PRELIMINARY EVALUATION OF DUAL ENERGY X-RAY ABSORPTIOMETRY TO ASSESS INTRAMUSCULAR FAT FROM THE *Longissimus thoracis* MUSCLE OF BEEF

Ó. López-Campos[1,2*], I. Larsen[1], N. Prieto[1], M. Juárez[1] and J. L. Aalhus[1]

[1]Lacombe Research Centre, Agriculture and Agri-Food Canada, 6000 C&E Trail, Lacombe, Alberta, Canada T4L 1W1

[2]Livestock Gentec, Edmonton AB Canada T6G 2C8

Abstract – The objective of this study was to test the potential of dual energy X-ray absorptiometry (DEXA) to estimate the proportion of intramuscular fat (IMF) and the marbling score in *Longissimus thoracis* (LT) sections from cattle. A total of 30 LT sections from steer carcasses were collected, assessed for marbling at both the Canadian (12-13th rib) and Japanese (6-7th rib) grade sites, and scanned using a Lunar iDXA unit. For scanning, the LT sections were trimmed of all subcutaneous fat and peripheral muscles and scanned with and without epymisium. The LT without epymisium was ground, again scanned and analyzed for chemical IMF content. Pearson correlation coefficients were low among DEXA fat estimations, IMF, and marbling scores at the 12-13th and 6-7th rib locations. However, a remarkable increase in these coefficients was observed when comparing IMF and marbling at the 12-13th rib with the DEXA fat estimations of the completely denuded or completely denuded and ground LT. Coefficient of determination increased and root mean square error was lower when the DEXA estimations from the completely denuded and completely denuded ground LT were included in the regression. The results show that DEXA technology may be a useful technique for objective estimations of IMF content.

Key Words – DEXA, Intramuscular fat, Marbling

I. INTRODUCTION

One of the most important criteria for evaluating beef quality is the amount of chemically extractable intramuscular fat (**IMF**), also known as marbling. Grading systems use visual assessments as the preferred method for evaluating the marbling [1,2]. However, the correlation between visual marbling scores and IMF percentage is variable [3]. Additionally, there is a lack of standardization in assessment procedures and marbling grades among grading systems. For instance, in North America graders evaluate the amount of marbling fat in the rib eye muscle after the carcass has been ribbed between the 12th and the 13th rib cross-section whereas in the Japanese Beef Grading System the evaluation site is located between the 6th and 7th rib cross-section.

Objective methods are needed to quantify the degree of marbling since is one of the primary determinations of quality grade. In this sense, there have been several attempts to develop objective technologies for marbling evaluation [3]. Over the last few years there has been a trend to implement image analysis at the grading stand of the slaughter plants to increase the speed and objectivity of grading. However, there are some concerns about these technologies regarding their consistency, accuracy or, in some cases, the time required for the assessment.

Dual energy X-ray absorptiometry (**DEXA**) is an alternative technique that has been successfully used to measure body composition in humans [4]. This technique has the capability of measuring bone mineral content, bone mineral density, lean tissue mass, fat tissue mass, and percentage fat. Recently there has been an increased interest in using DEXA technology because of its low cost, speed of data collection, reliability and ease of use, compared with other technologies such as computer tomography. DEXA holds promise as an indirect method of estimation of the composition of the carcasses. However, only a few evaluations have been conducted in poultry, pigs, sheep, and calves [5] and on the use of DEXA to predict carcass composition of market age beef [6,7].

Therefore, the objective of this study was to evaluate the precision and accuracy of the DEXA technology for estimating IMF content and the

degree of marbling in the *Longissimus thoracis* (**LT**) muscle.

