Meat Science 140 (2018) 78–85

Contents lists available at ScienceDirect

Meat Science

journal homepage: www.elsevier.com/locate/meatsci

Prediction of intramuscular fat content and shear force in Texel lamb loins using combinations of different X-ray computed tomography (CT) scanning techniques

N. Clelland[a,*], L. Bunger[a], K.A. McLean[a], S. Knott[b], K.R. Matthews[c], N.R. Lambe[a]

[a] Animal Breeding and Genetics, Animal and Veterinary Sciences Group, Scotland's Rural College, West Mains Road, Edinburgh EH9 3JG, United Kingdom
[b] Institute of Evolutionary Biology, School of Biological Sciences, University of Edinburgh, Ashworth Laboratories, West Mains Road, Edinburgh EH9 3JT, United Kingdom
[c] Agriculture and Horticulture Development Board, Stoneleigh Park, Kenilworth, Warwickshire CV8 2TL, United Kingdom

ARTICLE INFO

Keywords:
Spiral X-ray computed tomography
Lamb
Meat quality
Intramuscular fat

ABSTRACT

Computed tomography (CT) parameters, including spiral computed tomography scanning (SCTS) parameters, intramuscular fat (IMF) and mechanically measured shear force were derived from two previously published studies. Purebred Texel (n = 377) of both sexes, females (n = 206) and intact males (n = 171) were used to investigate the prediction of IMF and shear force in the loin. Two and three dimensional CT density information was available. Accuracies in the prediction of shear force and IMF ranged from R^2 0.02 to R^2 0.13 and R^2 0.51 to R^2 0.71 respectively, using combinations of SCTS and CT scan information. The prediction of mechanical shear force could not be achieved at an acceptable level of accuracy employing SCTS information. However, the prediction of IMF in the loin employing information from SCTS and additional information from standard CT scans was successful, providing evidence that the prediction of IMF and related meat eating quality (MEQ) traits for Texel lambs *in vivo* can be achieved.

1. Introduction

Computed tomography (CT) is a non-invasive, diagnostic tool initially developed for use in human medicine to improve the imaging of soft tissue structures and assist in diagnosing conditions or diseases not directly associated with bone structure. Over the last few decades CT has been adopted for use in animal breeding and is now routinely used in selective breeding programs for sheep in the UK to accurately estimate carcass composition of live animals. More recently, the prediction of aspects of meat quality (MQ) such as intramuscular fat levels (IMF), fatty acid profiles and tissue composition have been investigated both *in vivo* and *post mortem* in meat producing species (Bünger et al., 2011; Font-i-Furnols, Brun, Tous, & Gispert, 2013; Kongsro & Gjerlaug-enger, 2013; Prieto et al., 2010). The basic principle of CT is the measurement of the spatial distribution of any physical quantity. Offering greater contrast in the imaging of soft tissue to that seen in conventional radiography (Kalender, 2006). The first method of image capture most commonly used is 'single-slice' scanning. During single-slice scanning, X-rays are used to generate cross-sectional, two-dimensional images of the selected region of a subject. Each image is produced by rotation of the X-ray tube 360° around the subject. Attenuation of radiation through the tissues can then be measured, with differences indicating different tissue densities.

Advances in scanning technology have resulted in the development of contiguous scanning procedures such as spiral CT scanning (SCTS), capable of producing a series of images in a single contiguous scan at intervals of as little as 0.6 mm apart. The advantage is that multiple images can be acquired faster, at reduced intervals, resulting in increased information acquisitions in less time. Recent studies provide evidence that muscle density information from single or multiple CT scans in sheep, can provide moderately accurate predictions of IMF content *in vivo*. Prediction accuracies range from $R^2 = 0.33$ to 0.68 using several approaches including various CT parameters (Clelland et al., 2014; Karamichou, Richardson, Nute, McLean, & Bishop, 2006; Lambe et al., 2008; Lambe et al., 2010; J. M. Macfarlane, 2006). The aim of this study was to investigate any gains in the prediction of IMF content and shear force in the loins of Texel sheep that may be achieved by utilizing the wealth of information that relatively new SCTS techniques may provide.

