Jurnal Teknologi

Full paper

Prediction of Texture of Raw Poultry Meat by Visible and Near–Infrared Reflectance Spetroscopy

Herlina Abdul Rahim[a*], Rashidah Ghazali[a], Shafishuhaza Sahlan[a], Mashitah Shikh Maidin[b]

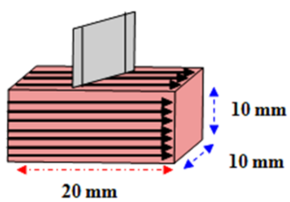
[a]*Process Tomography and Instrumentation Engineering Research Group (PROTOM-i), Infocomm Research Alliance, Faculty of Electrical Engineering, Universiti Teknologi Malaysia, 81310 UTM Johor Bahru, Johor, Malaysia*
[b]*Faculty of Biology, Universiti Putra Malaysia, 43400 UPM Serdang, Selangor, Malaysia*

*Corresponding author: herlina@fke.utm.my

Article history

Received :2 May 2013
Received in revised form :
20 June 2013
Accepted :5 July 2013

Graphical abstract



Abstract

Near-infrared (NIR) spectroscopy is a non-destructive, low cost and fast measurement technique that is required to improve the meat texture quality prediction. In this research, visible/NIR spectroscopy has been used for the prediction of raw chicken meat texture from different types of chickens by referring to the reference data obtained from destructive measurement using a Volodkevich Bite Jaws texture analyser. The Partial Least Squares analysis shows that the prediction accuracy is higher for the Az-Zain village organic chickens (85–95%) than for village chickens (42–68%) and broiler chickens (42–44%). The high prediction accuracy and low absorbance spectra of Az-Zain village organic chickens compared to broiler and village chickens could be correlated with the food composition of the chicken meal.

Keywords: Chicken meat; tenderness; NIRS; Volodkevich Bite Jaws; partial least squares

1.0 INTRODUCTION

In the meat industry, important sensory attributes of meat are appearance, juiciness, flavour, nutritional value, wholesomeness and texture [1-3]. The characteristics of texture include the tenderness, springiness, chewiness, cohesiveness, and juiciness. However, tenderness has been identified as the most important factor with regard to consumer's eating satisfaction for meat products [4]. Tenderness which is the force required to attain a given deformation or penetration of a product, is the most important factor in meat quality assessment [5]. In food for example, it is achieved with molar teeth where the hardness is represented at the first bite. Therefore, to check the meat quality in terms of tenderness or toughness, manual inspection is performed by human graders [6], and invented destructive devices have been applied.

Some of the destructive devices that been implemented in evaluating meat quality are the 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], the Meat Industry Research Institute of New Zealand (MIRINZ) Tenderometer [11, 13], Texture Profile Analysis (TPA) [7], and Volodkevich Bite Jaws [14-15]. The WB instrument is one of the most popular devices and been used in many researches to indicate the meat sensory tenderness. However, the WB instrument required complicated sample preparation and therefore the Volodkevich Bite Jaws texture analyser as shown in Figure 1, is chosen to obtain the shear-force data measurement.

Volodkevich Bite Jaws texture analyser is another destructive shearing device applied to foods with a pronounced fibrous structure including meat and meat products as well as vegetables. This instrument is intended to simulate the teeth when biting through the food sample [16]. The apparatus carries out 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 tough (less tender) samples resulting in higher values [15]. This device also allows a cross-section of the sample of up to 1 cm to be measured [16-17]. For this purpose, the samples need to be cut into rectangular shapes with dimension of 10 mm × 10 mm × 20 mm to fit in the bite jaws. Manual inspection by human graders and destructive devices have many disadvantages in that they are time consuming and labour intensive and the samples are destroyed [18].

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

The objective of this study was to determine the ability of visible/NIR spectroscopy for the prediction of texture of raw chicken meat from different types of chickens. In addition, we present a comparison of the tenderness of raw meat from different types of chickens using destructive measurement (the Volodkevich Bite Jaws texture analyser) and non-destructive measurement (NIRS).

