

ROBUST PREDICTION OF MEAT QUALITY ATTRIBUTES USING NEAR INFRARED SPECTROSCOPY

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ABSTRACT

The main purpose of the present study is to evaluate the ability of near infrared technology as an alternative method in determining and assessing quality parameters of meat product where in this case is frozen beef. At first, beef samples from chest and legs parts were sliced and taken at the amount of 100 g per sample to be frozen. Then spectra data of beef samples were obtained using near infrared spectrophotometer (PSD IR i16) in wavelength range from 1000 to 2500 nm with optical gain 4x. Actual protein contents were obtained by Kjeldahl method and measured in triplicate. The near infrared spectra data were enhanced and improved by means of Mean Centering (MC) and Baseline Shift Correction (BSC) methods. The results showed that protein content of frozen beef samples can be predicted rapidly with maximum correlation coefficient was 0.90. Heat properties of beef samples changes exponentially during freezing and thus, optimum freezing temperature and time can be predicted as well. It may conclude that near infrared technology can assess frozen beef qualities rapidly and effectively.

Key words: beef, freezing, near infrared, prediction, protein

ABSTRAK

Tujuan utama dari penelitian ini adalah untuk mengevaluasi kemampuan teknologi near infrared sebagai metode alternatif dalam menentukan dan menilai parameter kualitas produk daging sapi beku. Sampel daging sapi bagian dada dan kaki terlebih dahulu diiris dan diambil sebanyak 100 g per sampel untuk dibekukan. Kemudian data spektra sampel daging sapi diperoleh dengan menggunakan spektrofotometer near infrared (PSD IR i16) pada rentang panjang gelombang 1000 hingga 2500 nm dengan optical gain 4x. Kandungan protein aktual diperoleh dengan metode Kjeldahl dan diukur dalam rangkap tiga. Data spektra near infrared ditingkatkan dan diperbaiki dengan metode mean centering (MC) dan baseline shift correction (BSC). Hasil penelitian menunjukkan bahwa kandungan protein sampel daging sapi beku dapat diprediksi secara cepat dengan koefisien korelasi maksimum 0,90. Sifat panas dari sampel daging sapi berubah secara eksponensial selama pembekuan. Dengan demikian, suhu dan waktu pembekuan yang optimal juga dapat diprediksi. Disimpulkan bahwa teknologi near infrared dapat menilai kualitas daging sapi beku secara cepat dan efektif.

Kata kunci: daging sapi, pembekuan, near infrared, prediksi, protein

INTRODUCTION

Beef is one of many livestock products that a lot of people use and eat all over the country, including Indonesia. Beef is typically used in processed products like corned beef, sausages, meat balls, and other processed forms or directly as fresh meat (fresh meat). Beef is in high demand because of its distinctive flavor and delicious nutritional content, which is beneficial to the growth of human organs (Iskandar *et al.* 2019).

Indonesia Statistics Center (BPS) state that, the all out meat interest in 2019 is anticipated to increment to 982 000 tons contrasted with 2018, which was 590,000 tons, and in 2017 added up to 722,000 tons of beef (Samadi *et al.* 2018a; Iskandar *et al.* 2019). Beef that has just been cut must naturally be processed right away for consumption. However, in order to extend the shelf life of fresh beef, it may need to be preserved first. Freezing is one of the most widely used methods of preservation in small towns and the livestock processing industries. To put it simply, meat products are kept on ice-filled medium so that the media's ambient temperature drops below water's freezing point.

Beef must be frozen at controlled low temperatures to maintain its best quality. Also, freezing needs to be done until the best time so that the microbes can be turned off or deactivated. In order to preserve the

material's nutritional value, freezing must be carried out optimally, both in terms of the temperature of the freezing medium and the amount of time it takes to freeze. Freezing that endures too lengthy will bring about the development of ice gems in frozen meat in huge amounts. The ice crystallization will damage to cell walls and the release of meat's important nutrients (Iskandar *et al.* 2019; Suci *et al.* 2019).

However, if meat is frozen too quickly, harmful microbes will remain inside. Before the meat is processed, freezing aims to kill any microbes that may be present. However, improper freezing will actually result in new issues, including the release of most nutrients or the presence of microbes in the meat.