* Corresponding author at: Scotland's Rural College, Roslin Institute Building, Edinburgh EH25 9RG, United Kingdom.
E-mail address: Neil.Clelland@sruc.ac.uk (N. Clelland).

https://doi.org/10.1016/j.meatsci.2018.03.003
Received 21 March 2017; Received in revised form 25 December 2017; Accepted 5 March 2018
Available online 06 March 2018
0309-1740/

2. Materials and methods

2.1. Experimental animals

The CT parameters, including SCTS parameters, IMF and shear force in the loin were derived from two previously-published studies. The first of these studies (Exp. 1), was conducted over two years (2003 to 2004) and investigated the use of various *in vivo* measurement techniques (ultrasonography, video image analysis and CT), to predict carcass and meat quality in purebred Texel (n = 240) and Scottish Blackface (n = 233) lambs. The full study and methods are detailed in Lambe et al. (2008). The second study (Exp. 2) was conducted in 2009 and investigated the genotypic effects of the Texel muscling quantitative trait loci (TMQTL) on carcass and meat quality in purebred Texel lambs (n = 137). Full details are published in Lambe et al. (2010), Lambe, McLean, et al., 2010. The combination of these data from Exp. 1 and Exp. 2 comprised data from pure-bred Texel lambs (n = 377) of both sexes, females (n = 206) and intact males (n = 171). Lambs were reared to weaning as either singles (n = 184), twins (n = 168) or artificially hand reared (n = 25). Mean age at CT was 132 d (SD 21.1, range 91–202 d); with mean live weight 35.3 kg (SD 4.9, range 20-49 kg). Lambs were CT scanned pre-slaughter using a Siemens Somatom Esprit scanner. All lambs were lightly sedated (Rompun®, Bayer animal health, Bayer plc., Newbury, UK) at a dose of 0.1–0.2 mg xylazine hydrochloride/kg body weight, then secured in a purpose-built cradle before being CT-scanned.

2.2. Single-slice and spiral X-ray CT measurements and image analysis

A series of spiral CT images at intervals of 8 mm were selected from the loin region of each lamb. The first image was taken where the transverse process of the 7th lumbar vertebra appears and the last image in the series where the transverse process of the 1st lumbar vertebra is no longer visible (Fig. 1a). Two-dimensional cross-sectional single-slice scans were also used, taken at two defined anatomical positions, through the top of the leg at the ischium bone (ISC), and through the chest at the 8th thoracic vertebra (TV8), details of the images used and the location are presented in Fig. 1b.

This two dimensional method of scanning at these particular anatomical sites (including an additional scan at the 5th lumbar vertebra, which was not used in this study), is currently used in UK terminal sire breeding programs to provide accurate predictions of fat and muscle weights in the carcass. This method, defined as 'reference' scanning (Bünger et al., 2011), optimizes the number of images required to be taken across the body of the sheep while maximizing the accuracy of estimations for carcass traits. Images were produced with a resolution of 512 × 512 pixels with a 450 mm field of view, producing images with a pixel size of 0.77 mm^2 in two dimensions. Spiral images were produced at the same resolution and field of view at intervals of 8 mm, producing images with a voxel size of 6.2 mm^3.

