Effect of Grinding on Color and Chemical Composition of Pork Sausages by Near Infrared Spectrophotometric Analyses

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ABSTRACT : Near Infrared spectroscopy was applied to the samples of processed pork to see the effect of grinding on chemical components analyses. Data from conventional chemical analyses of moisture, fat, protein, NaCl were put into calibration model by NIR of reflectance mode. The other properties observed were pH and color parameters (L*, a*, b*). Spectral ranges of 400~2500 nm and 400~1100 nm were compared for color parameters. Spectral ranges of 400~2500 nm and 1100~2500 nm were compared for chemical components and pH. Different spectral ranges caused little changes in the coefficients of determination or standard errors. R^2's of calibration models for color parameters were in the range of 0.97 to 1.00. R^2's of calibration models of intact sausages for moisture, protein, fat, NaCl and pH were 0.98, 0.89, 0.95, 0.73 and 0.77, respectively using spectra at 1100~2500 nm. R^2's of calibration models of ground sausages for moisture, protein, fat, NaCl and pH were 0.97, 0.91, 0.97, 0.42 and 0.56, respectively using spectra at 1100~2500 nm. ***(Asian-Aust. J. Anim. Sci. 2001. Vol. 14, No. 6 : 858-861)***

Key Words : Near Infrared Spectroscopy, Processed Pork, Chemical Component, pH

INTRODUCTION

Near infrared (NIR) spectroscopy becomes widely used in animal production research and in animal industry due to its convenience and advantage of simultaneous analyses of many properties (Kim and Lee, 1997; Lanza, 1983; Oh, 1994). NIR analyses replace traditional chemical analyses that took many hours or days for sample preparation and analytical processes. One of the great advantages of using NIR spectroscopy is that it can analyze raw and fresh samples without chemical loss or renaturation while processing (drying, grinding etc.). Another point that makes NIR technique useful is that it may be readily applicable and therefore can be used in-line or at-line processing (Kim and Lee, 1997). Recent software development in reading NIR spectrum enhanced usage of NIR technology in many research or industrial areas in agriculture.

NIR analyses are based on spectrophotometric device and statistical solutions to transfer spectra into predicted values interested. Therefore, the output from the machine would be affected by the precision of machine and the efficiency of statistical models applied (Shenk and Westerhaus, 1991b). Factors that come from machinery are mechanical noise control, light array, linearity of the signal, selection of wavelength(s), mathematical treatment, smoothness of optical signal, electromagnetic status, temperature control, power supply or the sample cells used. Variation in the sample is related with mechanical control and statistical models. Factors affecting NIR analyses that come from sample variation are chemical composition, interrelationship among chemical components, combined effect of chemical composition and physical structure of each component, moisture content before or after grinding, density of ground sample, external factors such as ambient temperature, temperature inside the sample, storage, shape, the size and distribution of particles or the technical experience of operators (Kim, 1996).

The objective of this study was to see the effect of grinding on the evaluation of coloring parameters and chemical composition of pork sausages through NIR analyses.

MATERIALS AND METHODS

Sample preparation

Ham, loin and back fat were purchased from Mokuchon meat market and Dongbang Mart, Korea and processed at the processing unit in Dankook Univeristy, Chonan. Sausages were manufactured by the process of chopping - emulsifying - stuffing - drying - smoking - cooking cooling according to the laboratory protocol (New England sausage, unpublished) of Kansas State University. Supplements to sausage were Prague powder (salt, $NaNO_2$, Na_2CO_3), salt, sugar, vitamin C and phosphoric salt. Final batch of 10 kg contains approximately 7.5 kg pork loin, 2.5 kg ham, 1.0 kg water, 275.0 g salt, 55.0 g sugar, 17.0 g monosodium glutamate and 22.0 g Prague powder.

Half of sausage samples were ground and refrigerated at 4℃ with the other sausage samples

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intact.

NIR analyses

Samples were set still at room temperature for 30 minutes before analyses and stuffed into coarse sample cups (cubic with 4 cm×20 cm area) at thickness of 10 mm. NIR spectra of each sample were collected with reflectance mode at wavelengths in the range of 400~2500 nm. Near Infrared spectroscopy manufactured by Foss NIRSystems, Inc., MD, U.S.A. (Model No. 6500) at the National Livestock Resesarch Institute, Korea was used with WinISI II software. Modified least squares regression models were applied for calibration after data selection by the algorithm of Shenk and Westerhaus (1991a). Variables predicted were L* (lightness of meat color), a* (redness), b* (yellowness), % moisture, % crude protein, % crude fat, % NaCl and pH.

Conventional lab analyses

Color determination : A Chromameter (Model CR-200b, Minolta, Japan) was used with C light source. Hunter scale of standard white board was set at L=96.7, a=0.0 and b=2.3.

