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Application of dual-energy x-ray absorptiometry for ovine carcass evaluation

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ABSTRACT

Twenty-four frozen ovine sides were scanned in a medical dual-energy x-ray absorptiometry (DXA) scanner, producing measures of fat, lean and bone mineral content for each side. These sides were then partially dissected into muscle, fat and bone and the whole sides chemically analysed. DXA measurements correlated well with chemical analysis for % fat ($r^2 = 0.92$, rsd = 1.2%), fat mass ($r^2 = 0.97$, rsd = 163 g) and chemical lean (protein and water, $r^2 = 0.98$, rsd = 232 g). DXA estimates of lean, fat and weight for the leg region of each side were correlated with dissected lean ($r^2 = 0.96$, rsd = 115 g), fat ($r^2 = 0.93$, rsd = 66 g) and scale weight ($r^2 = 0.99$, rsd = 92 g). DXA estimates of side and leg mass mirrored scale measurement to within measurement accuracy (~ 100 g). These results indicate that DXA may be used as a reliable method for measuring carcass composition and distribution.

Keywords: Dual energy x-ray absorptiometry; DXA; carcass composition; ovine.

INTRODUCTION

Traditionally, measurement of backfat depth, coupled with subjective assessment of eye muscle area, have been used an indication of the composition of the entire animal or carcass. Recent research has focused on a variety of technologies designed to obtain more detailed information from 'inside' the animal or carcass. A variety of techniques have been used, including ultra sound (Binnie *et al.,* 1997), computed tomography (Young *et al.*, 1996), electrical conductivity, NIR, X-ray and video imaging (Topel and Kauffman, 1988).

Dual-energy x-ray absorptiometry (DXA) evolved from a similar technique, dual-energy photon absorptiometry (DPA), and was originally developed to measure bone density in humans. More recently it has been used to measure body composition (Lukaski, 1993). Such composition measurements are based on differential attenuation of low- and high-energy x-rays (by bone, fat and other soft tissues).

This differential attenuation enables the mineralisation of bone to be determined independent of any surrounding soft tissue. The fat and lean content can also be determined from this differential attenuation at each measurement location (pixel) of a total body scan that does not overlie bone and is reported to be independent of tissue thickness (Mazess *et al.*, 1990). These features, combined with DXA's low radiation levels (0.01-0.10 mSv per scan), and its ability to detect the differential attenuation of the radiation by bone, fat and lean tissue, make DXA an attractive method of choice for measuring human body composition.

More recently, DXA scanners have been used to assess the composition of live pigs, pig carcasses, beef cuts (Mitchell *et al.,*1996, 1997) and whether lambs (Rozeboom *et al.,*1998). This study was conducted to investigate the potential of DXA for estimating ovine carcass composition. Results were compared with those obtained by dissection and chemical analysis. DXA information and dissection results were also obtained for the leg region of each ovine carcass.

MATERIALS AND METHODS

Animals and carcass composition

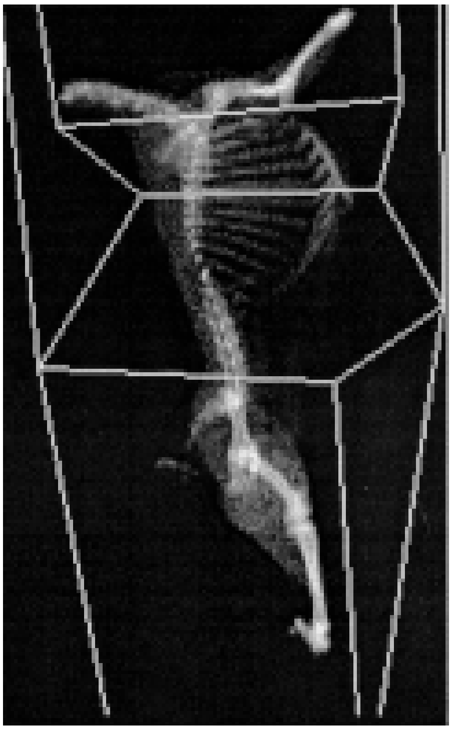
Animals used in this study were part of a larger trial. Animal breeds, slaughter and carcass analysis, are described by Kirton *et al.,* (1997). Water was determined by oven drying, ether-extract (fat) by soxhlet extraction and ash by subjecting the remaining dried material to ashing in a muffle furnace. Protein was determined by difference as the dried, fat-free, ash-free residue.

