health without resorting to invasive methods. Bioimpedance has been demonstrated to be an effective, risk-free, and non-invasive diagnostic method to quantify bioimpedance, an externally known electrical charge must be injected, and the value that is produced must then be recorded at a specific frequency [3]. Trying to inject and monitoring are the two primary components that make up bioelectrical impedance sensors in their normal configuration. (Fig. 2).

2.2. AC Circuit Theory and Representation of Complex Impedance Values

The idea of electrical resistance is familiar to a relatively high percentage of the population. One of the characteristics of a circuit element is its ability to oppose the electromotive force. According to Ohm's rule, resistivity is defined as the proportion of voltage to current. Both alternating current (AC) and voltage impulses, when sent through a resistor, remain in phase with one another. Due to the presence of several components, we need to relinquish the straightforward idea of resistance and replace it with impedance. Impedance is an indicator of the capacity of a connection to oppose the electromotive force and is analogous to resistance in this regard. Despite this, the simplification qualities stated above do not place any restrictions on resistance. Imagine that we are using an oscillatory potential to excite the system. The output of this potential is an alternating current signal. Standard procedures involve measuring electron microscopy using a small excitation signal. This is done to ensure that the reaction of the unit is pseudo-linear. The initial approach to a sinusoidal perspective will be a sine wave at the same frequencies but displaced in a phase when the machine in question is straight or pseudo-linear (Fig. 3). The concept of linearity is broken down into its component in the subsequent sections.

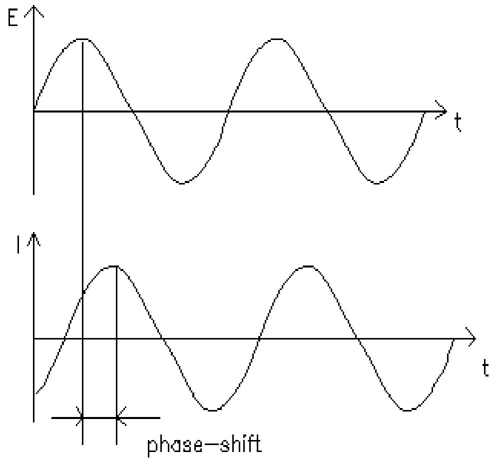

Figure 3. *Present Sine wave Reaction in a Linear Model.*

The structure of the energizing represented a function of the period.

$$E_t = E_0 \sin(\omega t) \tag{1}$$

Where Et represents the prospective at period t, E0 represents the strength of the signal and represents the circumferential rate. The correlation between zonal frequency (measured in degrees per second) and bandwidth f (measured in hertz) is as follows:

$$\omega = 2\pi f \tag{2}$$

The reply output, in a step input, is phase-shifted and has an allusion to I0.

$$I_t = I_0 \sin(\omega t + \phi) \tag{3}$$

We can determine the resistance of the device by using a formula that is similar to Ohm's Law, which is as follows:

$$Z = \frac{E_t}{I_t} = \frac{E_0 \sin(\omega t)}{I_0 \sin(\omega t + \phi)} = Z_0 \frac{\sin(\omega t)}{\sin(\omega t + \phi)} \quad (4)$$

Therefore, the resistance is described using a magnitude, which is denoted by Zo, and a phase margin, which is denoted by.

2.3. EIS Equivalent Circuit Models

The purpose of the experiment was to test the difference between clean meat and meat after being treated with KNO_3. After being purchased at the supermarket, the meat was treated as in experiment 1, and the meat was measured using a measuring system. After measuring once, the piece of meat is soaked in 1.5M KNO_3 solution; after soaking for an hour, remove the amount of meat, wash the meat thoroughly, and continue to put it in the mold again. Preservation of the meat continued for 24 hours, then rechecked with the same system and assessed the quality of the meat after storage.

