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Prediction of Raw Poultry Meat Texture Using PLS Analysis

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Abstract: The visible/near-infrared (Vis/NIR) reflectance spectroscopy (680-1100 nm) has been applied to determine the meat texture prediction of raw chicken meat. The chicken breed; Az-Zain Organic Village chicken, Village chicken and Broiler chicken were used as the samples. Destructive measurement, Volodkevich bite jaws texture analyzer had been used to obtain the shear-force (kg) as the reference value. From Partial Least Squares (PLS) analysis, it is shown that the correlation accuracy for the Az-Zain organic village chicken is higher (R^2> 0.85) than the village chickens (R^2> 0.42) and broiler chickens (R^2> 0.42). The Az-Zain organic village chicken has high correlation for the relationship between the Vis/NIR spectroscopy and Volodkevich bite jaws shear force. This can be related with the different food composition where organic chicken fed with mixture of organic products while the broiler ad village chickens fed with commercial and pelleted diets. Thus, Vis/NIR spectroscopy can be used to predict the tenderness of the raw chicken meat samples without destroying the samples. *Copyright © 2014 IFSA Publishing, S. L.*

Keywords: Chicken meat, Tenderness, NIR spectroscopy, Partial least squares.

1. Introduction

Global chicken production has been increasing rapidly since chicken meat was discovered as a economical protein basis [1]. In Meat industry, important highlighted that the value of meat production mainly depends on the appearance, juiciness, flavour, nutritional value, wholesomeness and texture of meat [2, 3]. Most importantly, hardness or tenderness of meat has been identified as the main significant feature to satisfy preferences of consumer's eating satisfaction [4]. Tenderness or hardness in definition is the force required to attain a given deformation or a penetration in a product [5]. In food for example, it is achieved with molar teeth where the hardness is represent at the first bite.

Therefore, to determine the meat quality check in term of tenderness or hardness, manual inspection performed by human graders [6] and invented destructive devices have been applied. Some of the destructive devices that have been implemented in evaluating the meat quality are Warner–Bratzler (WB) shear force instrument [7-11], Allo–Kramer shear compression system (multiple blade) [7, 11, 12], Razor Blade Shear Measurement [7, 11, 12], Meat Industry Research Institute of New Zealand (MIRINZ) Tenderometer [11, 13], Texture Profile Analysis (TPA) [7] and Volodkevich Bite Jaws [14, 15].

Warner-Bratzler is one of the most popular devices that have been used in many researches for the indicator of the meat sensory tenderness. Even

though the Texture Profile Analysis is widely used for texture assessment of other food, it is rarely used in meat research. Reference [2] shows the research in investigating which instrument for assessment of meat texture is more useful, either WB or TPA both in raw and cooked meat for the prediction of the sensory texture. It was found that WB measures the force to shear a piece of meat while TPA measures the compression force when a piece of meat is compressed. In TPA, the test will stop when 25 % of sample thickness lasts while in WB, the shear plate must continue running until the sample has been completely cut. The result shows that the best prediction for hardness of raw meat is by TPA while for the cooked meat, the WB method is better. However, WB is not very accurate in predicting the meat texture because the samples need to be cooked and hence, the hardness of the meat samples will increase [2, 5].

Volodkevich bite jaws texture analyzer is another destructive shearing device applied to foods with a pronounced fibrous structure including meat, meat products and vegetables. This instrument is intended to simulate the teeth when biting through food sample [16]. The apparatus involved the process of shearing and compression [14, 15]. The toughness measurement of Volodkevich bite jaws was recorded as the force (kg) required for shearing and compressing the sample, with toughness (less tender) samples resulting in higher values [15]. This device also enables the cross section of the sample, to be measured, up to 1 cm [16, 17]. As for that matter, the samples need to be cut in rectangular sizes, of 10 mm x 10 mm x 20 mm to fit in the bite jaws. The manual inspection by human graders and the destructive devices have many disadvantages in term of time consuming, labor intensive and the destroyed samples[18].