DXA measurements

DXA measurements were taken on the frozen ovine sides with a Hologic QDR 4500A X-ray Bone Densitometer (Hologic, Inc., Waltham, Massachusetts, USA), installed in 1996 at Wakefield Hospital, Wellington. A full-body scan was performed on each ovine side. In addition to the whole-body DXA information, the leg region was analysed by using the DXA scanner software to position a line immediately forward of the pelvic bone on the DXA image as shown in Figure 1[1].

DXA results have been correlated with chemical analysis/dissection results, and prediction equations for the DXA measurements generated from chemical analysis/dissection results using linear regression. The residual standard deviation (rsd) was then calculated as a measure of prediction accuracy.

Figure 1: The DXA scan of a ovine side showing lines that defined the areas analysed. DXA composition measurements of the lower central region were correlated with leg dissection data, while the total side composition was correlated with side chemical analysis.



[1]Because of an error in positioning the lines when scanning the first side, DXA leg data was obtained for only 23 of the 24 sides.

RESULTS AND DISCUSSION

Whole side measurements

Relationships with fat content

The relationship between the DXA measurements for percent fat and those produced by chemical analysis was linear for whole ovine sides (Figure 2). DXA consistently underestimated fat mass, with the mean percentage fat differing by 19%. This is consistent with findings reported in the literature (Jebb, 1995; Lukaski, 1993; Mitchell *et al.*, 1996, 1997). While some of these studies have indicated that more fat was measured at extremes of depth than at intermediate depths, no evidence of this trend was observed. This effect may have been minimised by ensuring that each side was laid cut side down on the scanner bed, as well as the relatively minimal variation in carcass thickness observed within the sides scanned.

The weight of total side fat measured by DXA was highly correlated ($r^2 = 0.97$) with that measured by chemical analysis. The high correlation for this linear relationship indicates that DXA should provide an accurate measure of total body fat for ovine carcasses (Figure 3).

Measurement of mass

Summation of the DXA measurements of total fat, lean body mass and bone mineral content yields a figure that should be equivalent to total body mass. Not only were DXA measurements highly correlated with the corresponding scale measurements for whole sides (Figure 4), but also the mean values for the two methods differed by only 2%.

Figure 2: Relationship between DXA measurement of percentage fat and that measured by chemical analysis for 24 ovine sides. The solid line represents the regression line and the dashed line the 95% prediction limits.

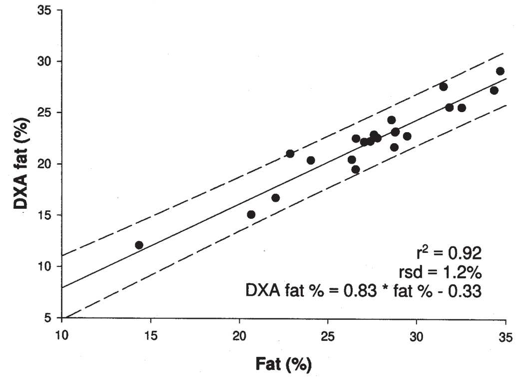


Figure 3: Relationship between DXA measurement of total side fat and that measured by chemical analysis for 24 ovine sides. The solid line represents the regression line and the dashed line the 95% prediction limits.

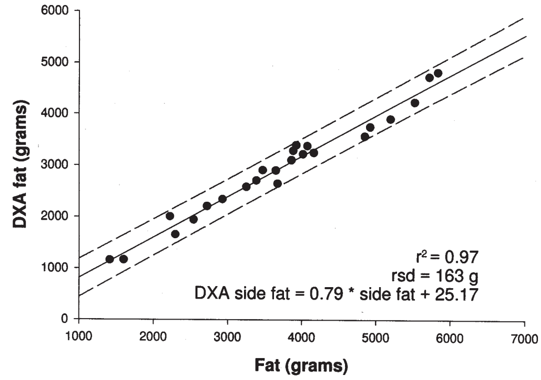
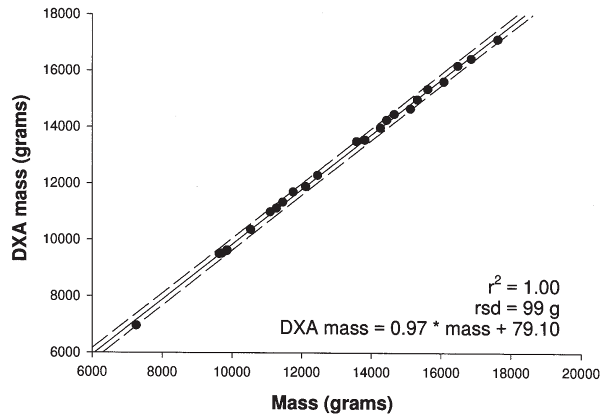


