USING DUAL ENERGY X-RAY ABSORPTIOMETRY FOR A RAPID, NON-INVASIVE CARCASS FAT AND LEAN PREDICTION IN BEEF

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Abstract – The aim was to evaluate the potential use of the DEXA technology for estimating total lean, fat and bone of beef carcasses and primal cuts. A total of 158 left carcass sides were broken down into main primal cuts. Primals were scanned with an iDXA unit and then fully dissected into fat (subcutaneous, intermuscular and body cavity), lean and bone and weighed. The highest coefficient of determination (R^2) values were observed between DEXA fat content estimation and full dissected fat content while the lowest were found between the DEXA bone content estimation and bone content obtained in the full dissection. The R^2 values between the DEXA fat content and full dissection fat content were over 0.79 (round), excluding the foreshank primal (R^2=0.19). The highest R^2 values for fat were observed for the rib (R^2=0.92), flank and loin (R^2=0.87). The R^2 values for lean predictions were slightly lower than those for fat. The highest R^2 values for lean were observed for the flank (R^2=0.87), rib and loin (R^2=0.82). Overall R^2 values for total carcass fat, lean and bone were 0.96, 0.86, and 0.52. These results suggest that DEXA technology has the potential to estimate carcass traits such as lean yield performance.

Key Words – bone, carcass cut-out, DEXA, fat, lean, yield.

I. INTRODUCTION

Body composition analysis is fundamental for the evaluation of growth in animal research and for genetic selection in animal production but also plays an important role for determining carcass market value. For instance, in the beef industry, lean meat yield, either total or saleable, is one of the main merits for determination of beef carcass value. The ongoing evolution of the cattle population, as well as improved management strategies during the last decades has led to a need to upgrade the yield algorithms on a regular basis. In addition, the diversity of the markets, the different basis of payment (such as slaughter weight, rail weight, trimmed retail cuts), the different method of defining hot carcass weight and different methods of calculating lean yield across the world have led to confusion in the industry [1]. For these reasons, there is an ongoing need to establish the relationships amongst the different yield assessments (e.g. lean yield Canadian Beef Grading *vs*. % closely trimmed retail cuts USDA) to make the appropriate conversions at the time of trade. Likewise, relationships amongst equations based on primals, sub-primals and trimmed retail cuts should be established.

Dual energy X-ray absorptiometry (DEXA) is an alternative technique that has been successfully used to measure body composition in humans [2]. This technique has the capability of measuring bone mineral content (BMC), bone mineral density (BMD), 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 [3] and on the use of DEXA to predict carcass composition of market age beef [4, 5]. The development of DEXA as a platform technology first requires calibrations and development of robust equations to attain precision and accuracy before using for routine predictions of carcass yields.

Therefore, the objective of this study was to evaluate the potential use of the DEXA technology for estimating total lean, fat and bone content of beef carcasses and main primal cuts.

II. MATERIALS AND METHODS

A total of 158 crossbreed steers finished on a common commercial diet were used to build calibration equations. All the animals were maintained and cared for according to the guidelines of the Canadian Council on Animal Care [6]. Cattle were ultrasounded monthly (using an Aloka 500V diagnostic real time ultrasound machine with a 17-cm 3.5-Mhz linear array transducer; Overseas Monitor Corporation Ltd., Richmond, BC) and steers were serially slaughtered from 300 to 800 kg of live weight and at ultrasound backfat depth end points from 2 to 20 mm.

Following splitting of the carcasses, hot carcass side weights were recorded. After conventional chilling at 2°C for 24 h, left and right carcass sides were weighed to determine cooler shrink loss. Then, both carcass sides were knife-ribbed at the Canadian grade site, between the 12th and 13th rib. After 20 min exposure to atmospheric oxygen, full blue tag Canadian grade data were assessed by a certified grader from the Canadian Beef Grading Agency. The assessment included fat thickness (fat thickness over the rib at ¼, ½ and ¾ position from the spinous process), grade fat (minimum fat thickness over the rib in 4th quadrant from the spinous process), rib-eye area (REA: in cm^2 of the *longissimus lumborum*), estimated lean yield from Canada grade [7] and marbling score was assessed subjectively using United States Department of Agriculture beef marbling pictorial standards as reference points [8]. Carcasses were fabricated following normal commercial conditions in plant or in meat laboratory facilities. Carcass break points were identified following USDA [9] Institutional Meat Purchase Specifications (IMPS) for Fresh Beef Products, Series 100. The primals collected from the left fabricated carcass side were the chuck (IMPS #113) rib (IMPS #103), brisket (IMPS #118), flank (IMPS #193, non-trimmed), foreshank (IMPS #117), loin (IMPS #172A), round (IMPS #158A) and plate (IMPS #121) primal cuts. Each primal cut was scanned with a Lunar iDXA unit (GE Lunar Prodigy Advance, General Electric, Madison, WI, USA) using the whole body scan option on the standard mode to estimate DEXA fat, lean and bone tissues. After the DEXA scanning, each left primal cut was fully dissected into subcutaneous fat, intermuscular fat, body cavity fat, lean and bone and weighed by qualified personnel.