2.0 EXPERIMENTAL SET-UP

Three types of chicken carcasses (of both sexes) were bought from different locations. Broiler chickens (aged 40 days) were bought from Bangi Giant supermarket, Az-Zain village organic chickens (aged 60 days) were bought from a branch of Mumtaz Meat and Marine Foods Sdn. Bhd. in Bangi, and village chickens (aged 30 days) were bought fresh from a farmer in Bangi as well. The Az-Zain village organic chickens and the village chickens came from same breed but the broiler chickens did not. The Az-Zain village organic chickens were bought frozen, whereas the broiler chickens were stored at a temperature of 4 °C and the village chickens were bought immediately after slaughter and processing. The chickens were stored overnight in the freezer at a temperature of 4 °C before the deboning process. The next day, the raw breast meat from each chicken carcass was cut into rectangular blocks 10 mm - thick × 10 mm - wide × 20mm - long with the long axis in the direction of the muscle fibres [15].

For the non-destructive measurement, a low cost portable VIS-NIR spectroscope the Ocean Optics USB4000 Miniature Fibre Optic Spectrometer with a range of 650 to 1000 nm from ORNET Sdn. Bhd., Selangor, Malaysia was used to non-invasively acquire 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. A reflection probe (R400-7-VIS/NIR, Ocean Optics, USA) was positioned at a 45˚ angle and 5 mm distance from the skin of the chicken meat for the diffuse reflection measurement. The spectrometer and the energy source were warmed up for 30 minutes before spectra acquisition began. The spectrometer was interfaced with the computer using SpectraSuite, software from Ocean Optics, USA, for spectral data acquisition. The raw chicken meat samples were scanned in the reflectance mode from 650 to 1000 nm in 2 nm increments. An average of six scans was carried out for each sample. The acquired spectrum was smoothed with a boxcar value of 5 in order to increase the signal to noise ratio of the acquired spectrum. All the spectra obtained were saved and imported into Excel for analysis.

The textural assessment of raw chicken meat samples was conducted using a computer-assisted TA.HD plus Texture Analyser (Stable Micro Systems, UK) fitted with Volodkevich Bite Jaws set with the compression setting for the test mode, a 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 automatic trigger type. Each cut raw chicken meat sample was placed into the texture analyser slot before measurement. Each chicken meat block was sheared and compressed once in the centre and perpendicular to the longitudinal direction of the fibre using the Volodkevitch Bite Jaws (a stainless steel probe shaped like an incisor), which were fitted to a TA-HD plus texture analyser (Stable Micro Systems, UK) at an angle of 90˚ [15]. The shear force data, also called the reference tenderness, were recorded in kilograms. All the reference data and the spectral data from NIRS were loaded into Microsoft Excel and processed to perform partial least squares (PLS) regression data analysis using MATLAB simulation software [MATLAB – Version 7.12.0.635 (R2011a)].

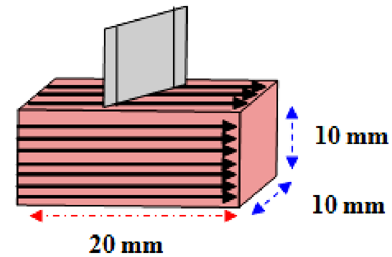


Figure 1 Direction of fibres and measurement of the chicken meat samples by Volodkevich Bite Jaws

3.0 RESULTS AND DISCUSSION

The data analysis was performed with MATLAB simulation software [MATLAB – Version 7.12.0.635 (R2011a)]. PLS regression was used to predict the Volodkevich Bite Jaws's shear force in the 680 – 1000 nm spectral region. The PLS model was developed either without spectral smoothing or with spectral smoothing with either a first order Savitzky-Golay (SG) smoothing filter, SG + first derivative or SG + second derivative. The predictive accuracy of the PLS models was given by RMSEP (root mean square error of prediction) and R^2 (coefficient of determination).