As a result, optimal freezing conditions must be met in terms of both the freezing time and the temperature of the freezing medium. The high quality beef that can be processed and eaten by humans will be produced by optimal freezing. In addition, chemical analysis is typically used to determine and analyze meat quality. In most cases, a series of laboratory procedures involving chemicals that have the potential to pollute the environment are used to determine the nutritional value of beef, such as its fat, protein, and mineral content (Arcanjo *et al.* 2019; Hou *et al.* 2019).

Additionally, the testing procedure in the laboratory frequently takes a long time. As a result, beef quality

cannot be determined using just one method. The application of electromagnetic wave technology become one innovation that can be used for determining the quality of beef which does not require chemical applications, fast, effective, and without damaging meat.

As previously stated, beef must be frozen at the right temperature and for the right amount of time. This was done to prevent the freezing process from having unexpected effects. When meat is frozen improperly, it can result in a loss of nutrients and nutrients in beef as a result of freezing for an excessive amount of time at high temperatures. Another effect is the presence of harmful microbes or bacteria in beef as a result of the premature and suboptimal freezing process.

We need to know the rate of freezing and the changes in the thermal or thermo-physical properties of beef during the freezing process in order to determine the optimal freezing temperature. The freezing process duration and the ideal temperature for achieving optimal results could be determined by knowing the changes in the thermo-physical properties of the meat and the freezing rate (Kim *et al.* 2019; Zequan *et al.* 2019).

The conductivity of the meat's heat, the density of the meat, and the heat density of the meat that will be frozen all have an impact on the quality of the frozen meat. The profile or characteristics of meat that will or is being frozen are typically determined using the three heat properties of meat. Hou *et al.* (2019) had been able to determine the most optimal freezing time and freezing rate by knowing the changing patterns of the material's three heat properties. This will allow us to produce frozen meat of high quality for public consumption and possibly for export to other nations. Freezing optimization can be investigated and predicted using the Planck method. As long as the meat is frozen, this method simulates changes in the meat's thermo-physical properties. The optimal freezing time and temperature can then be determined using data on the changes in the thermo-physical properties and freezing environment.

Near infrared optical wave technology can be utilized to estimate beef quality parameters. The idea and phenomenon that every biological object, including meat, has specific electro-optical characteristics in the form of a spectrum underpins this technology (Munawar *et al.* 2013; Agussabti *et al.* 2020). This spectrum can be analyzed to discover information about the object's chemical composition. This phenomenon has prompted a number of researchers to investigate the possibility of using optical wave methods to predict the quality of organic materials that will be used in drug manufacturing, such as meat (Kartakoullis *et al.* 2019), fruit, flour, animal feed, and herbal leaves (Munawar *et al.* 2019a; Sudarjat *et al.* 2019; Yusmanizar *et al.* 2019).

Fruit quality evaluation (Munawar *et al.* 2019b), prediction of animal feed quality parameters (Samadi *et al.* 2018b; Samadi *et al.* 2019), cocoa and coffee quality in intact green bean form (Yusmanizar *et al.* 2019; Agussabti *et al.* 2020), prediction of soil quality

attributes (Devianti *et al.* 2019; Ramli *et al.* 2019), and other biological material properties are just a few examples of related studies that have been carried out and reported regarding the application of NIR technology in numerous fields, particularly agriculture. Therefore, the purpose of this paper is to rapidly and simultaneously predict the protein content of frozen beef using NIR technology.

MATERIALS AND METHODS

Freezing Model

The best way to freeze is to choose the best freezing time based on the kind of freeze, the freezing temperature, and the shape or geometry of the frozen meat material (Munawar *et al.* 2019a; Syahrul *et al.* 2019). The Planck method can be used to examine the optimal freezing time. The quality of the frozen meat material that is preserved will be greatly affected by how the Planck method is used. The Planck method looks at how the heat changes from the outside to the inside of a frozen product at its center using the Planck method.

Near Infrared Spectrum

Near infrared spectra data of beef samples were acquired using a benchtop NIR instrument. It was controlled and configured under integrated software Thermo Integration® and Thermo Operation®. Specified tasks were performed by establishing workflow using Thermo Integration software. High resolution measurement with integrating sphere was chosen as a method for spectra acquisition.