To improve the meat texture assessment, a non-destructive device, Near-Infrared Spectroscopy (NIRS) [1, 5, 8, 19] has been used in many applications for prediction of the quality of the fruits [20] and vegetables and even the meat industry to determine fatty acid [21], fat [22], moisture, protein level [23] in raw and cooked products. NIRS has many advantages in term of fast measurement speed, low cost measurement, less sample preparation and high precision. The non-destructive measurement of NIRS does not require the meat samples to be cooked and destroyed hence can be applied directly for the raw meat samples texture assessment.

In this study the ability of visible/NIR spectroscopy for the prediction of raw chicken meat texture from three different types of chickens is determined. In addition, the comparison of the raw meat tenderness from different types of chickens using destructive measurement (Volodkevich Bite Jaws texture analyzer) and non-destructive measurement (Near-infrared Spectroscopy) is presented.

2. Materials and Methods

2.1. Meat Samples

Three chicken breeds; Az-Zain Organic Village chicken, Village chicken and broiler chicken were bought from local supermarket. The chickens were stored in the freezer under temperature of 0°C overnight before the deboning process. The next day, the raw breast meats from each chicken carcass were cut into rectangular blocks with dimension of 10 mm-thick x 10 mm-wide x 20 mm-length with the long axis in direction of the muscle fibers as shown in Fig. 1 [15].

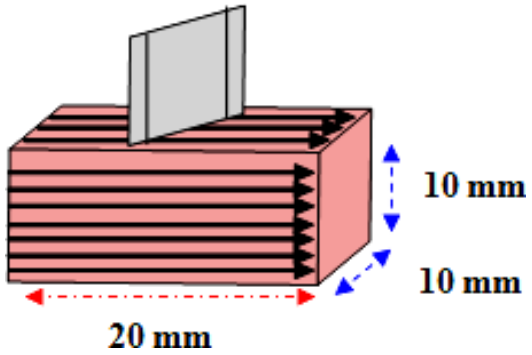

Fig. 1. The direction of fiber and the measurement of chicken meat samples for Volodkevich Bite Jaws measurement.

The Az-Zain organic village chickens were fed with organic foods consists of corn and herbs that rich with anti-oxide and anti-cancer [24]. The black seed (Habbatus Sauda) are also added in the chicken food as the antibiotic [24]. Meanwhile, the broiler and the village chickens were fed with commercial and pelleted diets contains animal and plant proteins, grains, with additives mixed in including the growth hormones [25], antibiotic and chemicals in order to make the chickens grow faster and looks lush and interesting when they were slaughtered for sale in the market. Detailed compositions of the feeds for broiler chickens, Village chickens and Az-Zain organic chickens are shown in Table 1, Table 2 and Table 3, respectively.

Table 1. Diet composition fed by broiler chickens.

Composition
Crude protein
Crude fibre
Crude fat
Moisture
Calcium
Phosphorus

Table 2. Diet composition fed by village chickens.

Composition
Crude protein
Crude fat
Crude fibre
Moisture
Calcium
Phosphorus

Table 3. Diet composition fed by Az-Zain village organic chickens.

Composition
Mixture of organic product
Corns and herbs rich with anti-oxide and anti-cancer
Black seed act as antibiotic

(Source: Dr. Zainol Mumtaz Marine Food Sdn. Bhd.)

2.2. Visible/NIR Spectroscopic Measurement

For the non-destructive measurement, a non-invasive low cost portable VIS-NIR spectroscopy Ocean Optics USB4000 Miniature Fibre Optic Spectrometer (at the range of 650 to 1000 nm) from ORNET Sdn. Bhd., Selangor, Malaysia is used to obtain the reflectance spectra from the surface of raw chicken meat. The VIS-NIR energy source and the optical standard reference used in this work were a tungsten halogen light (360-2000 nm) (LS-1, Ocean Optics, USA) and a diffuse reflectance standard (WS-1, Ocean Optics, USA) respectively. For the diffuse reflection measurement, a reflection probe (R400-7-VIS/NIR, Ocean Optics, USA) was positioned at 45˚ angle and 5mm from the surface of the chicken. The spectrometer and the energy source were warmed up for 30 minutes before spectra acquisition began. The spectrometer was interfaced with the computer using Spectra Suite, Ocean Optics, USA software for spectral data acquisition. The raw chicken meat samples were scanned in the reflectance mode from 650 to 1000 nm at 2 nm increments. An average of 6 scans was calculated for each sample. The acquired spectrum was smoothed with the boxcar value of 5 in order to increase the signal to noise ratio of the acquired spectrum. Absorbance data were stored as log (1/R), R being the reflectance. The instrument was operated by the software package NIRS2 version 3.01 (InfraSoft International, State College, PA, USA). For analysis purposes, all the spectra obtained were saved and imported in an Excel file.