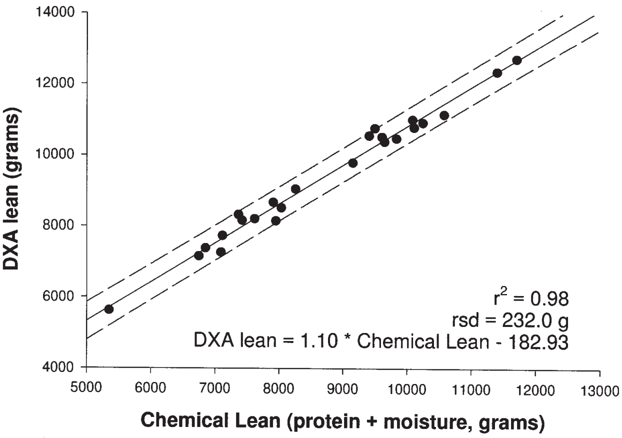
Figure 4: Relationship between DXA measurement of total tissue mass and scale measurement of side weight for 24 ovine sides. The solid line represents the regression line and the dashed line the 95% prediction limits.



Measurement of protein and water content (chemical lean)

DXA does not provide a direct measure of protein, water or muscle, reporting lean mass in terms of fat free mass less bone mineral content. However, water to protein ratios are to all intents and purposes a constant (and the two variables essentially co-linear). Since protein and water are primarily contained within lean mass, DXA lean was compared to a prediction of chemical lean based on protein and water content. This relationship was highly correlated, (Figure 5), with a residual standard deviation (rsd) of 232 g, and mean values differing by only 8 %. While it would be more meaningful to relate DXA lean mass to muscle mass, the strong correlation between DXA lean mass and chemical lean indicates the two are closely related.

Figure 5: Relationship between DXA measurement of lean tissue mass and chemical lean (protein and water) mass as measured by chemical analysis for 24 ovine sides. The solid line represents the regression line and the dashed line the 95% prediction limits.



Leg Measurements

Configuring the DXA scanner to produce measurements for the leg region for each ovine side allowed leg fat, lean and mass to be correlated with leg dissection results. These correlations mimicked those for the whole side (Table 1).

TABLE 1: Relationship between DXA measurements and dissection results of ovine legs.

	r^2	rsd	DXA prediction equation	Mean
% fat	0.83	1.6 %	0.92 * DXA leg fat % - 2.25	22.25%
% lean	0.85	1.4 %	1.04 * DXA leg lean % + 4.53	63.40%
Mass	0.99	92 g	1.02 * DXA leg mass – 63.14	4292 g
Lean	0.96	115 g	1.21 * DXA leg lean + 55.45	2714 g
Fat	0.93	66 g	0.87 * DXA leg fat – 49.16	966 g

GENERAL DISCUSSION

Medical DXA instruments of the type used in this study have been calibrated against phantoms of known fat content and which are representative of soft tissue distribution commonly seen in human subjects. Currently the computation of soft tissue composition by these instruments is optimised for human subjects and can probably be modified to more closely reflect the attributes of specific animal species, for which true body composition can be determined by chemical analysis.

In spite of this, comparison with chemical analysis indicates that DXA scans of ovine sides can be used to accurately measure the percentage and total amount of fat in the carcass. In addition, DXA values for lean body mass correlate very well chemical lean. With proper calibration, DXA may also offer a potential measurement of muscle mass.

Comparison of localised DXA measurements in the leg region with dissection results also indicates that DXA can be used to accurately determine percentage and total amount of fat, lean and mass within primal cuts. Regional analysis of DXA scans may provide important composition information for valuable wholesale cuts, allowing more detailed evaluation of carcasses prior to carcass breakdown, and a more detailed evaluation of carcass and cut yield and market value.

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