In equivalent circuit models during the assessment, supermarket-bought flesh specimens were used as reference points. The piece of meat provided is of the sort known as tenderloin, which does not include any fatty. A portion of the meat will be divided into two smaller samples of comparable size (5 cm long, 3 cm wide, and 2.5 cm high). The transverse crack of the flesh will be on the two minor edges (width and height) of the rectangular if two specimens of newly sliced meat are judged to be a rectangle. A set of professional knitting needles was repurposed as a sensor for the assessment. -stainless steel (type 4B-3, size 0.9x36 mm, Czech standard CSN 85 59 36). They are originally bent and then stretched, but only if the turning operation causes no blemishes. As can be seen in figure 4, two simultaneous syringes were mounted to a clear quartz sheet to serve as the electrical base. The needles' lengths were 2.3 centimeters and placed at a length of 2 centimeters from one another.

After the specimen of flesh has been prepared, it will be placed in a transparent box (shown in figure 5) with the following parameters: 50 millimeters long, 30 millimeters wide, and 25 millimeters high (length x width x height). It is softly squeezed on the four edges of the pork meat specimen to ensure that the meat sample is distributed uniformly throughout the bottom four edges of the box. Connect the electrodes to the TV, and then secure it to the inside wall of the box using two pieces of tape. At last, two jars containing samples were wrapped in Clingfilm and placed inside two more plastic tubs. To protect the reliability of the prediction from the potential impact of germs and parasites.

Figure 4. *Electrodes are used to measure the impedance of pork meat.*

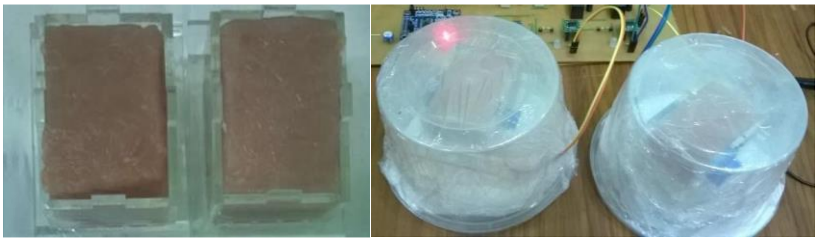

Figure 5. *Meat sample and covered for the experiment.*

To verify the presence of KNO_3, samples taken after 24 hours of assessment were subjected to the second round of testing with diphenylamine ($(C_6H_5)_2NH$) in a cold and solid H_2SO_4 solution. Nitrobenzene ($(C_6H_5)NO$), a dark blue molecule in its high performance and bright yellow when it is in light conditions, was produced as a byproduct of the reaction. The expression for the process is:

$$2(C_6H_5)_2NH + 2KNO_3 + H_2SO_4 \rightarrow K_2SO_4 + 2H_2O + 4(C_6H_5)NO \quad (5)$$

We can determine whether or not the flesh contains KNO_3 by observing the change in color that occurs during the process. The research has been done with three steps of the experiment such as:

1. Evaluate the complicated resistance of the platform by employing absolute values of inductors and capacitors according to the theory of Fricke and Cole-Cole, described in the research article [15], to validate the program's degree of detail.

2. Take readings of the resistivity of the fresh meat specimen each hour for twenty-four hours and compare those readings to the results of the test for the presence of KNO_3 mentioned earlier.

3. Remove the meat that has been weighed, treat it with KNO_3, and then measure it when the treatment has been completed.

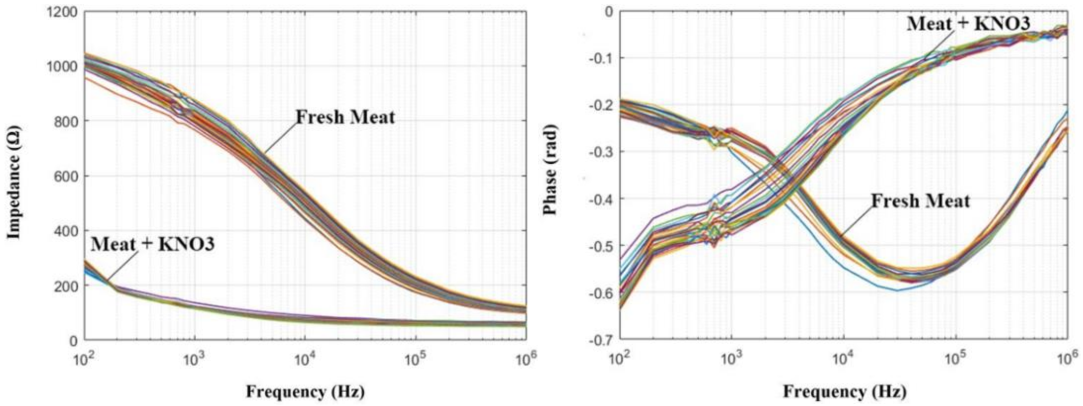

Figure 6. a) *Amplitude-frequency spectrum of fresh meat and meat treated with* KNO_3 *measured in 24 hours.* ***b)*** *Phase-frequency spectrum of fresh meat and meat treated with* KNO_3 *measured for 24 hours.*

