BEEF TENDERNESS BY NMR: DETERMINATION IN A NON-DESTRUCTIVE WAY

Fabiane de Souza Costa[1*], Karla Rodrigues Borba[1], Daniel Martelozo Consalter[1], Giancarlo Tosin[1], João Rafael Florentino Silva[1], Cristina Consalter[1], Silvia de Azevedo[1]

[1] Fine Instrument Technology, São Carlos, Brazil.

*Corresponding author email: fabianedesouzacosta@gmail.com

I. INTRODUCTION

Tenderness is one of the most desired requirements by producers, consumers, and the meat industry, and this has become more evident every day with the year-over-year increase in supply and demand for meat from *Bos taurus* breeds and/or crosses with *Bos indicus* cattle predominant in Brazil.
The beef industry requires methods for analyzing the quality of this product that are non-destructive and work in real time, in order to improve production efficiently and still meet consumer expectations [1]. The most common methods for evaluating meat tenderness are mechanical, destructive and time-consuming, such as the Warner-Bratzler Shear Force (WBSF) and the Slice Shear Force techniques, or even sensory evaluation.
Nuclear magnetic resonance (NMR) is a non-invasive, fast and accurate method and has been used to analyze meat quality [2]–[4]. Therefore, the objective of this study was to develop a piece of equipment (Figure 1a) and an NMR method capable of quickly and non-destructively determining the tenderness of packaged meat.

II. MATERIALS AND METHODS

Low-field NMR equipment capable of analyzing meat samples with maximum cross-sectional dimensions of 70 mm x 170 mm was developed. NMR signals were collected in duplicate from 750 samples of the *longissimus* muscle with a thickness of 2.5cm for the development of the equipment software and the NMR analysis method. These signals were correlated, using chemometrics, with the WBSF values [5] of the same samples. Afterwards, another 100 *longissimus* muscle samples were analyzed in duplicate and a PLS (Partial Least Squares) model was developed to predict meat tenderness based on NMR signals. The sample set was divided into a calibration and external validation set in proportions of 80 and 20%, respectively. The calibration was done with leave-one-out cross validation.

III. RESULTS AND DISCUSSION

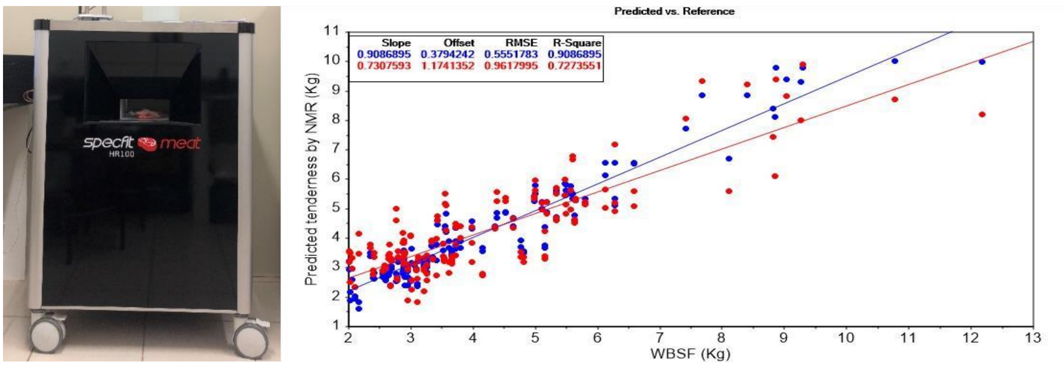

Figure 1. **a:** NMR equipment developed; **b:** PLS correlation plot using NMR signals and WBSF (blue points: calibration; red points: cross-validation).

The tenderness values predicted by NMR and determined by WBSF, as well as the parameters for evaluating the performance of the PLS model (errors and coefficients of determination, R^2) are presented in figure 1. Models with R^2 values above 0.70 show high correlation between techniques (Figure 1b), in addition, we believe that the average error is within an acceptable limit for the industry. In the external validation stage (Table 1), the tenderness results obtained by the PLS model were close to those determined by WBSF. Tenderness determination in a non-destructive way brings great benefits to the beef industry and consumers, as it makes it possible to market and sell the product with tenderness information on the packaging.

Table 1 – Meat tenderness results as predicted by NMR technique and determined through WBSF testing.

Sample	Predict RMN	WBSF	Standard deviation	Sample	Predict RMN	WBSF	Standard deviation
1	3.74	3.34	0.20	21	2.99	2.89	0.05
2	3.71	3.34	0.18	22	3.49	2.89	0.30
3	3.63	3.72	0.05	23	3.54	3.66	0.06
4	3.88	3.72	0.08	24	3.57	3.66	0.05
5	2.96	2.06	0.45	25	3.00	3.26	0.13
6	2.59	2.06	0.26	26	2.84	3.26	0.21
7	2.39	2.68	0.15	27	3.79	3.53	0.13
8	2.39	2.68	0.15	28	3.57	3.53	0.02
9	3.43	3.66	0.11	29	3.34	3.35	0.01
10	3.40	3.66	0.13	30	3.32	3.35	0.02
11	3.02	2.89	0.06	31	3.28	3.26	0.01
12	3.02	2.89	0.06	32	2.67	2.78	0.06
13	3.58	2.89	0.34	33	2.56	2.78	0.11
14	3.27	2.89	0.19	34	3.18	3.26	0.04
15	3.25	3.22	0.02	35	3.66	4.16	0.25
16	3.07	3.22	0.08	36	3.56	4.16	0.30
17	2.87	2.95	0.04	37	3.48	2.36	0.56
18	3.07	2.95	0.06	38	3.39	2.36	0.51
19	3.31	2.80	0.25	39	2.78	2.55	0.11
20	3.18	2.80	0.19	40	2.68	2.55	0.06

IV. CONCLUSION

The results prove the viability of using the developed equipment in a non-destructive way to predict beef tenderness, using a developed method of NMR that shows high correlation and low average error.

ACKNOWLEDGEMENTS

The authors are thankful to the Sao Paulo Research Foundation (FAPESP) for providing financial support (2017/15336-5 and 2021/15223-1).

REFERENCES

1. J. M. . Balage, J. M. . Amigo, D. S. . Antonelo, M. R. . Mazon, and S. L. . Silva, “Shear force analysis by core location in Longissimus steaks from Nellore cattle using hyperspectral images – A feasibility study,” *Meat Sci.*, vol. 143, no. April, pp. 30–38, 2018.
2. T. Antequera, D. Caballero, S. Grassi, B. Uttaro, and T. Perez-Palacios, “Evaluation of fresh meat quality by Hyperspectral Imaging (HSI), Nuclear Magnetic Resonance (NMR) and Magnetic Resonance Imaging (MRI): A review,” *Meat Sci.*, vol. 172, no. October 2020, 2021.
3. N. R. B. Cônsolo *et al.*, “Preliminary study on the characterization of Longissimus lumborum dark cutting meat in Angus × Nellore crossbreed cattle using NMR-based metabolomics,” *Meat Sci.*, vol. 172, no. October 2020, 2021.
4. V. Pereira, F, M, S. B. Pflanzer Junior, T. Gomig, L. Gomes, C, P. E. De Felıcio, and L. A. Colnago, “Fast determination of beef quality parameters with time-domain nuclear magnetic resonance spectroscopy and chemometrics,” *Talanta*, pp. 88–91, 2013.
5. AMSA, *Research guidelines for cookery, sensory evaluation and tenderness measurements of fresh meat*, 2nd ed. Champaign, Illinois USA: American Meat Science Association. 205p., 2005.