2.3. Volodkevich Bite Jaws Texture Analyzer

The textural assessment of raw chicken meat samples was conducted using a computer-assisted TA.HD plus Texture Analyzer (Stable Micro Systems, UK) fitted with Volodkevich bite jaws set with setting compression for the test mode, pre-test speed of 0.2 cm/sec, test speed of 0.2 cm/sec, post-test speed of 0.2 cm/sec distance of 0.5 cm and trigger type, auto. Each raw chicken meat samples that were cut before was placed into the texture analyzer slot before measurement. Each chicken meat block was sheared and compressed once in the center and perpendicular to the longitudinal direction of the fibers using Volodkevitch bite jaw (stainless steel probe shaped like an incisor) which was fitted to a TA-HD plus texture analyzer (Stable Micro Systems, UK) at the angle of 90° angle [15]. The sheared force data, referred to as the reference tenderness, was recorded in kilogram (kg). All the references data and the spectral data from NIR spectroscopy were loaded into Microsoft Office Excel 2007 and processed to perform partial least square (PLS) regression data analysis via MATLAB simulation software (MATLAB_Version 7.12.0.635(R2011a)).

2.4. Spectral Pre-Treatment and Model Development

The data analysis was performed in MATLAB simulation software (MATLAB_ Version 7.12.0.635 (R2011a)). Partial least squares (PLS) regression was used to predict the Volodkevich bite jaws shear force in 680-1000 nm spectral region. The PLS model were developed either with no spectral smoothing or with spectral smoothing of either first order Savitzky-Golay (SG) smoothing filter or SG + 1st derivative or SG + 2nd derivative. The predictive accuracy of the PLS models was given by RMSEP (root mean square error of prediction) and R2 (coefficient of determination).

3. Results and Discussion

3.1. Visible/Near-infrared Spectra

Fig. 2(a) represents the average raw absorbance NIR spectroscopy spectra of raw chicken meats samples from three different types of chickens; Az-Zain Village Organic chicken, Broiler chicken and the Village chicken. The first order Savitzky-Golay (SG) smoothing filter was applied to smooth the spectral data as shown in Fig. 2(b). Then, to remove the unwanted baseline shift effects, the first order approximate derivative of the spectral was computed as illustrated in Fig. 3.

The red spectrum which indicated the mean absorbance spectra of Village chickens shows high absorption compared to the mean absorbance spectra of Az-Zain village organic and broiler chicken samples. According to S. Andrés et al. [26], the most tender meat samples showed higher absorbance in the visible (400-950 nm) and lower absorbance in the NIR region (1100-2498 nm) [26, 29]. This statement

is acceptable because when comparing average raw absorbance NIR spectroscopy spectra with the value of mean from Volodkevich bite jaws shear force; the mean of Village chickens (0.3493 kg) is smaller than the mean of Broiler chickens (0.3788 kg) and Az-Zain Organic chickens (0.5757 kg) by referring to Fig. 2(b).

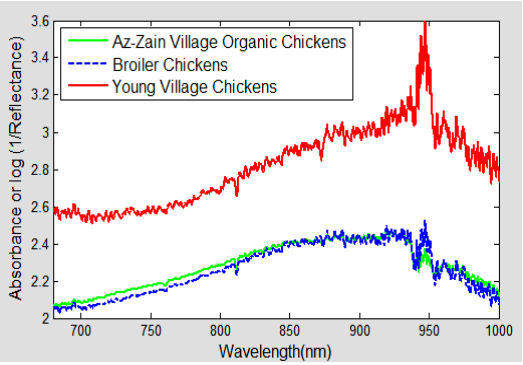

Fig. 2 (a). Raw absorbance spectra of raw chicken meat samples.

