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Report Title: Initial analysis of lamb DEXA predicting GR tissue depth

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Abstract

Recently, a dual energy X-ray absorptiometry (DEXA) system has been successfully developed to measure lamb lean meat yield (LMY) with high precision and accuracy at abattoir line speed. However, the GR tissue depth (thickness of tissue over the 12th rib, 110 mm from the midline) and fat scores remain the Australian industry standard for estimating fatness in lamb carcases. To satisfy AUS-MEAT measurement requirements, DEXA must be able to predict GR tissue depth in lamb carcases within ±2 mm of the score boundary, with a maximum error of 10%. Lambs (n = 189) with a diverse range in carcase weight and fatness were slaughtered at a commercial abattoir. GR tissue depth and hot carcass weight were measured immediately post-slaughter, before the carcases were then chilled and DEXA scanned the following day. Predicting GR tissue depth using DEXA image components data (pixel number and mean negative log of low energy pixel values) along with mean DEXA values did meet AUS-MEAT requirements for 90% accuracy in fat score prediction. This means the lamb DEXA system could predict single site GR tissue depth to current commercial standards. These findings suggest processing plants could use the objective DEXA system which operates at line speed instead of the slow and subjective palpation or GR tissue measure for fat scoring carcases.

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1 Introduction

Lean meat yield (LMY) is an important trait driving profitability in the lamb industry, as carcases of the same weight can vary markedly in the amount of lean meat they contain and thereby the weight of saleable meat produced from a carcase. Current Australian industry standards for measuring lamb carcase fatness and thereby estimating LMY are via subjective palpation for fat class or measurement of tissue depth at the GR site (Anonymous, 2005). The GR site is located 110mm from the midline of the carcase along the lateral surface of the 12th rib on either side of the carcase. There are 5 fat classes in lamb, each fat score being associated with visual and palpated characteristics and with a range in GR tissue depth (mm). Fat Score (FS) 1 is equivalent to 0–5 mm GR tissue depth, FS 2 is > 5 up to 10 mm, FS 3 is >10 up to 15 mm, FS 4 is >15 up to 20 mm and FS 5 is >20 mm. However, measuring GR tissue depth using the GR knife is a slow technique (often unable to keep up with industry chain speeds of 15 lambs per minute) (Fowler et al., 2020), requires a human operator and is prone to operator error, particularly when grading hot carcases before the fat has set (Pearce, 2016).

In recent years a novel dual energy X-ray absorptiometry (DEXA) system has been successfully developed to measure lamb LMY with high precision and accuracy at abattoir line speed. The DEXA system has been trained on computed tomography (CT) measures of LMY, as the gold standard method capable of providing a complete 3D dissection of lamb carcases into lean, fat and bone. While the DEXA system is capable of providing a more objective, repeatable, precise and accurate prediction of lamb carcase LMY commercially (Gardner et al., 2018), GR tissue depth and fat score remain the industry standard for estimating fatness in lamb carcases. Therefore, commercial plants with DEXA systems still require an operator employed to measure fat score or GR tissue depth on all lamb carcases to meet AUS-MEAT grading standards. However, if DEXA systems can be demonstrated to meet AUS-MEAT standards for measurement of GR tissue depth then they could be approved as a GR measurement device and save processing plants the need for manual GR or fat score measurement when a DEXA system is in use. The object of this work was to assess the ability of lamb DEXA LMY estimates to accurately, repeatably and reliably predict hot GR tissue depth for future AUS-MEAT accreditation of DEXA fat measurement in sheep abattoirs.

2 Materials and methods

2.1 Lamb selection and data collection

Genetically diverse lambs (n = 189) were selected from the MLA Resource Flock to represent a wide phenotypic range in carcase weight and fatness for this study. The lambs were a mixture of sexes and a combination of Maternal (n = 30), Merino (n = 72) and Terminal (n = 87) sired lambs. The lambs were slaughtered at a commercial abattoir where an AUS-MEAT accredited employee measured GR tissue depth on hot carcases using a GR knife. All carcases were dressed to a hot standard carcase before weighing for hot standard carcase weight (HSCW), chilling overnight and DEXA scanning at abattoir line speed the following day.

2.2 AUS-MEAT GR measurement standards

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The AUS-MEAT calibration, auditing and accreditation standards for GR fat score prediction state that the correct fat score must be assigned with a tolerance of ±2 mm of the score boundary, as measured by a GR knife on a stationary carcase, with 90% accuracy. Therefore, to meet AUS-MEAT measurement requirements, DEXA must be able to predict GR tissue depth in lamb carcases within ±2 mm of the score boundary, with a maximum error of 10%.