After the collection of numerical data is complete, the obtained unprocessed information will be evaluated using MATLAB software. The resistance analysis and phasing computation will both be carried out by this application. Experiments have been done over 100 meat samples, and some of the data are shown (Fig. 6).

According to the findings presented in Fig. 6, the resistance magnitude of pork meat both during treatment with KNO_3 reduced with increasing velocity. The resistivity variation of the test sample is approximately 500 to 1200, but after being treated with KNO_3, the number is mainly in the range of 200 to 300.

This is a significant decrease from the initial value. At 1 MHz, the resistivity magnitude of the pork samples is in the field of 50 to 150, and the divergence between the tests in between cleaning in KNO3 is not statistically significant.

The sequence continuum of the pork samples before they were handled with KNO_3 has two critical examples: the lowest value is in the wide bandwidth 20 KHz - 60 KHz and has a ratio of approximately -0.8 rad to -0.6 rad, and the highest peak is now in the operating frequency band 100 Hz - 700 Hz and also has a value of approximately of -0.2 rad to -0.4 rad. Both of these points are located in the bandwidth. The sequence continuum, just from being dealt with by KNO_3, is remarkably separate in both the worth at the wavelengths and the structure of the plot, particularly in the resonant frequencies of 100 Hz to 1 kHz and 10 kHz to 100 kHz. This is particularly true in the frequency of 100 Hz to 1 kHz. Based on the form of the graph, we can differentiate between pork prepared following the initial application of the KNO_3 mixture.

3. EXPERIMENTAL RESULTS

3.1. The meat sample is cut from the tenderloin bought at the market

The model is measured from frequency 100 Hz => 1 MHz; after measuring, wash the piece with KNO_3 and continue to count. The meat was then preserved with KNO_3, cleaned, and measured again after 24 h. Samples measured before and after treatment with KNO_3 were also checked for -NO_3 radicals with Diphenylamine solution in concentrated H_2SO_4.

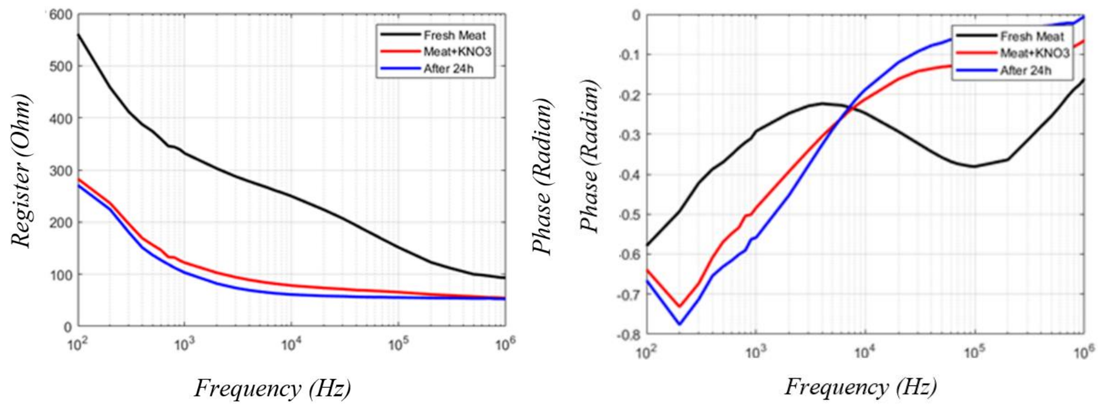

***Figure 7. a)** The meat sample's impedance vs. frequency comparison is cut from the tenderloin bought at the market. **b)** Phase vs. frequency comparison of the meat sample is cut from the tenderloin bought at the market.*