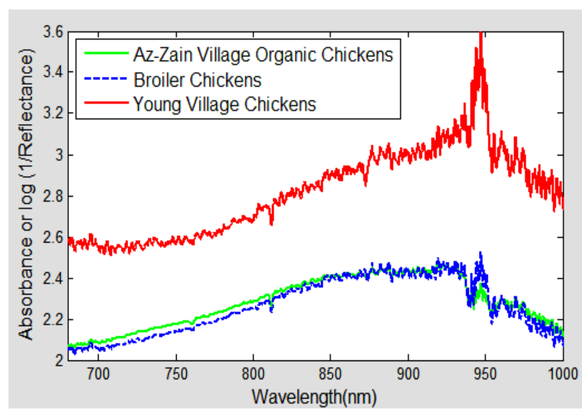


Figure 2(a) Raw absorbance spectra of raw chicken meat samples

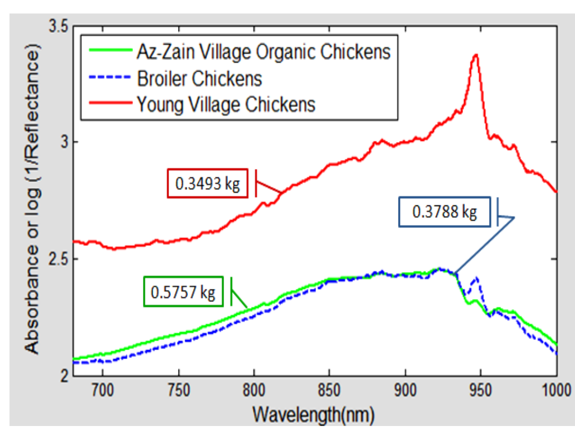


Figure 2(b) Absorbance spectra of raw chicken meat samples with SG smoothing

Figure 2(a) shows the average raw absorbance NIRS spectra of raw chicken meatsamples from three different types of chickens: Az-Zain Village Organic chicken, broiler chicken, and village chicken. The first order SG smoothing filter was applied to smooth the spectral data as shown in Figure 2(b). Then, to remove the unwanted baseline shift effects, the first order approximate derivative of the spectra was computed as illustrated in Figure 3.

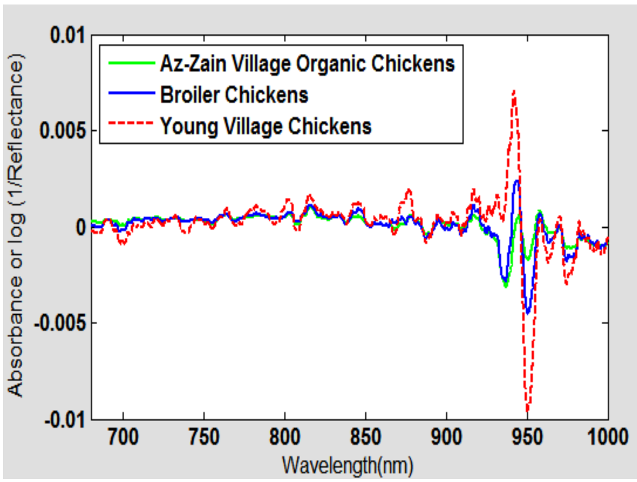


Figure 3 First order derivative absorbance spectra of chicken meat samples

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 Andre´s *et al*. (2007), the most tender meat samples showed higher absorbance in the visible region (400 – 950 nm) and lower absorbance in the NIR region (1100 – 2498 nm) [23-26]. This statement is acceptable because compared with the mean value of the Volodkevich Bite Jaws's shear force, the mean for village chickens (0.3493) is smaller than the means for broiler chickens (0.3788) and Az-Zain organic chickens (0.5757). These values could be correlated with the different ages of the chickens before slaughter and processing. The village chickens were slaughtered at the age of around 30 days, before reaching adulthood, the broiler chickens at around 40 days, and the Az-Zain organic chickens at around 60 days.