2.3 DEXA prediction of GR tissue depth

Lamb DEXA scans were processed using established algorithms to output a CT LMY% estimate for each lamb that can be used to predict GR tissue depth. Two different combinations of DEXA data, with and without hot standard carcase weight data, were used to output CT LMY% to test their relative ability to predict GR tissue depth in lambs:

a) Mean DEXA values

b) Mean DEXA values with HSCW

c) Mean DEXA values and DEXA image component data (pixel number and mean negative log of low energy pixel values)

d) Mean DEXA values, DEXA image component data and HSCW

The models predicting GR tissue depth using DEXA variables were all trained and validated using a five-fold cross-validation procedure. This was achieved by randomly dividing the data into 5 groups (though balanced for carcase weight and fatness), training predictions in four groups or 80% of the data and validating this prediction in the remaining group or 20% of data and repeating this a further 4 times so that each group and thus individual animal had a validated prediction of GR tissue depth.

The validated DEXA predictions of GR tissue depth was then designated into a predicted fat score and compared to the actual fat score determined by manual GR tissue depth measurements. The error rate was calculated by determining the percentage of erroneous fat score allocations where there was a prediction difference greater than 2 mm of the actual fat score.

3 Results

The lamb carcases selected for this study had a mean HSCW of 24.9kg (±5.6), ranging from 13.2 to 39.3kg, and had a mean GR tissue depth of 18.6mm (±6.7), ranging from 4 to 44mm (Figure 1). All fat scores were represented in this data set, though only 3 lambs were classified as FS 1 and 17 lambs as FS 2, with the majority of lambs classified as FS 3 (n= 40), FS 4 (n = 52) and FS 5 (n = 77).

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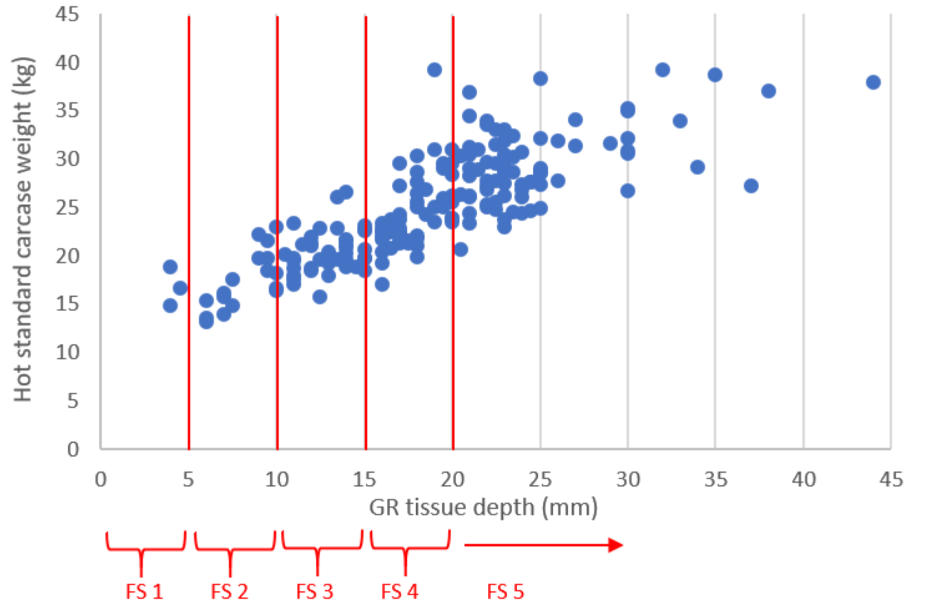

Figure 1. The distribution of hot standard carcase weight (kg), GR tissue depth (mm) and thus fat score (FS) of lambs in this study.

DEXA predictions of GR tissue depth and thereby lamb fat score varied depending on the DEXA variables included in the prediction models and on the inclusion of HSCW (Table 1). Using only mean DEXA values to predict GR tissue depth, 34 lambs or 18% inaccurately predicted to the wrong fat score by >2mm, failing to meet the AUS-MEAT requirements of 90% minimum prediction accuracy (Table 1, Figure 2a). Inclusion of HSCW into the prediction model improved the accuracy of DEXA GR prediction, where 85% of lambs were accurately assigned the correct fat score within 2mm. However, this meat 15% of the lambs tested were assigned the incorrect fat score by >2mm, thus failing to meet AUS-MEAT requirements (Table 1, Figure 2b).