All statistical analyses were performed using SAS 9.3 [10]. The PROC REG was 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 ($\sqrt{MSE}$). 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

The serial slaughter of the cattle from 300 to 800 kg of live weight and ultrasound backfat depths from 2 to 20 mm, resulted in beef carcasses with the characteristics described in Table 1. Carcass weight (range 208.8 - 452.8 kg), grade fat (range 2.0 - 20.0 mm), estimated lean yield (range 50.0 - 62.0 %) and REA (range 52.0 - 114.0 cm^2) values of the carcass population used in the present study were within the actual range of the Canadian beef carcass market [11].

Previous studies have reported the efficacy of DEXA technology as non-destructive method for determining body composition in pork, poultry, lambs and cattle [12, 13, 14]. Mostly, these studies established comparisons between DEXA technology estimations and body chemical compositions. In the present study, the comparisons were established between the DEXA fat, lean and bone content estimation and the content obtained through a full dissection of the beef carcasses. The relationships between the lean, fat and bone content estimated by DEXA technology and by the full dissection were proved using the coefficient of determination (R^2).

Table 1. Descriptive statistics of cattle live weight at slaughter and carcass characteristics for the population used in the present study.

Characteristic	n	Mean	SD[a]	Min	Max
Live weight, kg	158	562.4	86.35	302.0	754.0

Carcass weight, kg	158	319.8	52.89	208.8	452.8
Top, mm	158	13.6	5.22	3.0	31.0
Middle, mm	158	10.1	3.97	3.0	22.0
Bottom, mm	158	9.2	3.92	2.0	21.0
Grade fat, mm	158	8.5	3.84	2.0	20.0
Estimated lean yield, %	158	59.3	2.88	50.0	65.0
REA[b], cm^2	158	79.0	11.17	52.0	114.0

[a]SD: Standard deviation.
[b]REA: Rib eye area in cm^2 of the *longissimus lumborum.*

For each one of the primal cuts studied, the highest R^2 values were observed for the DEXA fat content and the full dissection fat content while the lowest were found for the DEXA bone content and the bone content obtained by the full dissection (Table 2). The R^2 values obtained for the DEXA fat content and full dissection fat content were all over 0.79, excluding the foreshank primal (R^2 = 0.19). The highest R^2 values were observed for the rib (R^2 = 0.92), flank (R^2 = 0.87) and loin (R^2 = 0.87) while those values were slightly lower for chuck (R^2 = 0.86), brisket (R^2 = 0.82), round (R^2 = 0.79) and plate (R^2 = 0.86). The percentage of variance explained by the model for the overall prediction of total dissectible fat content (R^2 = 0.96) was higher than those found in the primal cuts.

With regard to the lean predictions, although R^2 values were slightly lower than those for fat estimations, the percentage of variance explained by the model for the prediction of lean content were also high for the rib (R^2 = 0.82), flank (R^2 = 0.87) and loin (R^2 = 0.82). Likewise, the R^2 value found between the overall DEXA estimated content and total dissectible lean (R^2 = 0.86) was lower than that for fat (R^2 = 0.96). In practice, the full dissection of the different tissues is not 100% efficient. In this sense, the lean obtained in the full dissection process includes not only the lean *per se* but also other components such as connective tissue, intramuscular fat and small intermuscular and subcutaneous fat deposits attached, which are hard to remove in a practical full dissection. On the other hand, DEXA scans provide a measure of lean body tissue, which actually includes all other components of the soft tissue excluding fat. Both factors might have been the main reasons that lead to obtain slightly lower R^2 lean values compare with the fat correlations.

Previous studies have reported high correlations between the BMC and chemically determined ash [15]. DEXA units are designed for the clinical assessment of BMC and BMD in human bones. Therefore, the current DEXA units available in the market are not calibrated to estimate the whole bone tissue content. This could have been the main reason for the low correlations obtained in the present study between BMC and bone weights obtained both in the individual primals and total dissectible bone. Particularly poor relationships were observed in those beef primals that include big and thick long bones, such as foreshank (R^2 = 0.07) and round (R^2 = 0.29).

Table 2. Relationship $(R^2)^a$ between dual-energy x-ray absorptiometry values and the traditional carcass cut-out for lean, fat and bone of the different primal cuts (n=158).

Beef primal	Fat	Lean	Bone
Chuck	0.86	0.75	0.49
Rib	0.92	0.82	0.64
Brisket	0.82	0.68	0.45
Flank	0.87	0.87	0.31
Foreshank	0.19	0.08	0.07
Loin	0.87	0.82	0.58
Round	0.79	0.60	0.29
Plate	0.86	0.80	0.27
Overall	0.96	0.86	0.52

[a]R^2: coefficient of determination.

Currently, for the assessment of soft tissue composition, DEXA units have been calibrated against phantoms of known chemical analogue compound in terms of muscle energy absorption. These calibrations are optimized for human beings and might be implemented for specific animal populations in which tissue composition is determined chemically. The implementation of these customized phantoms for cattle populations might improve the calibrations purposes pursued in the present study.

IV. CONCLUSION

The results of the present study suggest that dual energy X-ray absorptiometry technology has the potential to estimate beef carcass traits such lean yield performance. Studies are ongoing to improve and validate calibration curves to increase the prediction accuracy for use in beef populations.

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