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Spectroscopic approach to beef tenderness and aging time evaluation (#21)

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Introduction

Consumers and industry are interested on technologies able to show *in situ* the meat tenderness or aging time of meat, and with which to verify that products that are labelled as 'aged' are genuine. Recently, low-cost NIR devices connected to smartphones specially designed for consumers are available in the market, showing promising result to predict several quality attributes. New X-ray multi energy sensors also showed the capacity to monitor meat aging during chilling-vacuum packaging of beef samples. The aim of this study was to evaluate the feasibility of a high performance and a portable low-cost NIR system and an X-ray multi energy sensor to predict aging time and Warner-Bratzler shear force (WBSF) in beef loin.

Methods

Samples: Twenty-four beef loins from Holstein young steers were vacuum packed and submitted to 5, 19, 40, 54, 67, 76, 84, 91, 98, 105, 112 or 119 days of tenderization at 4ºC. After each tenderization period, loins were further used for spectrometric and tenderness analysis.

Spectrometric acquisition systems: *High performance NIR device*: Spectra were recorded on a Fourier Transform NIR spectrometer model Matrix-F duplex (Bruker Optik GmbH, Germany). NIR reflectance spectra were collected over the 12,000–4000 cm−1 spectral region (830–2500 nm) using an on-contact probe. *Low-cost NIR device:* The SCiO handheld smartphone-based NIR spectrometer (Consumer Physics, Israel) was used. A reflection spectra in a range between 740 nm and 1070 nm were collected. *X-ray multi energy device*: An industrial X-ray prototype system with a multi energy detector (MXV-PACK 4010, Multiscan Technologies, Spain) was used to acquire a spectroscopic image (1000 x 256 pixels) of the sample with each pixel containing an X-ray energy spectra of 128 channels (recording energies from 20 to 160 keV).

Tenderness determination: Tenderness was determined using Warner–Bratzler shear force (WBSF) using a TAXT2i Texture Analyser.

Construction and cross-validation of predictive models: All spectra were pre-processed and multivariate calibration models constructed using PLS Toolbox, version 8.1.1 (Eigenvector Research, Inc., Wenatchee, WA, USA). Calibration models were developed by using Partial Least Squares (PLS) regression for aging time and share force in beef. Validations were made by a cross validation. Interval variable selection was applied to discard variables which may be adding complexity to a model and improve performance of a final model.

Results

There is a significant correlation (r=0.58) between aging time and WBSF. Mean WBSF was 28.17±11.68 N with a minimum and a maximum of 12.37 N and 54.20 N achieved from 5 to 119 days of tenderization.

The results of calibration and cross-validation for prediction of aging time and WBSF using three studied spectrometric systems are summarized in Table 1. Low-cost NIR system presented a lower ability than high performance NIR systems to predict both aging time and share force, showing RPD values of 1.7 and 1.4, respectively. Lower predictive abilities for WBSF could be in part explained by the fact that instrumental texture procedure can lead to a higher variability of the reference results. Figure 1a and b shows the relationship between the predicted and the measured days of tenderization and WBSF for the cross-validation data set. It must be remarked that high performance and low cost NIR systems uses different spectral regions to develop the aging time and WBSF predictive models. The higher accuracy for high performance NIR device compared with the low cost NIR device for WBSF determination could be related with the fact that the wavelength range used by low cost NIR device is not the adequate for this type of determination.

In the case of X-ray multi energy spectra, a similar predictive capacity for aging time to low-cost NIR device was obtained, showing a R^2_{cv} of 0.72, a $RMSE_{CV}$ of 18.7 days and a RPD value of 1.9, using only a mean center correction for the pre-processing of all the acquired spectra (Table 1). The most relevant spectral interval appears to be from 20 to 41 keV but the use of only this interval do not suppose an improvement of the predictive model. In the case of WBSF, predictive capacity was poor and similar to the other x-ray based technologies. However, it must be remarked that mean attenuation of X-ray multi energy spectrum decreases when increasing beef tenderness.

Conclusion

This study has demonstrated the ability of spectroscopic methods, especially high performance NIR, to provide a fast and effective method for aging and tenderness prediction. Spectrometric methods can predict beef aging time better than shear force. High performance NIR systems have a better predictive ability of aging time than low cost NIR and X-ray multi energy systems. The potential of studied spectroscopic devices in the prediction of aging time and tenderness in beef meat needs to be further investigated on a larger number of samples with different breeds and muscles included.

Acknowledgements

Notes

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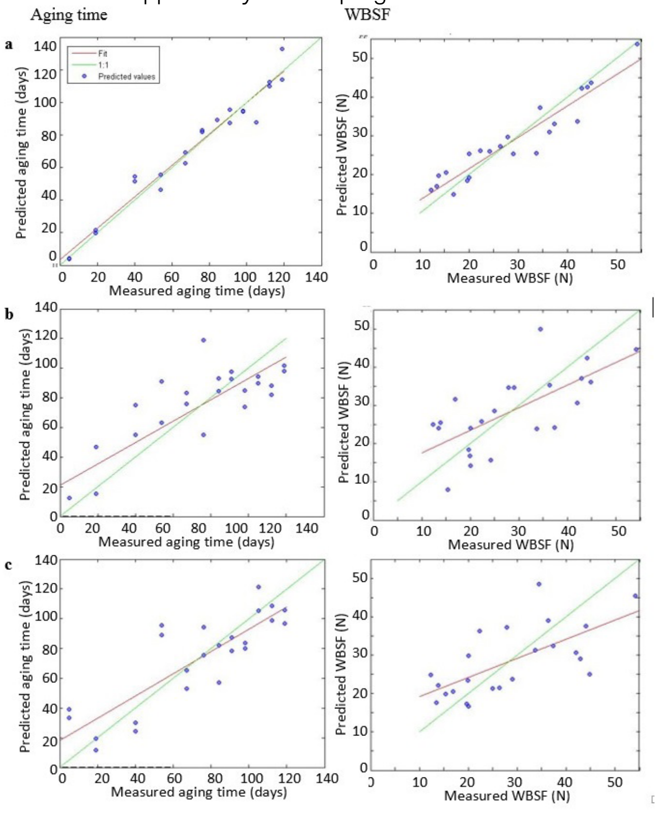

Figure 1.
Prediction plots for aging time and WBSF force using high performance NIR device (a), low-cost NIR device (b) and X-ray multi energy device (c).

Technology	Parameter	Pre-processing Wavelength or keV interval used as predictor	n	PLS factors	RMSE $_c$	R^2_c	RMSE $_{CV}$	R^2_{cv}	RPD
Matrix-F duplex FT-NIR	Aging time (days)	Mean center + First derivative 1134-1146 nm, 1356-1411 nm, 2282-2332 nm	24	5	4.8	0.98	7.1	0.96	5.0
	WBSF (N)	Mean center + First derivative 974-983 nm, 1075-1086 nm, 1122-1134 nm, 1258-1273 nm, 1339-1356 nm, 1661-1687 nm	24	5	2.3	0.96	4.0	0.89	2.9
NIR SCiO	Aging time (days)	First derivative 820-839 nm, 860-879 nm	24	4	16.9	0.77	20.7	0.66	1.7
	WBSF (N)	First derivative 740-1070.0 nm	24	4	6.0	0.73	8.4	0.48	1.4
X-ray Multi energy	Aging time (days)	Mean center 20-140 keV	24	4	14.8	0.82	18.7	0.72	1.9
	WBSF (N)	Mean center 20-140 keV	24	4	6.1	0.72	8.9	0.43	1.3

Table 1 Results of PLSR analysis for prediction of aging time and WBSF using the different technologies.

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