Venel *et al*. (2001) stated that the band at around 910 nm might indicate a contribution of proteins [27]. Besides, it has also 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 [28]. However, the moisture content of the samples was not monitored in this study.

Based on the absorbance spectra, log (1/R), SG smoothing, and first and second derivatives, PLS regression models for predicting the tenderness measured by Volodkevich Bite Jaws's shear force were developed. The range of wavelengths was from 680 to 1000 nm.

From Table 1, the prediction accuracy (R^2) for the Az-Zain village organic chickens is highest for the first and second derivatives compared to the broiler and village chickens. The high prediction accuracy and low absorbance spectra of Az-Zain village organic chicken compared to broiler and village chickens could be correlated with the feed composition of the chicken diets. The Az-Zain village organic chickens were fed with organic foods consistings of corn and herbs rich in anti-oxidant and anti-cancer agents [29]. *Habbatus Saudas* or black seed is also added to the chicken food as an antibiotic [29]. Meanwhile, the broiler and the village chickens were fed with cheap corn, soy and cotton seed meal with many additives mixed in. The additives included growth hormones [30], meat and bone meal, antibiotics and chemicals 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 Tables 2 to 4, respectively.

Table 1 Prediction of Volodkevich Bite Jaws Texture Analyser by NIRS

Chicken Meat Sample	Mean ± Standard Deviation	No. of Samples	Spectral Treat-ment	PLS Compo-nents	R^2	Root Mean Square Error
	0.3788 ±	21	NONE	3	0.1711	0.1840
Broiler	0.2071		SG	3	0.1637	0.1848
			SG + first	3	0.4273	0.1529
			SG + second	2	0.4389	0.1514
	0.5757 ±	15	NONE	2	0.1102	0.3698
Az-Zain Organic	0.4058		SG	2	0.1056	0.3708
			SG + first	4	0.8552	0.1492
			SG + second	4	0.9517	0.0861
	0.3494 ±	20	NONE	3	0.0664	0.2593
Village	0.2753		SG	3	0.0384	0.2631
			SG + first	3	0.4214	0.2041
			SG + second	3	0.6830	0.1511

Table 2 Composition of diet fed to broiler chickens

Composition
Crude protein
Crude fibre
Crude fat
Moisture
Calcium
Phosphorus

Table 3 Composition of diet fed to village chickens

Composition
Crude protein
Crude fat
Crude fibre
Moisture
Calcium
Phosphorus

Table 4 Composition of diet fed to 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

4.0 CONCLUSIONS

The PLS analysis shows that the prediction accuracy is higher for the Az-Zain village organic chickens (85 – 95%) than for the village chickens (42 – 68%) and broiler chickens (42 – 44%). The high prediction accuracy and low absorbance spectra of Az-Zain village organic chicken compared to broiler and village chickens could be correlated with the food composition of the chicken meals. Therefore, it can be concluded that the food composition of chicken meal affects the accuracy of prediction of tenderness of raw chicken using NIRS.

Acknowledgement

This work was financed by a MyPhd Scholarship from Ministry of Higher Education of Malaysia (MOHE) and Exploratory Research Grant Scheme with Vote No. 4L606 from Universiti Teknologi Malaysia (UTM).

References

[1] Grau, R., Sánchez, A. J., Girón, J., Iborra, E., Fuentes, A. & Barat, J. M. 2011. Nondestructive Assessment Of Freshness In Packaged Sliced Chicken Breasts using SW-NIR Spectroscopy. *Food Research International.* 44: 331–337.

[2] Ruiz de Huidobro, F., Miguel, E., Bla´zquez, B. & Onega, E. 2005. *A* Comparison Between Two Methods (Warner–Bratzler and Texture Profile Analysis) for Testing Either Raw Meat or Cooked Meat. *Meat Science*. 69: 527–536.