II. MATERIALS AND METHODS

A total of 30 *Longissimus* muscles were collected from the left sides of steer carcasses that had been assessed for marbling by two Canadian Beef Grading Agency certified graders. To assess marbling, following 24 h of chilling at 2 ºC, the carcasses were knife-ribbed at the Canadian beef grade site between the 12th and 13th ribs. Following a 20 min period of exposure to atmospheric oxygen, marbling was subjectively assessed using USDA beef marbling pictorial standards as reference points [2]. After the Canadian marbling assessment, the LT sections were removed from each carcass and trimmed of all subcutaneous fat and peripheral muscles but keeping the epymisium (silverskin). These partially trimmed LT sections were scanned with a Lunar iDXA unit (GE Lunar Prodigy Advance, General Electric, Madison, WI, USA) to estimate DEXA fat (% wet rib section weight) percentage. Following DEXA scanning, beef marbling was assessed at the Japanese beef grade site, between the 6th and 7th ribs cross-section using the same USDA beef marbling pictorial standards as reference points. Then, twelve LT sections were completely trimmed of all the epimysium and re-scanned with the same iDXA unit. Finally, each LT section was completely trimmed and ground three times (Butcher Boy Meat Grinder Model TCA22 with a 1/8-inch grind plate; Lasar Manufacturing Co., Los Angeles, CA, USA). The resulting ground samples were again scanned using the iDXA machine. Samples from each ground LT section were collected and used to determine crude fat content [8] by petroleum ether extraction (Foss SoxtecTM System Model 2050; Foss Analytical AB, Hoganas, Sweden).

Statistical Analysis

All statistical analyses were performed using SAS 9.3 [9]. The PROC CORR and PROC REG were used to evaluate the relationship of the variables. Single and stepwise regression model procedures were used to analyze the data. The accuracy of prediction was evaluated in terms of coefficient of determination (R^2) and root mean square error (√MSE). For stepwise regression, a significance level of $P<0.05$ for entry and retention of the variables within the equations was applied.

III. RESULTS AND DISCUSSION

Table 1 shows the mean and range of the IMF measurements and USDA marbling scores assessments between the 12th and 13th ribs and between 6th and 7th ribs for the LT sections used in the present study. The values of IMF content and USDA scores found in this study are in the range of those reported in the literature [10]. The mean value of the rib fat percentage estimated by DEXA technology in this study when the subcutaneous fat was removed previously to the scans (15.2 ± 4.65%) was lower than that shown by Ribeiro et al. [7] using DEXA technology in non-dissected beef rib sections from 9th to 11th (34.2 ± 8.99%).

Table 1. Descriptive statistics for chemical intramuscular fat, fat estimated by DEXA technology and USDA marbling scores between the 12th and 13th ribs and between 6th and 7th ribs for *Longissimus thoracis* sections.

Variable	n	Mean	Minimun	Maximun
IMF[a] (%)	30	3.6 ± 1.12	1.68	5.37
DEXAfat[b] (%)	30	15.2 ± 4.65	4.52	24.47
USDA[c] 12-13[d]	30	396 ± 50.0	290	470
USDA 6-7[e]	30	388 ± 48.8	280	490

[a]IMF: intramuscular fat.
[b]DEXAfat part: DEXA rib fat partially denuded.
[c]USDA Small = 400.
[d]USDA 12-13: USDA marbling scores between the 12th and 13th ribs.
[e]USDA 6-7: USDA marbling scores between 6th and 7th ribs.

Pearson correlation coefficients between DEXA estimations and intramuscular fat measurements and USDA marbling scores are shown in Table 2. In general, Pearson correlation coefficients showed low relationships among variables in all cases. Percentage of IMF and DEXA fat estimations for the completely denuded LT showed the highest correlation (r = 0.43). Despite the weak relationships between the different parameters, an interesting finding was the remarkable increase in the correlation coefficients when comparing IMF and marbling scores at the 12th -13th rib with the DEXA fat estimations of the LT on completely denuded or completely denuded and ground. When DEXA fat values were obtained from LT partially denuded (with the epymisium)

estimations of the fat percentage were clearly overestimated, while the DEXA fat estimations were closer to the IMF values when scanning samples of completely denuded LT (data not shown). Removing the epymisum tissue from the LT probably improved the accuracy of the DEXA technology scans and, hence, the correlations.

