Rapid Assessment Of Frozen Beef Quality Using Near Infrared Technology

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Abstract: The main purpose of this 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 100g 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 is 0.91. Heat properties of beef samples changes exponentially during freezing and thus, optimum freezing temperature and time can be predicted as well. Based on those obtained results, it may conclude that near infrared technology can assess frozen beef qualities rapidly and effectively.

Index Terms: Beef, near-infrared, technology, freezing, protein, prediction, quality.

1 INTRODUCTION

Beef is one of the many livestock products that are consumed and utilized by many people throughout the country, including in Indonesia. In general, beef is used either directly in the form of fresh meat (fresh meat), or in the form of processed products such as corned beef, sausages, meat balls and other processed forms. The taste is unique and delicious and nutritional content that is beneficial for the development of human organs, making the demand for beef continues to increase every year [1]. According to data from the Indonesian Statistics Center (BPS), the total beef demand in 2019 is predicted to increase to 982 000 tons compared to 2018, which was 590 000 tons, and in 2017 amounted to 722 000 tons of beef [1], [2]. Freshly cut beef must naturally be processed immediately for consumption. However, sometimes fresh beef must be preserved first to extend its shelf life. One of the most widely used preservation methods in small communities and livestock processing industries is freezing. Simply put, meat products are stored on ice-filled medium so that the ambient temperature of the media becomes low below the freezing point of water. To maintain optimal meat quality, beef must be frozen at controlled cold temperatures. In addition, freezing must be carried out until the optimal time limit so that microbes in the product can be deactivated or even turned off. Freezing must be carried out optimally, both in terms of the temperature of the freezing media and the length of freezing time, so that the nutritional content of the material is not lost. Freezing that lasts too long will result in the emergence of ice crystals in frozen meat in large quantities. This crystallization of ice will cause damage to cell walls and release of important nutrients from the meat [1], [3]. On the other hand, freezing too fast will leave harmful microbes in the meat. Freezing really aims to eliminate the microbes present in the meat before the meat is processed. However, freezing which is not carried out optimally will actually cause new problems, namely the release of most nutrients / nutrients or the presence of microbes in the meat. Therefore, freezing must be done optimally both in terms of the temperature of the freezing media, as well as the freezing time. Optimum freezing will certainly produce beef of good quality and is suitable for human consumption and processing. Furthermore, speaking of meat quality issues, meat quality determination and analysis is usually done using chemical analysis. The quality or nutrition of beef such as fat, protein, and mineral content is generally determined by carrying out a series of procedures in the laboratory and involving chemicals which can certainly cause environmental pollution [4], [5]. In addition, the testing process in this laboratory often requires a long time in the testing procedure. Therefore, another method is needed for determining the quality of beef. One technology that is developing and of concern at this time is the application of electromagnetic wave technology, where this technology does not require chemical applications, fast, effective, and without damaging meat. As explained earlier, freezing for beef must be carried out optimally both in terms of freezing time and temperature. This was done to avoid the unexpected effects of the freezing process. The impact of the freezing process of meat that is not optimum can be in the form of loss of nutrients and nutrients contained in beef, resulting from freezing too long with excessive freezing temperatures. Another impact is the presence of harmful microbes or bacteria found in beef as a result of the freezing process that is too early and not yet optimum. To determine the optimum freezing, we must know the rate of freezing and changes in the thermal or thermo-physical properties of beef during the freezing process. By knowing the changes in the thermo-physical properties of the meat and the freezing rate, we will be able to determine how long it takes and the temperature for the freezing process, so that the results of freezing are optimum [6], [7]. Meat heat characteristics that affect the quality of freezing are the conductivity of meat heat, density or density of meat and heat density of meat to be frozen. The three hot properties of meat are generally used to determine the profile or characteristics of meat that will or is being frozen. By knowing the changing patterns of the three heat properties of this material, we will be able to determine the most optimum freezing time and freezing rate so that frozen meat has good quality for consumption by the public and may be suitable for export to other countries [4]. Freezing optimization can be analyzed and predicted using a method, the Planck method. This method simulates changes in the thermo-physical properties of the meat as long as the meat is frozen and then, based on data on the changes in the

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thermo-physical properties along with the freezing environmental data, the optimum freezing time and temperature can be determined. For estimating beef quality parameters, optical wave technology like near infrared can be used for this purpose. This technology works based on the phenomenon and principle that every biological object, including meat, has certain specific electro-optical characteristics in the form of spectrum [8], [9]. This spectrum can then be analyzed into information about the chemical content of the object. This phenomenon has prompted many scientists to examine the possibility of applying optical wave methods to predict the quality of an organic material such as meat [10], fruit, flour, animal feed and herbal leaves [2], [11]–[13] which will be used as ingredients for drug manufacturing. Related studies have been performed and reported in the application of NIR technology in many fields, especially in agriculture like fruit quality evaluation [14], animal feed quality parameters prediction [2], [15], cocoa and coffee quality in intact green bean form [9], [13], soil quality attributes prediction [16]–[18] and other biological material properties. Therefore, the objective of this present paper is to employ the NIR technology in predicting protein content of frozen beef, rapidly and simultaneously.