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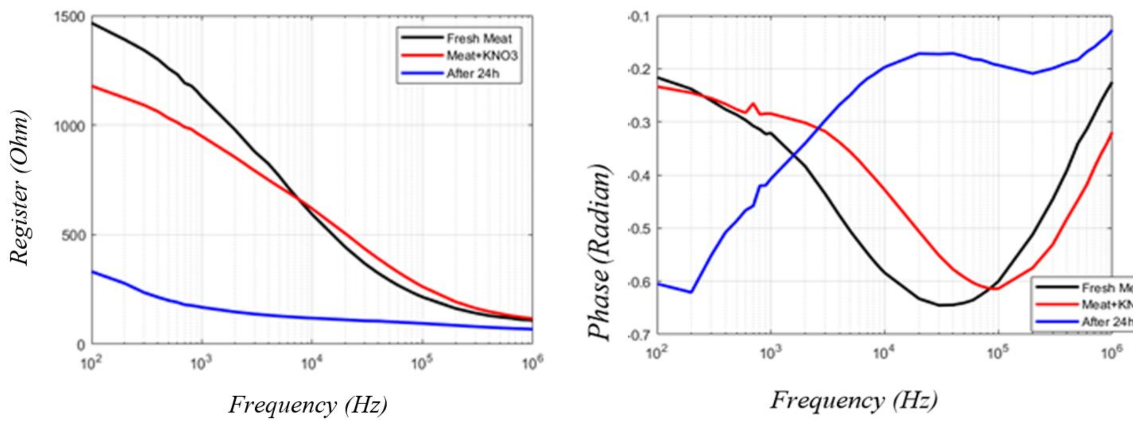

***Figure 8. a)** The meat sample's impedance vs. frequency comparison is cut from the tenderloin bought at the supermarket. **b)** Phase vs. frequency comparison of the meat sample is cut from the tenderloin bought at the supermarket.*

Samples measured before and after treatment with KNO_3 were also checked for $-NO_3$ radicals with Diphenylamine solution in concentrated H_2SO_4.

When the concentration of KNO_3 was increased, the meat sample after washing was more similar in color to the model before starting the measurement. At the same time, the stench was eliminated. The characteristic values of phase or impedance amplitude do not change significantly when increasing the concentration of KNO_3. From the amplitude and phase impedance results, we can see the shape of the impedance amplitude graph according to The time, and the phase-time chart for the meat samples before using KNO_3 is the same, similar to the models after KNO_3 washing. However, the difference between the experiments is unavoidable. Specifically, at times of experiment, the pieces may not be uniform in size (vertical chamfering, horizontal chamfering compared to the set size), and the slaughter time of pogs is not in the control or the time to start the measurement. What is different, at the same time, is the change in ambient temperature. In addition, the error of the electrode and the error of the system during the measurement will be presented in detail in the following sections. For a more in-depth look, let's explore the variation of pork over time in the following area.

Experiment 1 gives the characteristic impedance and phase spectra of a sample of meat considered clean as measured by the system. Experiment 2 offers a new method of testing meat quality through systematic measurement. The purchased piece of meat has a larger impedance amplitude than the heart washed with KNO_3. The phase-amplitude between the time of purchase and washing of KNO_3 in some samples did not show any difference, but compared with the meat preserved with KNO3 after 24 hours, there was a significant difference. After preservation with KNO_3, the piece of meat found that its ability to decompose was reduced, there was no smell, and rotten meat became fresh, even redder when bought at the supermarket. Although washed with water, meat samples preserved with KNO_3 still had residues because the meat samples reacted with the Diphenylamine indicator after washing with water.

4. CONCLUSIONS

The results of the study confirm that the modified model can meet the analysis of the parameters of the biological impedance model and, through the system, can evaluate the system's effectiveness in distinguishing harmful compounds in food today, namely KNO_3.

To summarize, using the resistivity selection of fresh pork at a short wavelength (100 Hz), it is simple to differentiate between raw meat and pork meat that has been cured with KNO_3. Still, this distinction is not possible using greater incidence (1 MHz). However, the best electrode for this measurement is from professional knitting needles. Data from that measurement's electrodes have no noise when comparison with the other one. In addition to this, the form of the plot for the mode band demonstrates that it is considerably simpler to differentiate between untreated raw meat and meat that has been cured with KNO_3. In the not-too-distant future, the framework will be improved by the construction of a server that is capable of storing a large number of measurements made and applying new tech known as synthetic intelligence (AI) to keep locating essential keys that are used to evaluate the quality of the meat.