[3] Byrne, C. E., Downey, G., Troy, D. J. & Buckley, D. J. 1998. Non-Destructive Prediction of Selected Quality Attributes of Beef by Near-Infrared Reflectance Spectroscopy Between 750 and 1098 nm. *Meat Science*. 46: 399–409.

[4] Meullenet, J.-F., Jonville, E., Grezes, D. & Owens C. M. 2004. Prediction of the Texture of Cooked Poultry Pectroralis Major Muscle by Near-Infrared Reflectance Analysis Of Raw Meat. *Journal of Texture Studies.* 35: 573–585.

[5] Rahim, H. A., & Ghazali, R., 2012. The Application of Near-Infrared Spectroscopy for Poultry Meat Grading, In Signal Processing and Its Applications (CSPA), 2012 IEEE 8th International Colloqium. Malacca, Malaysia. 58–62.

[6] Shiranita, K., Miyajima, T. & Takiyama, R. 1998. Determination of Meat Quality by Texture Analysis. *Pattern Recognition Letters*. 19: 1319–1324.

[7] Cavitt, L. C. Youm, G. W. Meullenet, J. F. Owens, C. M. & Xiong, R. 2004. Prediction of poultry meat tenderness using Razor Blade Shear, Allo-Kramer Shear and Sarcomere Length. *Journal of Food Science.* 69: 11–15.

[8] Liu, Y., Lyon, B.G, Windham, W.R., Realini, C.E., Pringle, T.D.D. & Duckett, S. 2003. Prediction of Color, Texture, and Sensory Characteristics of Beef Steaks by Visible and Near Infrared Reflectance Spectroscopy. A Feasibility Study. *Meat Science*. 65: 1107–1115.

[9] Wheeler, T. L., Shackelford, S. D., Johnson, L. P. Miller, M. F. Miller, R. K. & Koohmaraie, M. 1997. A Comparison of Warner-Bratzler Shear Force Assessment Within and Among Institutions. *Journal of Animal Science.* 75: 2423–2432.

[10] Yancey, J. W. S., Apple, J. K., Meullenet, J.-F. & Sawyer, J. T. 2010. Consumer Responses for Tenderness and Overall Impression Can Be Predicted by Visible and Near-Infrared Spectroscopy, Meullenet–Owens Razor Shear, and Warner–Bratzler Shear Force. *Meat Science*. 85: 487–492.

[11] Morse, B.Solomon, J. S. E., Ernie, W. Paroczay & Brian, C. B. *Chapter 27: Measuring Meat Texture*, in *Handbook of Muscle Foods Analysis*. F. T. Leo M. L.Nollet, Editor. 2008. CRC Press. 479–502.

[12] Meullenet, J.-F., Jonville, E., Grezes, D. & Owens, C.M., *Prediction of the texture of cooked poultry pectoralis major muscles by near-infrared reflectance analysis of raw meat*. Journal of Texture Studies, 2004. 35: p. 573-585.

[13] Chandraratne, M.R., Samarasinghe, S., Kulasiri, D. & Bickerstaffe, R. , *Prediction of lamb tenderness using image surface texture features.* Journal of Food Engineering, 2006. 77: p. 492-499.

[14] Rey, J.F., Martínez, C.L. & Urrea, A. . *Evaluation of sensory characteristics and texture of an economic Buffalo meat (Bubalus bubalis) sausage and an economic beef (Bos indicus) sausage with addition of bovine hemoglobin powder*. in *11th International Congress on Engineering and Food (ICEF11)*. 2011. Athens, Greece.

[15] Lambe, N.R., Navajas, E.A., Bünger, L., Fisher, A.V., Roehe, R. & Simm, G., *Prediction of lamb carcass composition and meat quality using combinations of post-mortem measurements.* Meat Science, 2009. 81: p. 711-719.