For each spectra measurement, sample labeling was required automatically prior to acquisition in order to distinct beef samples respectively. Spectra data were acquired and recorded as absorbance spectrum in wavelength range from 1000 to 2500 nm and saved in three different file formats: Nicolet (spa), Jcamp (jdx) and comma separated value (csv).

Each sample was hand placed manually right to the incoming hole of the light source to ensure direct contact and minimize noises due to light scattering. Absorbance spectrum in wavelength range from 1000 to 2500 nm was acquired with co-added of 32 scans. Background correction for optimum spectra acquisition was performed automatically every hour. Near infrared spectral data were analyzed and enhanced by means of multiplicative scatter correction followed by calibration models development (Agustina and Munawar 2019; Munawar *et al.* 2019c; Saputri *et al.* 2019).

Actual Protein Measurement

Beef quality parameters to be tested and measured is the protein content. Protein parameter was measured by the Kjeldhal method (AOAC 1997). Protein content testing using the Kjeldal method consists of three stages, namely the destruction, distillation and titration.

In the destruction stage, there was fresh meat samples were determined by size (using a Ruler the meat samples was then put into the Kjeldhal flask,

added with 10 mL of 97% concentrated sulfuric acid and 0.5 grains of Kjeldhal as a catalyst. After that, the Kjeldhal flask was heated over the destruction apparatus. The digestion process lasted for 2-4 hours and cooled down. The samples were then distilled using a steam distiller with 50 mL of distilled water was used as diluent. In each Kjeldahl flask was then added with 10 mL of 45% NaOH, 10 mL of 4% boric acid solution and 3 drops of indicator (methyl red) were prepared in Erlenmeyer flasks which was connected to the the end duct of the distillation apparatus (collecting lines). The duct should be immersed into the solution during the distillation process. Wait until 50 cc of solution in Erlenmeyer turns blue. At the titration stage, the 50 ml distillates were titrated with 0.1 N H_2SO_4 until the color changes from blue to reddish.

Spectra Correction and Prediction Models

The near infrared technology was applied to decide the quality beef's parameters and compare the result with standard laboratory chemical methods. By creating a regression model between the optical wave spectrum (data X) and beef quality parameters, such as protein, fat, carbohydrates, and minerals (data Y), the infrared spectrum data for beef samples will be used as data to predict beef quality. Regression models will be built utilizing the Principal Component Regression (PCR) and Partial Least Square Regression (PLSR) methods (Munawar *et al.* 2016).

The important core of NIRS practices and applications is to construct and develop models used to predict desired nutritive or quality attributes of studied samples. These quality attributes can be predicted rapidly and simultaneously through a process called as calibration, by regressing NIR spectra data (X variables) and actual measured nutritive attributes (Y variables). Ideally, the sample set employed in the regression stage must be representative of the present and of future prediction samples. It means that all

expected sources of variability must be considered in both, the calibration and validation sample datasets.

In most common NIRS practices, PLSR is one of the most widely used as regression method in constructing prediction models. The PLSR method continues to be the workhorse for regression software used: The Unscrambler X 10.3.

RESULTS AND DISCUSSION

The chest and leg parts of beef were sampled in this study, with 10 samples each (120 g per sample). We assumed that these both parts are represented whole parts of the body. The spectral data of NIR itself shows that both body parts are different in peaks and valleys for molecular vibration related to meat qualities. Figure 1 shows the spectrum acquisition results in beef samples. This spectrum described the absorption pattern of infrared waves absorbed by the material.

We also attempt to predict protein content in both fresh and frozen beef for all body parts of cows, from the head to the thighs. The optical properties of optical near infrared waves acquired at wavelengths of 1000-2500 nm or wavenumbers 4000-10000 cm^{-1} were used to predict fat and protein levels.

According to the findings of this study, the C-H-O structure vibrated (first overtone) in the wavelength range of 2200-2300 nm. While the molecular structure of N-H which related to protein content vibrated (first overtone) in the 1500-1650 nm wavelength range. The valleys of the NIR spectrum in 1500-1650 nm also represent the overtone. Thus, it is possible to determine meat quality parameter. Particularly in wavelength 1200 nm, first overtone for N-H from correlated to protein and fiber content of the meat. The resulting NIR spectrum may contain noise, which can interfere with the information extraction process. This has an impact on the accuracy of prediction of the quality parameters studied.