Predicting GR tissue depth using DEXA image components data (pixel number and mean negative log of low energy pixel values) along with mean DEXA values did however meet AUS-MEAT requirements for 90% accuracy in fat score prediction (Table 1, Figure 2c). Only 14 lambs or 7% of the lambs tested were assigned the incorrect fat score by > 2mm using this DEXA prediction model. This prediction of GR tissue depth improved only marginally with inclusion of HSCW in prediction models, reducing the inaccuracy of fat score prediction to 6% (Table 1, Figure 2d). Nevertheless, this again meant the mean DEXA values did meet the AUS-MEAT requirements for 90% accuracy in fat score prediction.

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Table 1. The prediction accuracy of dual energy X-ray absorptiometry (DEXA) models, with and without hot standard carcase weight (HSCW) data, predicting GR tissue depth and thereby fat score. The number of lambs assigned to each fat score via GR tissue depth measurement is shown, along with the number and percentage of lambs that were predicted to be >2mm outside the correct fat score GR tissue depth range (prediction inaccuracy).

Prediction model	**Fat Score**	**Number of lambs**	**Prediction inaccuracy**	
			Number	**Percentage**
a) DEXA values without HSCW				
	1	3	1	33%
	2	17	9	53%
	3	40	7	18%
	4	52	9	17%
	5	77	8	10%
	Total	**189**	**34**	**18%**
b) DEXA values with HSCW				
	1	3	1	33%
	2	17	6	35%
	3	40	5	13%
	4	52	9	17%
	5	77	7	9%
	Total	**189**	**28**	**15%**
c) DEXA values & image components without HSCW				
	1	3	1	33%
	2	17	2	12%
	3	40	0	0%
	4	52	7	12%
	5	77	2	3%
	Total	**189**	**14**	**7%**
d) DEXA values & image components with HSCW				
	1	3	1	33%
	2	17	3	12%
	3	40	0	0%
	4	52	8	12%
	5	77	2	3%
	Total	**189**	**12**	**6%**

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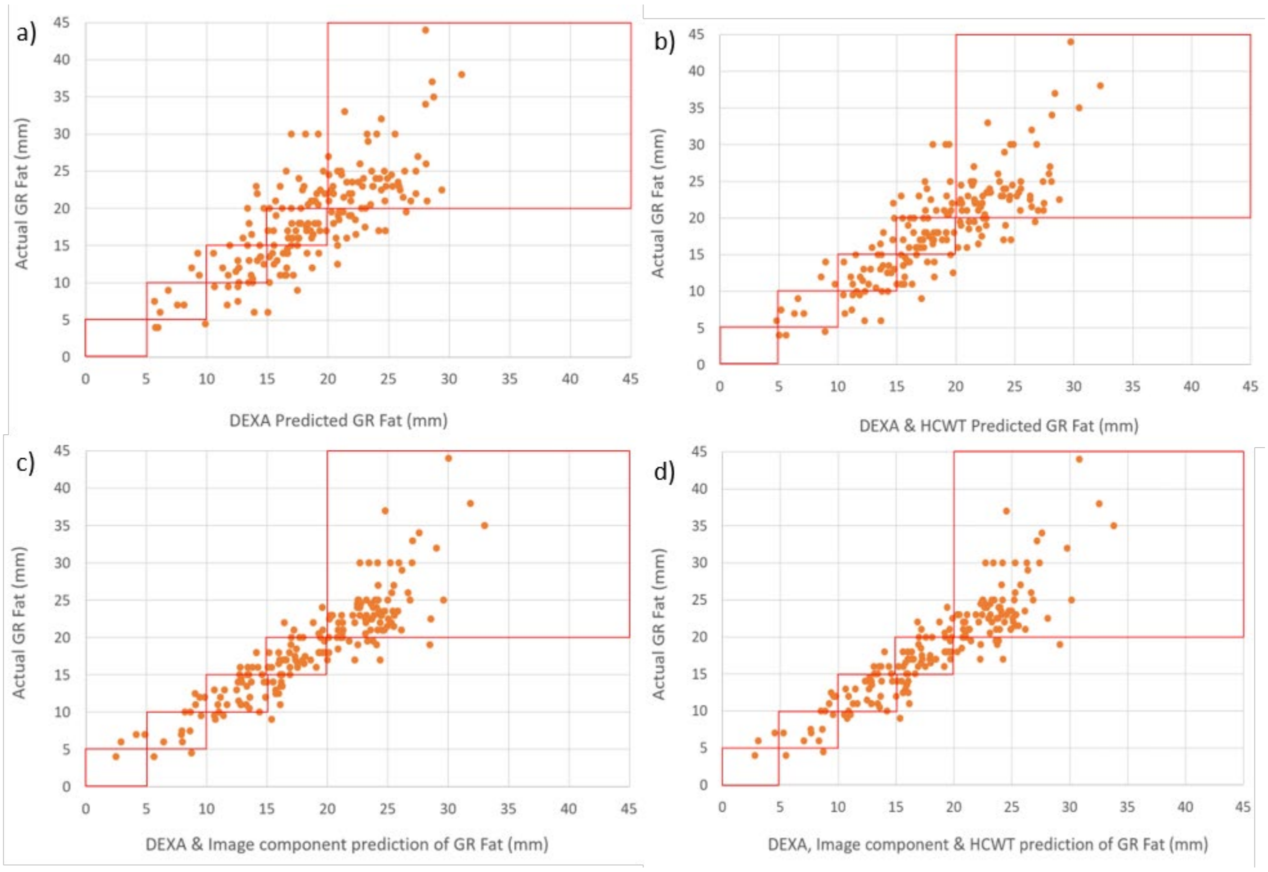
Figure 2. The association between dual energy X-ray absorptiometry (DEXA) predicted GR tissue depth or fat measures (mm) and manual or 'actual' GR tissue depth measurement (mm) using different DEXA prediction models of a) mean DEXA values only, b) mean DEXA values and hot standard carcase weight (HSCW), c) mean DEXA values and DEXA image component data and d) mean DEXA values, DEXA image component data and HSCW. Each point represents an individual lamb, while red borders demonstrate the fat scores corresponding to GR tissue depth measures.