[16] Engineering, B. *Brookfield Viscometers, Rheometers and Texture Analyzers for viscosity measurement and control and texture analysis*. . 2012 [cited 2012 27 Nov]; Available from: http://www.brookfieldengineering.com/products/accessories/texture-food.asp.

[17] FTC. *Food texture testing, tenderometer, food texture profile analyzers and consistometer*. 2012 [cited 2012 27 NOV]; Available from: http://www.foodtechcorp.com/tms-small-sample-holder.html

[18] Brosnan, T., & Sun, D.-W., *Inspection and grading of agricultural and food products by computer vision systems: A Review*. Computers and Electronics in Agriculture, 2002. 36: p. 193-213.

[19] Yancey, J.W.S., Apple, J.K., Meullenet, J.-F. & Sawyer, J.T., *Consumer responses for tenderness and overall impression can be predicted by visible and near-infrared spectroscopy, Meullenet–Owens razor shear, and Warner–Bratzler shear force.* Meat Science, 2010. 85: p. 487-492.

[20] Chia, K.S., Rahim, H.A. & Rahim, R.A., *Prediction of soluble solid contents of pineapple via non-invasive low cost visible and shortwave near infrared spectroscopy and artificial neural network.* Biosystems Engineering, 2012. 113: p. 158-165.

[21] Pla, M., Herna´ndez, P., Arin˜o, B., Ramı´rez, J.A. & Dı´az, I., *Prediction of fatty acid content in rabbit meat and discrimination between conventional and organic production by NIRS methodology.* Food Chemistry, 2007. 100: p. 165-170.

[22] Abeni, F.B., G., *Characterization of di€erent strains of broiler chicken by carcass measurements, chemical and physical parameters and NIRS on breast muscle.* Meat Science, 2001. 57: p. 133-137.

[23] Andre´s, S., Murray, I., Navajas, E.A.,Fisher, A.V., Lambe, N.R. & Bu¨nger, L., *Prediction of sensory characteristics of lamb meat samples by near infrared reflectance spectroscopy*. Meat Science, 2007. 76: p. 509-516.

[24] Hildrum, K.I., Nielsen, B. N., Mielnik, M., & Næs, T., *Prediction of sensory characteristics of beef by near-infrared spectroscopy*. Meat Science, 1994. 38: p. 67-80.

[25] Park, B., Chen, Y. R., Hruschka, W. R., Shackelford, S. D., & Koohmaraie, M., *Near infrared reflectance analysis for predicting beef longissimus tenderness*. Journal of Animal Science, 1998. 76: p. 2115-2120.

[26] Park, B., Chen, Y. R., Hruschka, W. R., Shackelford, S. D., & Koohmaraie, M., *Principal components regression of near infrared reflectance spectra for beef tenderness prediction.* Transactions of the American Society of Agricultural Engineers, 2001. 43: p. 609-615.

[27] Venel, C., Mullen, A. M., Downey, G., & Troy, D. J., *Prediction of tenderness and other quality attributes of beef by near infrared reflectance spectroscopy between 750 and 1100 nm; further studies.* Journal of Near Infrared Spectroscopy, 2001. 9: p. 185–198.

[28] Osborne, B.G., Fearn, T., & Hindle, P. H., *Practical near-infrared spectroscopy with applications in food and beverage analysis*. 2nd ed. 1993, New York: Wiley.

[29] Organik, A.K.A.-Z. *Organic Halal Chicken by Dr Mohamad Zainol*. 2010 [cited 2011 24 June]; Available from: http://ayamkampungorganik.blogspot.com/2010/02/az-zain-organic-halal-chicken-by-dr.html.

[30] Moellers, R.F., & Cogburn, L.A., *Chronic intravenous infusion of chicken growth hormone increase body fat content of young broiler chickens.* Comp. Biochem. Physiol, 1995. 110A: p. 47-56.