REFERENCES

[1]. M.D.OToole, L.A.Marsh, J.L.Davidson, Y.M.Tan, D.W.Armitage, and A. J. Peyton, *"Rapid Non-Contact Relative Permittivity Measurement of Fruits and Vegetables using Magnetic Induction Spectroscopy,"* Sensors Applications Symposium (SAS), 2015 IEEE, pp. 1 - 6, (2015).

[2]. G.H Geesink, F.H Schreutelkamp, R Frankhuizen, H.W Vedder, N.M Faber, R.W Kranen, and M.A Gerritzen, *"Prediction of pork quality attributes from near infrared reflectance spectra,"* Meat Science, vol. 65, no. 1, pp. 661 - 668, (2003).

[3]. K.Cluff, G.K.Naganathan, J.Subbiah, R.Lu, C.R.Calkins, A.Samal, *"Optical scattering in beef steak to predict tenderness using hyperspectral imaging in the VIS-NIR region,"* Sensing and Instrumentation for Food Quality and Safety, vol. 2, no. 3, pp. 189 - 196, (2008).

[4]. J. L. Damez, S. Clerjon, *"Modelling the electrical properties of meat mesostructure duringaging,"* 53rd International Congress of Meat Science and Technology, pp. 215 - 216, (2007).

[5]. S.Clerjon, J.L.Damez, *"Microwave sensing for an objective evaluation of meat ageing,"* Journal of Food Engineering, vol. 94, no. 3-4, pp. 379 - 389, (2009).

[6]. U.Erikson, I.B.Standal, I.G.Aursand, E.Veliyulin, M.Aursand, *"Use of NMR in fish processing optimization: A review of recent progress,"* Magnetic Resonance in Chemistry, vol. 50, no. 7, pp. 471 - 480, (2012).

[7]. A. Ziadi, X. Maldague, L. Saucier, C. Duchesne, and R. Gosselin, *"Visible and nearinfrared light transmission: A hybrid imaging method for non-destructive meat quality evaluation,"* Infrared Physics and Technology, vol. 55, no. 5, pp. 412 - 420, (2012).

[8]. Y. Liu, F.E. Barton, G.B. Lyon, W.R. Windham, and C.E. Lyon, *"Two-dimensional correlation analysis of visible/near-infrared spectral intensity variations of chicken breasts with various chilled and frozen storages,"* Journal of Agricultural and Food Chemistry, vol. 52, no. 3, pp. 505 - 510, (2004).

[9]. R. Karoui and C. Blecker, *"Fluorescence spectroscopy measurement for quality assessment of food systems A review,"* Food and Bioprocess Technology, vol. 4, no. 3, pp. 346 - 386, (2011).

[10]. D. T. Trung, N. Phan Kien, T. Duc Hung, D. C. Hieu, and T. Anh Vu, *"Electrical impedance measurement for assessment of the pork aging: A preliminary study,"* 2016 International Conference on Biomedical Engineering (BME-HUST), pp. 95-99, (2016), doi: 10.1109/BME-HUST.2016.7782109.

[11]. Nguyen Phan, K., Tran Anh, V., Dang Thanh, T., Phung Xuan, T.*," Upgrade and Complete the Electrical Impedance Measuring System Applying for Meat Quality Analysis and Evaluation,"* Tran, DT., Jeon, G., Nguyen, T.D.L., Lu, J., Xuan, and TD. (eds) Intelligent Systems and Networks. ICISN 2021. Lecture Notes in Networks and Systems, vol 243. Springer, Singapore, (2021).

[12]. J. R. M. a. J. A. Garber, *"Analysis of Impedance and Admittance Data for Solids and Liquids,"* Journal of the Electrochemical Society, vol. 124, no. 7, pp. 1022-1030, July, (1977).

[13]. Cook, D., *"Getting Started with Your First Experiment: EIS300 Electrochemical Impedance Techniques- Potentiostat Electrochemical Impedance Spectroscopy,"* Gamry (2014) 1.