2 MATERIALS AND METHODS

2.1 Freezing model
Freezing can be done optimally by determining the most appropriate freezing time according to the type of freeze, freezing temperature, as well as the shape or geometry of the frozen meat material [19], [20]. The optimum freezing time can be analyzed using the Planck method. The application of the Planck method will greatly determine the quality of the preserved meat material by freezing. The Planck method analyzes the pattern of heat changes of products that are frozen from the outer side of the product to the inner side of the product at its center.

2.2 Near infrared spectrum
Optical wave spectrum in the range of near infrared ray wavelengths for beef samples was acquired using the Fourier transform near infrared (FT-NIR) instrument. The wavelength range to be used is 1000-2500 nm with intervals of around 0.2 nm. The wave spectrum is then stored in the form of * .csv file for further processing and analysis [21]–[23] .

2.3 Actual protein measurement
Beef quality parameters to be tested and measured is the protein content. Protein parameter was measured by the Kjeldahl method. It measured in duplicate and averaged.

2.4 Spectra correction and prediction models
The near infrared technology was applied to determine the quality parameters of beef and compare the results with standard laboratory chemical methods. Infrared spectrum data for beef samples will be used as data to predict beef quality by making a regression model between the optical wave spectrum (data X) and beef quality parameters, namely protein, fat, carbohydrates and minerals (Y data). Regression models will be built using the principal component regression (PCR) and partial least square regression (PLSR) methods [24], [25].

3 RESULTS AND DISCUSSION
Before we can use infrared technology to predict meat quality, we must first know the features of the infrared light spectrum from beef samples. In this study, part of the beef sample taken was the chest and leg sections with 10 samples each (120g per sample). The results of spectrum acquisition in beef samples are shown in Fig. 1. This spectrum characterizes the absorption pattern of infrared waves absorbed by the material.

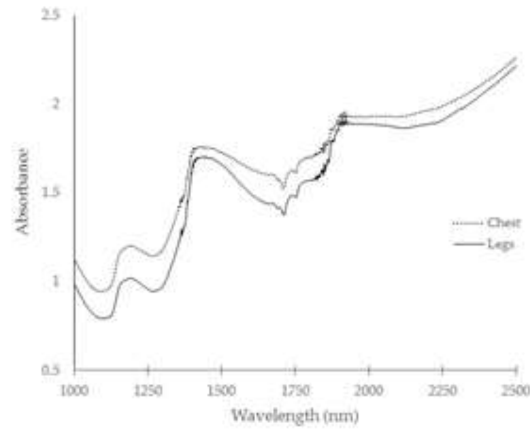

Fig. 1. Spectra feature of organic fertilizer samples in NIR region

We also try to predict protein content in fresh beef and frozen beef for all body parts in cows that include the head to the thighs. Fat and protein levels are predicted using the optical properties of optical near infrared waves acquired at wavelengths of 1000 - 2500 nm or wavenumbers 4000-10000 cm^{-1}. Based on the results of this study, it was found that the C-H-O structure vibrates (first overtone) in the wavelength range of 2200 - 2300 nm. While the molecular structure of N-H is correlated with protein content, it vibrates (first overtone) in the wavelength range of 1500 - 1600 nm. The resulting NIR spectrum sometimes contains noise that can affect the information extraction process from that spectrum. This of course will affect the results of the accuracy of prediction of the quality parameters studied. Typically, this disturbance is produced by several things including: overheated temperature sensor, light on other objects such as air, changes in curvature of integrating sphere and excessive optical gain. Therefore, the spectrum must be improved in order to produce a better and more accurate spectrum when it will be used for predicting the chemical content of quality ingredients. Spectrum improvement was also carried out in this study where the correction methods chosen were mean centering (MC) and baseline shift correction (BSC). These spectrum correction

TABLE 1

PREDICTION PERFORMANCE USING DIFFERENT NUR SPECTRUM

Spectrum	R^2	r	RMSE	RPD
Raw	0.77	0.87	1.64	2.15
MC	0.82	0.90	1.43	2.41
BSC	0.79	0.89	1.59	2.36

MC: mean centering, BSC: baseline shift correction, R^2: coefficient of determination, r: coefficient correlation, RMSE: root mean square error, RPD: ratio prediction to deviation.

methods are able to eliminate the effects of light interference and the strengthening of the peak spectrum [17], [24]. Prediction models are built using the principal component regression (PCR) method. For protein production, the performance of prediction models built using the spectrum of Raw, MC and BSC is shown in table 1.