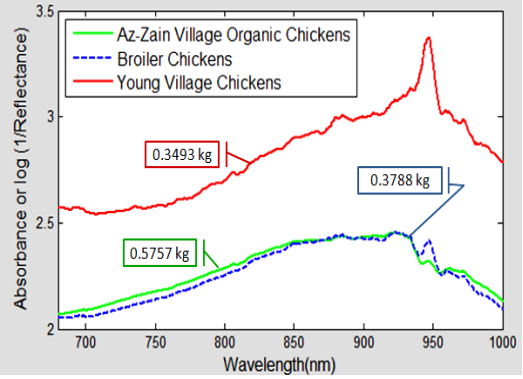

Fig. 2 (b). Absorbance spectra of raw chicken meat samples after filtered with SG smoothing.

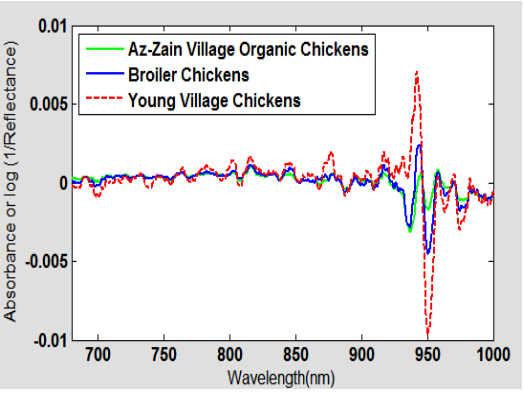

Fig. 3. First order derivative absorbance spectra of chicken meat samples.

Venel et al. suggested that the band around 910 nm as an indication of protein contribution [30]. Furthermore, it had been found that a weak NIR band at 760 nm is from the third overtone of O-H vibration while the strong and broad band at 980 nm is most likely due to water [31]. However, the moisture content of the samples was not monitored in this study.

3.2. Prediction Performance of PLS Models

Based on the absorbance spectra, log (1/Reflectance), Savitzky-Golay smoothing and first derivative, partial least squares (PLS) regression models for predicting the tenderness of Volodkevich bite jaws shear force were developed. The range of the wavelengths was from 680 nm to 1000 nm.

From Fig. 4(a) and Fig. 4(b), Fig. 5(a) and Fig. 5(b) and Fig. 6(a) and Fig. 6(b), the correlation plot for the 1st derivative show better extrapolation prediction for the raw chicken meat tenderness than the raw SG Smoothing. The 1st derivative correlation plot has more accurate information that is closer to the target line. The results for the accuracy of coefficient correlation are shown in Table 4. The prediction accuracy of the Az-Zain organic village chickens is the highest for the first derivative compared to the broiler and Village chickens. The high prediction accuracy of Az-Zain village organic chicken compared to broiler and village chickens could be correlated to the feed composition of the chicken diets.

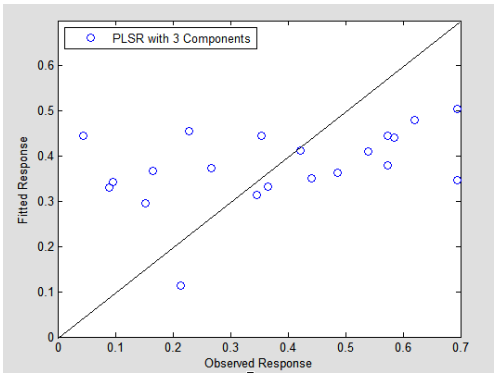

Fig. 4 (a). The correlation plot for the broiler chicken with SG Smoothing.

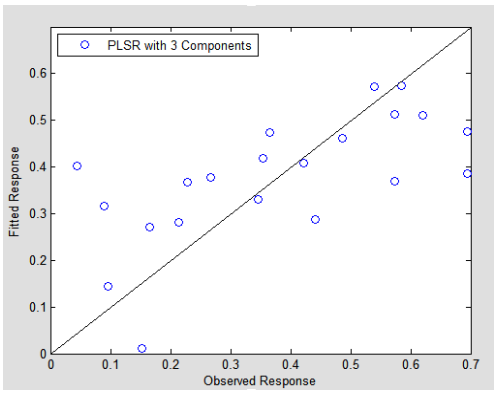

Fig. 4 (b). The correlation plot for the broiler chicken SGSmoothing and 1st derivative.