[14]. C. P. Canales, *"Electrochemical Impedance Spectroscopy and Its Applications,"* in 21st Century Nanostructured Materials - Physics, Chemistry, Classification, and Emerging Applications in Industry, Biomedicine, and Agriculture. London, United Kingdom: IntechOpen, (2021), doi: 10.5772/intechopen.101636

[15]. J. Caicedo-Eraso, F. Díaz-Arango and A. Osorio-Arturo, *"Espectroscopia de impedance electrical aplicada al control de la calidad en la industrial aliment aria",* Ciencia y Tecnología Agropecuaria, vol. 21, no. 1, pp. 1-20, (2019).

[16]. J. James, S. Clerjon, S. Abouelkaram, and J. Lepetit, *"Beef meat electrical impedance spectroscopy and anisotropy sensing for non-invasive early assessment of meat aging,"* Journal of Food Engineering, vol. 85, no. 1, pp. 116-122, (2008).

[17]. H. Nguyen and L. Nguyen, *"Rapid and non-invasive evaluation of pork meat quality during storage via impedance measurement,"* International Journal of Food Science & Technology, vol. 50, no. 8, pp. 1718-1725, (2015).

[18]. Y. Yang, Z. Wang, Q. Ding, L. Huang, C. Wang, and D. Zhu, *"Moisture content prediction of porcine meat by bioelectrical impedance spectroscopy,"* Mathematical and Computer Modelling, vol. 58, no. 3-4, pp. 819-825, (2013).

[19]. X. Zhao, H. Zhuang, S. Yoon, Y. Dong, W. Wang, and W. Zhao, *"Electrical Impedance Spectroscopy for Quality Assessment of Meat and Fish: A Review on Basic Principles, Measurement Methods, and Recent Advances,"* Journal of Food Quality, vol. 2017, pp. 1-16, (2017).

[20]. X. Zhao, H. Zhuang, S. Yoon, Y. Dong, W. Wang, and W. Zhao, *"Electrical Impedance Spectroscopy for Quality Assessment of Meat and Fish: A Review on Basic Principles, Measurement Methods, and Recent Advances,"* Journal of Food Quality, vol. 2017, pp. 1-16, (2017).

[21]. S. Huh, H. Kim, S. Lee, J. Cho, A. Jang, and J. Bae, *"Utilization of Electrical Impedance Spectroscopy and Image Classification for Non-Invasive Early Assessment of Meat Freshness,"* Sensors, vol. 21, no. 3, p. 1001, (2021).

TÓM TẮT

Nghiên cứu ảnh hưởng của điện cực tới việc đo trở kháng điện của miếng thịt

Một số nghiên cứu phát triển hệ thống đo phổ trở kháng điện đã được sử dụng để đánh giá các tiêu chuẩn chất lượng thịt. Trong nghiên cứu trước đây, một phương pháp tính toán phổ trở kháng điện của thịt đã được xây dựng và đã thực hiện thành công. Điện cực chế tạo từ kim khâu y tế hay kim tiêm y tế đã được sử dụng trong nghiên cứu này để đo phổ phân tán năng lượng của thịt. Hai đầu dò khác nhau này được chế tạo để phục vụ công tác điều tra và được sử dụng trong quá trình đo lường. Trong y học, cả hai loại điện cực đều được sử dụng; Tuy nhiên, các phát hiện đánh giá thu được khi sử dụng cùng một thiết bị cho thấy sự chênh lệch rõ rệt giữa các kết quả của hai phép đo. Điều này chứng tỏ rằng, việc lựa chọn một điện cực cho một phép đo cụ thể đòi hỏi sự cân nhắc kỹ lưỡng và cân nhắc tổng thể. Trong những năm tới, việc nghiên cứu và phát triển các điện cực, được sử dụng để đánh giá trở kháng điện của thịt lợn mà nhóm nghiên cứu đang tập trung nghiên cứu sẽ được tiếp tục thực hiện để phát triển hệ thống điện cực đo lường phù hợp và cần thiết nhất.

Từ khoá: Thịt lợn; KNO_3; Phổ trở kháng điện sinh học.