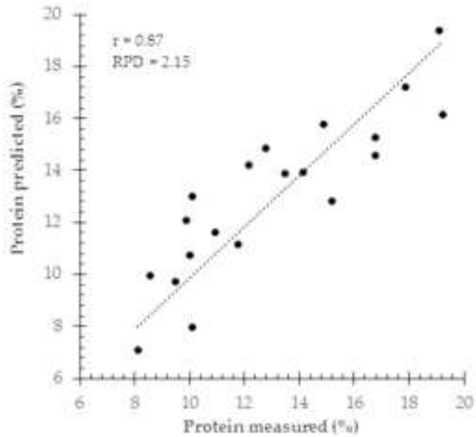

Fig. 2. Protein content measured and predicted using Raw spectrum

From the table above it can be seen that the protein content in beef can be predicted very well even though Raw data spectrum has not been improved. The correlation coefficient (r) generated from this data is 0.87 and the reliability coefficient (RPD) is 2.15 which, based on the literature, these results indicate or are classified as good performance. Comparison of protein prediction results using Raw spectrum data can be seen in Fig. 2. When the protein prediction model was built using the BSC spectrum improvement spectrum data, the performance results obtained slightly increased from the raw spectrum, but when compared to the MC spectrum correction method, the BSC method was no better. That is, the BSC spectrum correction method is not suitable for use in solid sample such as meat. This is in line with the opinion of some literature which states that the BSC spectrum correction method would be more suitable to be applied to samples with pile type (bulk) such as flour, soil or grain samples analyzed in the form of piles as shown in Fig 3. and Fig. 4.

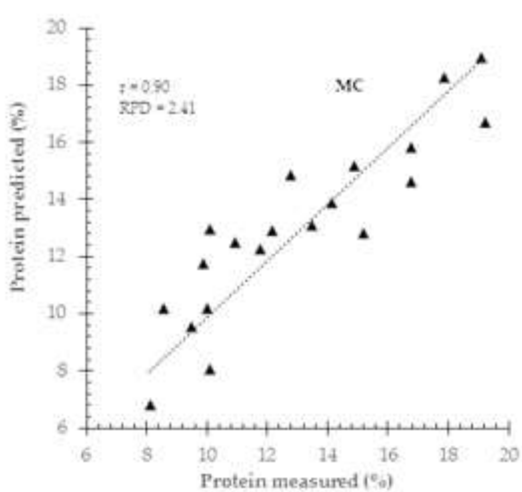

Fig. 3. Protein content measured and predicted using MC spectrum

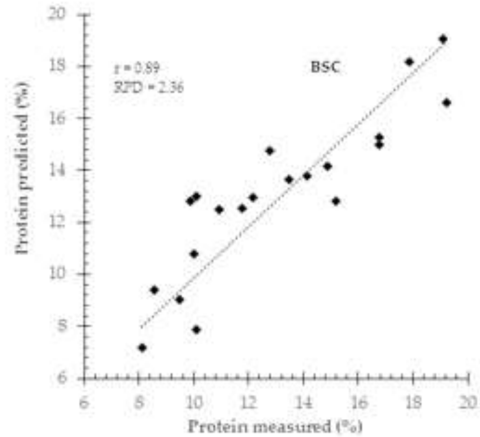

Fig. 4. Protein content measured and predicted using BSC spectrum

Protein prediction performance in beef samples increases when the model is built using infrared spectrum data that has been corrected (corrected spectra data) either using the MC or BSC method. When using the MC method, protein prediction in beef samples gets better with the correlation coefficient increasing to 0.89 and the reliability coefficient of RPD to 2.35. The prediction error also decreased from 1.64 to 1.50 when the prediction model was built using MC data spectrum. Changes in the heat properties of the material during freezing will affect the amount of freezing required. The optimum freezing rate will determine the truly optimum time for the freezing process of a material. Freezing for too long will cause a buildup of ice crystals and will certainly damage and reduce the nutritional content while freezing too fast will still leave microbes and other organisms in the product which ultimately preservation of the product becomes not optimal. The freezing rate will also affect the cell wall structure of the frozen beef or any other animal products [26], [27]. Damage in cell walls will cause the release of important nutrients in the product. In livestock products, such as in freezing beef, this damage can be detected during thawing. So, to prevent this damage freezing must be done properly, both in terms of time and in terms of freezing media. During freezing, heat properties such as beef density change along the freezing time. The pattern of change in density during this process follows an exponential trend in accordance with the literature which revealed that the mass of frozen meat mass changes exponentially and the formation of ice crystals will form after the optimum time has been reached.

4 CONCLUSION

Based on the research results obtained, it can be concluded that infrared ray technology has the potential to be applied in the field of animal and animal husbandry, while this is for evaluating beef quality. Levels of protein in beef samples can be predicted with good and robust category where the maximum correlation coefficient produced is 0.91. Furthermore, predictive performance will be better if the model is built using improved and corrected spectral data.

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