Moisture : 5 gram samples of each ground and un-ground sausage and ham were freeze-dried (Model No. MCFD5508) at -50℃ for 72 hours. Moisture content of each sample was the difference between pre and post drying.

Crude protein and crude fat (ether extract) : Crude protein and crude fat content of each sample were analyzed by A.O.A.C (1990) method with Kjeldahl and soxhlet apparatus, respectively.

NaCl : Five grams of each sample were homogenized in 50 ml distilled water for one minute at 10,000 rpm. After filtration through Whatman paper No. 6, NaCl content of samples were analyzed with Quantab analyzer (300-6000Cl, Environmental Test Systems, U.S.A.).

pH : Acidity of homogenized samples as in the preparation for NaCl were analyzed with Digital pH/ION meter (Model DP-215M).

Statistical analyses

Statistical procedures for instrumental calibration and output data summarization were performed using WinISI II (version 1.02A) program developed by Infrasoft International, LLC (FOSS NIRSystems/ TECATOR, 1999).

Modified multiple partial regression models were fit. The first derivatives of reflectance energy (log 1/R) were taken mathematically to reduce baseline offsets from variations in particle size and composition.

Multiple partial correlations between NIR measures and colorimetric measures were estimated as R^2 values from above models taken separately for each parameter. Standard errors for calibration (SEC) and for prediction (SEP) were calculated by the methods described by Park (1999).

$$SEC = \{(x_i\ y_i)^2 / (N\text{-}k)\}^{1/2}$$
$$SEP = \{(x_i\ y_i\ d)^2 / (N\text{-}1)\}^{1/2}$$

Where, x_i : predicted value of ith sample from NIR measures from regression of parameter on reflectance at each wavelength, y_i : parameter estimator of ith sample from colorimetric measure, d : bias as average deviation of predicted values from colorimetric measures (= $\sum(x_i\ y_i)$ / N), N : number of samples, k : number of parameters in the regression models.

RESULTS AND DISCUSSIONS

Color and chemical composition of the samples from NIR analyses are presented in table 1. Lightness values (L*) were not different between ground and intact samples. Redness (a*) and yellowness (b*) values of ground samples were some less and with wider range than intact samples. This might be due to redistribution of fat particles by grinding. Nitrate and NaCl affect the coloring of processed pork. However, Ellekjaer et al. (1994) showed that fat content in pork was the major source of variation in color properties of processed pork rather than NaCl content.

Moisture content of pork sausages became higher by grinding while protein and fat contents became less. Variation of moisture, protein or fat all became less by grinding. NaCl content or pH of pork, which are determined mainly by additives were invariable by grinding. Increase in moisture content would be due to extraction of intramuscular moisture. Decreased protein and fat content would be due to a dilution effect by increase in moisture because the contents on equal moisture content basis did not differ greatly. Protein content of ground pork was 19.3% when converted to moisture content of 60.9%. Decrease in the variation of two components and moisture would be due to homogenizing by grinding and remixing of pork, therefore, reducing the sampling errors for analyses.

Table 2 summarizes the results from NIR analyses for color parameters using the first derivatives of absorbed spectral energy. Both ground and intact pork sausage samples showed high coefficients of determination (R^2) for both calibration set and prediction set. There was no difference in R^2 between using whole range of wavelengths (400~2,500 nm) and using only visible range (400~1,100 nm). SEPs from prediction set were generally somewhat greater than SEC from calibration set. These values in accuracies were better than beef samples (higher R^2 and lower SEC or SEP) applied to the same NIR machine (Kang

Table 1. Color and chemical composition of intact and ground pork sausages

	Intact			Ground		
Variable	N[1]	Mean	Range	N	Mean	Range
L*	152	67.6	61.7~73.7	148	67.6	61.0~72.6
a*	152	13.1	8.4~18.1	148	11.3	5.3~18.0
b*	152	10.4	6.9~17.2	148	10.1	5.4~21.9
Moisture, %	85	60.9	36.0~87.1	86	62.6	51.8~70.3
Protein, %	85	19.7	5.4~44.1	86	18.8	14.9~29.5
Fat, %	85	18.5	5.0~27.0	86	17.7	8.6~26.8
NaCl, %	76	1.7	1.1~ 3.4	86	1.6	1.1~ 5.0
pH	84	5.5	4.7~ 5.9	86	5.4	4.7~ 6.0

[1] N: number of samples.