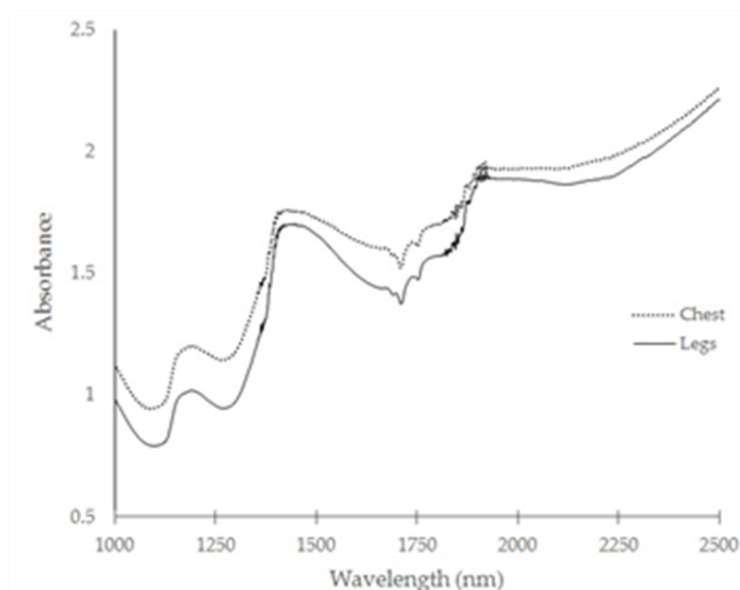


Figure 1. Spectra feature of protein content samples in NIR region

Several factors can cause this disturbance, including an overheated temperature sensor, light on other objects such as air, changes in the curvature of the integrating sphere, and excessive optical gain. As a result, the spectrum must be improved in order to produce a better and more accurate spectrum when used to predict the chemical content of high-quality ingredients. This study also included spectrum improvement, with the correction methods chosen being Mean Centering (MC) and Baseline Shift Correction (BSC). These spectrum correction methods can eliminate the effects of light interference and peak spectrum strengthening (Munawar *et al.* 2016; Yunus *et al.* 2019).

The principal component regression (PCR) method is used to create prediction models. The performance of prediction models was built using the Raw, MC, and BSC spectrums for protein production. It showed that the protein content of beef can be predicted very well, despite the fact that the raw data spectrum has not been improved. Figure 2 shows a comparison of protein prediction results using raw spectrum data.

Based on Figure 2, the correlation coefficient (r) generated from protein predicted and protein measurement was 0.87, while the reliability coefficient (RPD) was 2.15. This data indicated that the result considered as good performance. When the protein prediction model was built using the BSC spectrum improvement spectrum data, the performance results obtained slightly improved over the raw spectrum, but the BSC method was no better than the MC spectrum correction method. That was interpreted that the BSC spectrum correction method was incompatible with solid samples like meat. This is consistent with some literature, which suggested that the BSC spectrum correction method would be better suited for use on samples with pile type (bulk), such as flour, soil, or grain samples analyzed in the form of piles (Iskandar *et al.* 2019; Kartakoullis *et al.* 2019). The predicted and measured protein content using MC spectrum is shown in Figure 3 and Figure 4.

Protein prediction performance in beef samples improves when the model was built with corrected

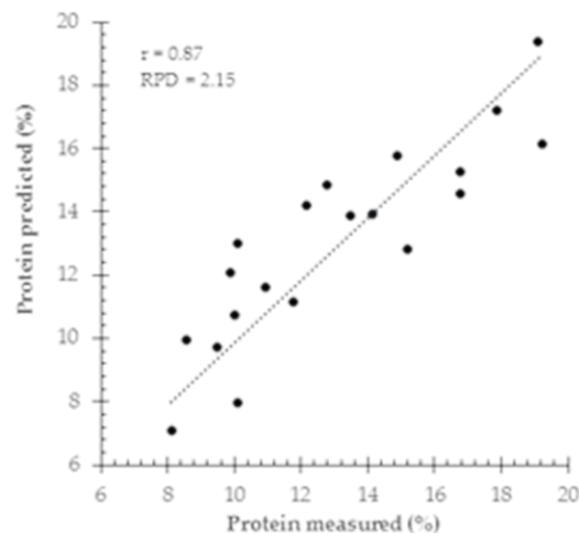


Figure 2. Measurement and prediction of protein content measured and predicted using raw spectrum