4 Discussion

These results demonstrate that when assessed under the calibration and auditing standards for AUS-MEAT lamb fat classification, DEXA was within the 90% accuracy requirements for prediction of fat score. Lamb DEXA systems therefore do have the ability to predict single site GR tissue depth to current commercial standards. However, this study needs to be repeated using a larger volume of lamb carcases (particularly fat score 1 and 2 lambs) to conclusively demonstrate that lamb DEXA meets current commercial standards for GR tissue depth measurement and thereby to accredit the DEXA as an AUS-MEAT approved fat measurement device in lamb. A large volume of data can be relatively easily acquired to achieve this, given that fat scoring and DEXA LMY measures are now routinely being outputted for lambs processed at several sites across Australia. Accreditation of DEXA as a fat measurement device in lamb will encourage commercial abattoirs to adopt this superior LMY measurement device, as it will allow DEXA outputs to replace manual measurement of fat score or GR tissue depth and thereby save a labour unit for processing plants with a DEXA system.

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Transforming lamb DEXA outputs into a GR tissue depth measure and fat score is not however a desired industry outcome in the long term, given that GR tissue depth and fat score are less accurate and precise measures of whole carcase composition (Gardner et al., 2018) than DEXA LMY measures. Transforming DEXA values into fat scores will therefore reduce the value of LMY data provided to the lamb supply chain. This will be overcome with the establishment of CT LMY% as a trait with the Language and Standards Committee and AUS-MEAT, allowing DEXA outputs of CT lean, fat and bone % to underpin payment of lamb carcases. Nonetheless, while fat score remains the legislated measure of carcase fatness in lamb, accrediting DEXA to measure GR will improve the value of this system and its adoption across the industry.

5 Conclusions

Overall there is good potential for the lamb DEXA system to predict single site GR tissue depth to current commercial standards. However, a larger volume of data, particularly capturing fat score 1 and 2 lambs, is required to conclusively demonstrate the DEXA can meet the current commercial standards for GR tissue depth measurement. This should be relatively easy to attain as DEXA LMY measures are now routinely outputted for lambs processed at several sites across Australia. Accrediting the DEXA as an AUS-MEAT approved fat measurement device in lamb will encourage further commercial abattoirs to adopt this superior LMY measurement device over the manual measurement of fat score or GR tissue depth, and thereby save labour units for the processing plants using DEXA.

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