Table 2. Accuracy in calibration and prediction of color parameters by NIR analyses with intact and ground sausages

	Intact				Ground			
	Calibration		Prediction		Calibration		Prediction	
	R^2	SEC[#]	R^2	SEP[#]	R^2	SEC	R^2	SEP
400~2500 nm								
L*	0.98	0.49	0.96	0.64	0.99	0.38	0.93	0.75
a*	0.98	0.24	0.95	0.45	0.98	0.38	0.95	0.51
b*	0.99	0.30	0.97	0.52	0.99	0.32	0.98	0.41
400~1100nm								
L*	0.97	0.51	0.98	0.50	0.97	0.55	0.94	0.72
a*	0.98	0.26	0.96	0.42	0.97	0.42	0.96	0.47
b*	0.99	0.32	0.97	0.50	1.00	0.24	0.98	0.38

[#] SEC=standard error of calibration; SEP=standard error of prediction.

et al., 1999). This shows another possibility that NIR analyses can be used to discriminate between pork and beef. Oh (1994) mentioned that NIR absorption at C-H and HC=CH bonds might be a tool to identify beef and pork.

Slightly higher difference in SEP for L* of ground pork relative to the value of SEC when the whole spectral range was used shows possible over-fitting of calibration curve.

Table 3 is a summary of NIR analyses for chemical contents and property of processed pork. As was the analyses for color parameters, the first derivatives of energy at selected wavelengths were fit for calibration models.

Moisture and fat contents from both wavelength ranges were not affected by the physical nature of the samples, i.e. coefficients of determination and SEC or SEP were similar for both intact and ground samples. Protein contents calibration sets were similar for both physical types of samples. However, the R^2 values for protein contents of prediction sets were much lower than those for calibration sets when ground pork samples were used. For these ground samples, SEP's were about as twice as SEC's. Park (1999) stated that this might be due to possible errors in input chemical analysis data (Lanza, 1983) for protein into calibration models. Both wavelength ranges responded similarly for protein.

NaCl contents analyzed with spectra at 400~2500 nm range showed better results than those with spectra at 1100~2500 nm range only. Ground samples showed much smaller R^2 and standard errors for both calibration and prediction sets. pH of ground pork sausage samples also showed smaller R^2 's for both spectral ranges than intact sausage samples. SEC of pH for ground sausage, however, didn't change by grinding when wavelengths of 1100~2500 nm range was applied while that of 400~2500 nm range became higher by grinding sausage samples. This lower R^2's for NaCl and pH parameters would be due to increased moisture contents (table 1) in ground samples which might create interference spectra with sodium or hydrogen bonds in the pork.

Cho (1998) stated that large particles might have multiplicative scatter effects and that NIR analyses with wavelengths over 1900 nm would not fit for linear equations. The results from this study for NaCl and pH do not support his statement. This may not be

Table 3. Accuracy in calibration and prediction of chemical properties by NIR analyses with intact and ground pork sausages

	Intact				Ground			
	Calibration		Prediction		Calibration		Prediction	
	R^2	SEC#	R^2	SEP#	R^2	SEC	R^2	SEP
400~2500nm								
Moisture	0.89	0.77	0.81	1.01	0.98	0.68	0.93	1.15
Protein	0.83	0.68	0.74	0.77	0.93	0.50	0.54	1.12
Fat	0.92	0.89	0.71	1.49	0.97	0.85	0.88	1.53
NaCl	0.91	0.17	0.77	0.31	0.69	0.09	0.55	0.14
pH	0.96	0.06	0.92	0.12	0.52	0.20	0.41	0.27
1100~2500nm								
Moisture	0.98	0.30	0.76	1.21	0.97	0.79	0.92	1.13
Protein	0.89	0.56	0.68	0.88	0.91	0.57	0.57	1.13
Fat	0.95	0.67	0.60	2.09	0.97	0.89	0.90	1.44
NaCl	0.73	0.27	0.56	0.30	0.42	0.17	0.34	0.19
pH	0.77	0.16	0.85	0.17	0.56	0.18	0.42	0.28

\# SEC=standard error of calibration; SEP=standard error of prediction.

the problem of the size of sample particles. Because sausage or the other processed meat passed grinding and mixing with chemical additives by processing, another grinding or mincing would not make great difference in particle sizes. Rather, changes in chemical composition and possibly modified interactions between chemical components would be the main cause of difference in NIR reflectance. In meat, moisture, fat and protein are three major components. Kim and Lee (1997) showed that as the time for grinding meat increased, water and fat contents were affected the most by increase in absorbed energy. However, our study showed that there was little difference between intact sausage and ground sausage by NIR analyses with only slight increase in moisture and slight less protein and fat contents in ground samples than in intact sausages. V

In general, NIR analyses were found to be an exact and effective alternative to conventional chemical analyses of processed pork sausages. Moreover, NIR approach could be used for analyses of minor components such as sodium chloride.

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