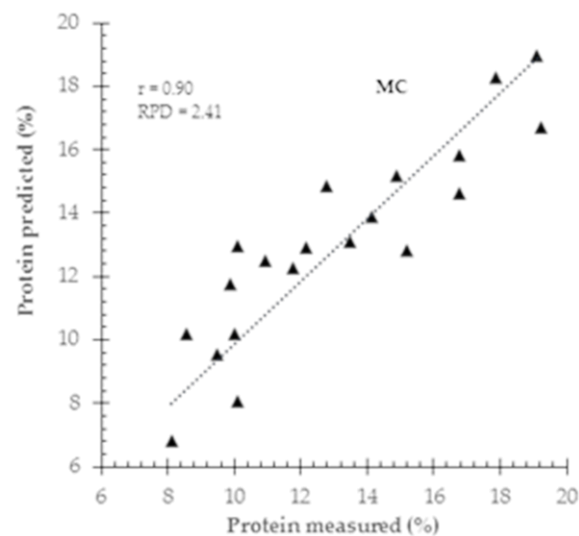


Figure 3. Protein content measured and predicted using MC spectrum

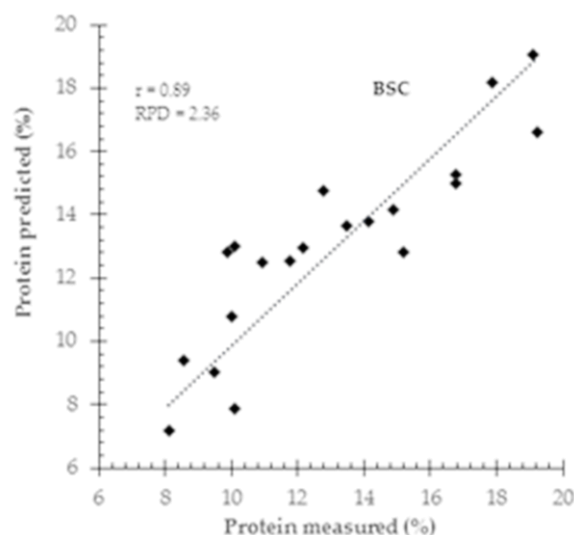


Figure 4. Protein content measured and predicted using BSC spectrum

infrared spectrum data (corrected spectra data), either using the MC or BSC method. Protein prediction throughout beef samples improved when the MC method was used, with the correlation coefficient increasing to 0.90 and the RPD reliability coefficient increasing to 2.35. When the prediction model was built using the MC data spectrum, the prediction error decreased from 1.64 to 1.50.

The amount of required freezing is affected by changes in the heat properties of the material during freezing. The optimum freezing rate will determine the truly optimum time for a material's freezing process. Freezing for an extended period of time will result in the formation of ice crystals, which will certainly damage and reduce the nutritional content, whereas freezing for an extended period of time will still leave microbes and other organisms in the product, resulting in poor preservation. The freezing rate will also have an effect on the cell wall structure of frozen beef or other animal products (Lee *et al.* 2019; Pavlidis *et al.* 2019). Cell wall damage will result in the release of important nutrients in the product. This damage can be detected in livestock products, such as frozen beef, during thawing. To avoid this damage, freezing must be done correctly, both in terms of time and freezing medium.

Heat properties, such as beef density, changed during the freezing process. According to the literature, the pattern of change in density during this process follows an exponential trend, indicating that the mass of frozen meat mass changes exponentially and the formation of ice crystals occurs after the optimum time has been reached (Iskandar *et al.* 2019; Lee *et al.* 2019).

CONCLUSION

Based on the research findings, it is possible to conclude that infrared ray technology has the potential to be used in the field of animal and animal husbandry, specifically for evaluating beef quality. Protein levels in beef samples can be predicted using a good and

robust category, with a maximum correlation coefficient of 0.90 produced. Furthermore, if the model is built with improved and corrected spectral data, predictive performance will improve.

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