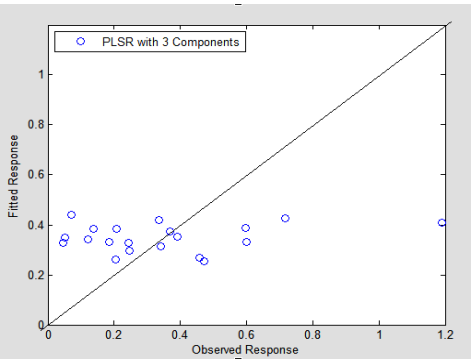

Fig. 5 (a). The correlation plot for the village chicken with SG Smoothing.

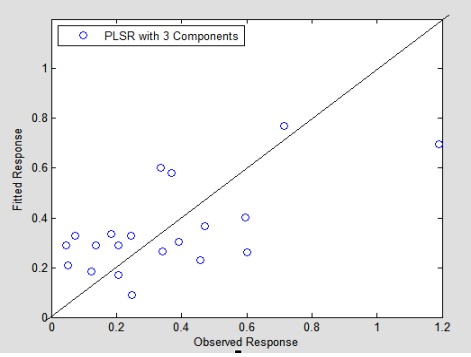

Fig. 5 (b). The correlation plot for the village chicken SG Smoothing and 1st derivative.

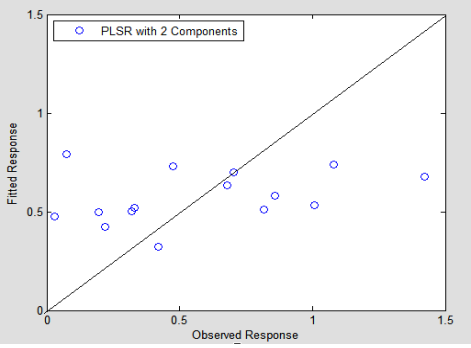

Fig. 6 (a). The correlation plot for the Az-Zain Organic Villagechicken with SG Smoothing.

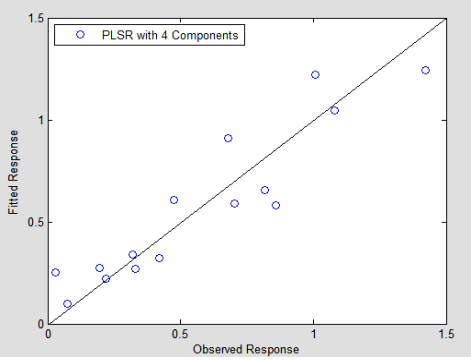

Fig. 6 (b). The correlation plot for the Az-Zain Organic Village chicken SG Smoothing and 1st derivative.

Table 4. Prediction of Volodkevich Bite Jaws Texture Analyzer by visible/NIR spectroscopy

Chicken Meat Sample	Mean ± Standard Deviation	No. of Samp-les	Spect-ral Treat-ment	PLS Compo-nents	R^2	RMSE
Broiler	0.3788 ± 0.2071	21	NONE	3	0.1711	0.1840
			SG	3	0.1637	0.1848
			SG + 1st	3	0.4273	0.1529
Az-Zain Organic	0.5757 ± 0.4058	15	NONE	2	0.1102	0.3698
			SG	2	0.1056	0.3708
			SG + 1st	4	0.8552	0.1492
Village	0.3494 ± 0.2753	20	NONE	3	0.0664	0.2593
			SG	3	0.0384	0.2631
			SG + 1st	3	0.4214	0.2041

4. Conclusion

The PLS analysis shows that the prediction accuracy for the Az-Zain village organic chickens is higher (R2 >$R^2$0.85) than the village chickens (R2 > 0.42) and broiler chickens (R2 > 0.42). The high prediction accuracy and low absorbance spectra of Az-Zain village organic chicken compared to broiler and village chickens is closely related to the food composition of the chicken meals. Therefore, it can be concluded that the food composition of chicken meals lead to the accuracy prediction of the raw chicken using Near-Infrared Spectroscopy.

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