Ribeiro et al. [7] suggested that the inclusion of marbling fat in addition to the physically separated fat from the 9th to 11th rib section might increase the accuracy of the DEXA fat percentage. These authors concluded that DEXA technology has the potential to estimate physically separable and chemical fat and lean content of the 9th to 11th beef rib, which is used to estimate carcass tissue composition. Another study [11] using Merino sheep with body weight ranging from 44 to 81 kg reported that DEXA explained 90 and 86% of the variation in chemical lean and fat, respectively.

Table 2. Correlations between dual-energy x-ray absorptiometry values and intramuscular fat measurements, USDA marbling scores between the 12th and 13th ribs and between 6th and 7th ribs for *Longissimus thoracis* sections.

Variable	n	r[a]	*P*
Longissimus thoracis partially denuded			
IMF (%)[b]	30	-015	0.442
USDA 12-13[c]	30	0.08	0.694
USDA 6-7[d]	30	-0.01	0.956
Longissimus thoracis completely denuded			
IMF (%)	12	0.43	0.167
USDA 12-13	12	0.37	0.238
USDA 6-7	12	-0.03	0.934
Longissimus thoracis completely denuded and ground			
IMF (%)	12	0.41	0.185
USDA 12-13	12	0.38	0.224
USDA 6-7	12	-0.06	0.857

[a]r**:** Pearson coefficient correlation.
[b]IMF: intramuscular fat.
[c]USDA 12-13: USDA marbling scores between the 12th and 13th ribs.
[d]USDA 6-7: USDA marbling scores between 6th and 7th ribs.

In the literature, several studies reported accurate predictions for fat using different technologies such as X-ray computer tomography [12] or nuclear magnetic resonance [13]. However, because of the low radiation and the faster scans, the DEXA technology is considered as the method of choice for carcass performance assessments. Previous studies in sheep and pigs showed promising results using DEXA to estimate chemically determined fat percentages [11,14].

The R^2 and √MSE obtained in the regression models are shown in Table 3. In concordance with the previous observations in the Pearson correlation coefficients, the relationship between the DEXA fat values and the percentage of chemical IMF and USDA marbling scores increased when the regression models included the DEXA fat estimations from the completely denuded and completely denuded ground LT (see Table 3). The DEXA predictions for the percentage of IMF were not strongly related to the percentage of IMF determined by Soxtec ($R^2<0.1$) when only the DEXA fat values of the partially denuded LT section were included in the model. However, when the DEXA fat estimations of the completely denuded and completely denuded ground LT sections were included in the regression model, the coefficient of determination increased ($R^2 \geq 0.43$) and the √MSE was lower (see Table 3).

Table 3. Relationship between dual-energy x-ray absorptiometry values and intramuscular fat measurements, USDA marbling scores between the 12th and 13th ribs and between 6th and 7th ribs for *Longissimus thoracis* sections.

Dependent variable	Independent variables	n	R^{2a}	√MSE[b]
IMF[c] (%)	DEXAfat part[d]	30	0.0213	1.125
USDA 12-13[e]	DEXAfat part	30	0.0056	50.749
USDA 6-7[f]	DEXAfat part	30	0.0001	49.616
IMF (%)	DEXAfat[g]	12	0.4299	0.841
USDA 12-13	DEXAfat	12	0.5852	36.214
USDA 6-7	DEXAfat	12	0.4589	30.358

[a]R^2: coefficient of determination.
[b]√MSE: root mean square error.
[c]IMF: intramuscular fat.
[d]DEXAfat part: DEXA rib fat partially denuded.
[e]USDA 12-13: USDA marbling scores between the 12th and 13th ribs.
[f]USDA 6-7: USDA marbling scores between 6th and 7th ribs.
[g]DEXAfat: DEXA rib fat partially denuded, completely denuded and ground.

These low relationships observed in the present study may be a result of comparing ether

extractable fat values of the fat tissue with the DEXA fat values derived from the total fat tissue mass. Suster et al. [14] pointed out that DEXA technology measurements are based on X-ray attenuation by lipid in the animal. However, although fat mass is composed mainly of lipids, this portion is not totally anhydrous and some corrections should be made. These authors also reported that chemically determined lipid was overestimated by the DEXA algorithms when the lipid component was below 2.5 kg. The lipid component of the LT used in the present study was much lower than 2.5 kg.