Automated analyses were performed on the images produced, to separate carcass from non-carcass tissues (Glasbey & Young, 2002), and calculate the density of each pixel in Hounsfield units (HU), the standard quantitative scale for describing radiodensity. In the final segmented image each pixel was allocated to fat, muscle or bone using image thresholding techniques (Mann, Young, Glasbey, & McLean, 2003). The thresholds in Hounsfield units (HU) defined for the CT scanner (Siemens Somatom Esprit single slice) were Fat = −174 to −12 HU, Muscle = −10 to 92 HU and Bone = 94 HU and above, based on previous calibration trials. Areas (mm^2) and average densities (HU) of muscle and fat in each two dimensional image were calculated, as well as standard deviations of the density values allocated to each tissue. Combining all pixels allocated as either fat or muscle enabled the use of a novel average 'soft tissue density' and standard deviation. The SCTS images were used to calculate weighted average densities of muscle, fat and soft tissue (average tissue density, in each individual scan image, weighted for tissue area in that image and averaged across all images in the spiral scan series). Volumes of each tissue (mm^3) were also calculated. The resulting SCTS parameters included; weighted muscle and fat densities and relating standard deviations, weighted soft tissue densities and standard deviation, and calculated muscle and fat volumes (mm^3). The CT parameters measured from the two dimensional reference scans in the ISC and TV8 regions were muscle density, fat density and related standard deviations, as well as the soft tissue densities and standard deviations of soft tissue densities. Muscle area and fat area tissue measurements (mm^2) were also calculated for each of the reference scan images. Total CT predicted carcass fat (PrCfat), as a measure of subcutaneous and intermuscular fat in the entire carcass, was also predicted using a breed-specific prediction equation developed from previous research (Macfarlane, Lewis, Emmans, Young, & Simm, 2006):

$$PrCfat\,(kg) = (-2236 + (LW \times 80.26) + (ISCFA \times 0.21) + (LV5FA \times 0.19) + (TV8FA \times 0.221))/1000$$

where PrCfat is the CT predicted weight of subcutaneous and intermuscular fat (kg), LW is live weight at CT scanning, ISCFA is the area of pixels allocated as fat in the scan image taken at the ischium (mm^2), LV5FA is the area of pixels allocated as fat in the scan image taken at

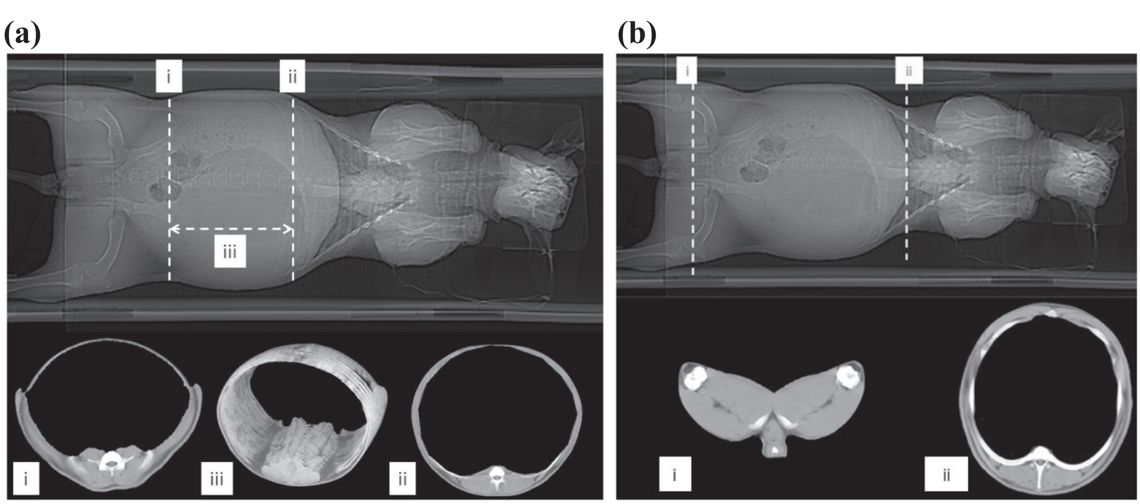

Fig. 1. Detailed tomogram's, single slice and spiral images produced during CT scanning. (a) First image where TPLV7 appears (i), last image where TPLV1 is no longer visible (ii) and 3D rendered stack of selected images (iii). (b) Scan image from ischium region (i) and scan image from 8th thoracic vertebra region (ii).