IV. CONCLUSION

The results from this preliminary study suggest that dual energy X-ray absorptiometry technology may have the potential to estimate beef quality traits, such as marbling. However, further studies to obtain calibration curves are needed to increase prediction accuracy for use in beef populations.

ACKNOWLEDGEMENTS

The authors gratefully acknowledge funding support from Canadian Beef Grading Agency (CBGA), Alberta Livestock and Meat Agency Ltd. (ALMA), Beef Cattle Research Council (BCRC) of Canada, Livestock Gentec University of Alberta, and the in-kind contribution of animals, facilities and people received from Agriculture and Agri-Food Canada (AAFC), Lacombe Research Centre, AB, Canada. We also wish to thank the significant technical contributions of Fran Costello, Stan Landry and Rhona Thacker. Also thanks are extended to Cletus Sehn, Ken Grimson, and their staff at the Lacombe Research Centre Beef Unit of AAFC for animal care and animal management. Special thanks are extended to Mr. Chuck Pimm and the Meat Processing staff at AAFC for animal slaughter and carcass data collection.

REFERENCES

1. Japan Meat Grading Association (1988) New Beef Carcass Grading Standards. Tokyo: Japan Meat Grading Association.
2. USDA. (1989). Official United States Standards for Grades of Beef Carcasses. Agricultural Marketing Service, U.S. Dept. of Agriculture, Washington, DC.
3. Ferguson, D. M. (2004). Objective on-line assessment of marbling: a brief review. Australian Journal of Experimental Agriculture 44: 681-685.
4. Oates, M. K., Puhl, S. & Wacker, W. K. (2006). Total body % fat Comparison of DXA with other body composition methods. Journal Bone Mineral Research 21: S117.
5. Scholz, A. M. & Mitchell, A. D. (2010). Body Composition: Indirect Measurement. Encyclopedia of Animal Science, Second Edition 1: 152 - 156.
6. Mitchell, A. D., Rosebrough, R. W. & Conway, J. M. (1997). Body composition analysis of chickens by dual energy x-ray absorptiometry. Poultry Science 76:1746-1752.
7. Ribeiro, F. R. B., Tedeschi, L. O., Rhoades, R. D., Smith, S. B., Martin, S. E. & Crouse, S. F. (2011). Evaluating the application of dual X-ray energy absorptiometry to assess dissectible and chemical fat and muscle from the 9th-to-11th rib section of beef cattle. The Professional Animal Scientist 27: 472-476.
8. AOAC (1996). Official Methods of Analysis 16th ed., Assoc. Off. Anal. Chem., Washington, DC.
9. SAS Institute Inc. (2012). What's New in SAS® 9.3. Cary, NC: SAS Institute Inc.
10. Savell, J. W., Cross, H. R. & Smith, G. C. (1986). Percentage Ether Extractable Fat and Moisture Content of Beef Longissimus Muscle as Related to USDA Marbling Score. Journal of Food Science 51: 838-839.
11. Pearce, K. L., Ferguson, M., Gardner, G., Smith, N., Greef, J. & Pethick, D. W. (2009). Dual X-ray absorptiometry accurately predicts carcass composition from live sheep and chemical composition of live and dead sheep. Meat Science 81: 285-293.
12. Prieto, N., Navajas, E. A., Richardson, R. I., Ross, D. W., Hyslop, J. J., Simm, G. & Roehe, R. (2010). Predicting beef cuts composition, fatty acids and meat quality characteristics by spiral computed tomography. Meat Science 86: 770-779.
13. Corrêa, C., Forato, L. & Colnago, L. (2009). High-throughput non-destructive nuclear magnetic resonance method to measure intramuscular fat content in beef. Analytical and Bioanalytical Chemistry 393: 1357-1360.
14. Suster, D., Leury, B. J., Ostrowska, E., Butler, K. L., Kerton, D. J., Wark, J. D. & Dunshea, F. R. (2003). Accuracy of dual energy X-ray absorptiometry (DXA), weight and P2 back fat to predict whole body and carcass composition in pigs within and across experiments. Livestock Production Science 84: 231-242.