# Incorporating computed tomography based predictors of meat quality into a breeding program – Breeding lambs for more taste less waste

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**Abstract – Computed tomography (CT) scanning provides very good *in vivo* estimates of intramuscular fat (IMF) in the loin of sheep. These IMF estimates are of interest as an objective proxy trait in the determination of eating quality. Previously, accurate assessment of IMF *in vivo* or *post mortem* was only possible on samples of meat with subsequent chemical analysis. The time, expertise and cost required complicate the inclusion of such a trait into breeding programmes. This non-invasive CT based method of estimation overcomes previous complications associated with destructive methods of measurement. The aim of this study is to evaluate the use of CT for both *in vivo* and *post-mortem* predictors of eating quality in sheep breeding programmes.**

**Key Words – Genetics of sheep meat quality, Intramuscular fat, Meat eating quality, Mechanical tenderness,**

## I. INTRODUCTION

Meat eating quality (MEQ, e.g. tenderness, juiciness) is known to be linked to fat levels, and this is largely due to positive associations with intra-muscular fat (IMF). Continued selection for leaner carcasses in the sheep industry will result in further reduction of IMF and in turn this will have an impact on eating quality of lamb. Genetic selection for meat quality is rare, and difficulties in measuring meat quality traits in a non-invasive way limit the inclusion of such traits into modern sheep breeding programmes. Various non-invasive methods to predict lamb meat quality *in vivo* and *post mortem* have been investigated, and the results of these studies have scope for inclusion into UK sheep breeding programmes.

Tissue densities change after slaughter (due to blood loss, chilling etc.), therefore established relationships and protocols developed for the live animal may not necessarily be transferable to carcass joints. UK research has investigated relationships between meat quality traits and parameters resulting from x-ray computed tomography, both *in vivo* and *post mortem*. Previous studies have shown that accurate estimations of IMF produced from CT technology are heritable and have the potential to be included in current two-stage selection programmes for sheep in the UK [1].

This project, funded by Innovate UK, will involve a combination of cutting-edge technologies and the aim is to integrate them directly in to industrial application in lamb. These technologies could lead to higher product quality, less waste, improved efficiency and lower production costs. Sustainable food production is about competitive/affordable food produced profitably and sustainably which this work aims to address.

## II. MATERIALS AND METHODS

*Computed Tomography predictions of intramuscular fat in vivo:* Two dimensional (2D) cross-sectional CT scans (FOV = 450mm, Resolution = 512x512 pixels) were taken at 3 defined anatomical positions, through the back of the pelvis at the ischium bone (ISC), the loin at the fifth lumbar vertebra (LV5), and through the chest at the 8$^{th}$ thoracic vertebra (TV8). This method of scanning has been defined as 'reference' scanning, and is used in commercial UK breeding programmes to optimise the number of images required versus accuracy of prediction for carcass tissue weights, with these specific anatomical sites derived from previous research trials validated against physical dissection [2]. Image analyses were performed to separate carcass from non-carcass tissues [3] and the density of each pixel (0.77mm$^2$) in the carcass portion was allocated to fat, muscle or bone, according to density thresholds using sheep tomogram analysis routines (STAR) software [4]. The thresholds in Hounsfield units were; Fat = -174 to -12HU, Muscle = -10 to 92HU and Bone = 94HU and above. Areas (mm$^2$) and average densities (HU) of each tissue in each 2D image were calculated, as well as standard deviations for the density values of all pixels allocated to each tissue.

Total carcass fat (kg), as a measure of subcutaneous and intermuscular fat, was predicted using a breed specific prediction equation developed from previous research [5]. Intramuscular fat content in the loin was predicted using a prediction equation based on tissue density values, entirely independent of any CT fat area or weight measurements [1].

*Computed Tomography predictions of intramuscular fat post mortem:* The saddles of 303 lambs were scanned using similar processes as described previously. Loins were uniformly orientated and positioned on a multiplex scanning frame and spiral CT scanned (contiguous scans at 8mm intervals) in batches of 3. CT images were segmented using a multi-object animal tomograph analysis routine (ATAR). Each pixel in each image from individual loins were allocated as fat, muscle or bone, using previously developed density thresholds, specific to the analysis of images obtained from carcasses, primal cuts and dissected muscles. The thresholds in Hounsfield units were; Fat = -244 to 24HU, Muscle = 141 to 230HU and Bone = 231HU and above.

*Incorporation into a sheep breeding programme:* A combination of CT scanning of live terminal sire rams and *post-mortem* CT scanning of loin cuts from their crossbred progeny (from Scotch Mule ewes) is being tested within a sheep breeding programme. Around 5000 crossbred lambs will be produced from over 100 sires across 4 years. Preliminary analyses of CT results from year 1 have been obtained to look at sire differences (n = 28 Suffolk sires) between IMF levels in the loins of crossbred progeny (n = 1203, ranging from 8 to 90 offspring per sire), as an indicator of genetic variation.

*Statistical analysis In-vivo:* Data were extracted from the National genetic evaluation database (BASCO) comprising of entire males (n=1971) from 525 sires and 1576 dams from 265 flocks over 12 years. Fixed effects and covariates affecting the traits of interest were identified, and variance and covariance components were estimated from the data using ASReml (Release 3.0) software[6] . Univariate and bivariate analyses were performed between all combinations of traits included in the study.

*Statistical analysis Post-mortem:* Multiple ordinary linear regression (OLR) analyses were performed to predict objective and sensory meat quality traits, the final model was selected using the stepwise GLM procedure in Genstat14™ [7]. The dataset was then split into a calibration and validation set to test the predictive ability of the model.
A second regression method, partial least squares regression (PLSR) was also investigated considering the frequency distributions of pixel density values.

## III. RESULTS AND DISCUSSION

*Genetic Parameters for in-vivo CT-predicted IMF:* The trait of particular interest in this study was the novel CT predicted intramuscular fat level, the heritability of this novel trait, and the relationship with traits currently included in the selection index for terminal sires. The CT intramuscular fat trait included in this study was found to be of moderate heritability ($h^2$ 0.31). The genetic correlation between CT intramuscular fat and carcass fat was also moderate to high ($r_g$ 0.59), whilst genetic correlations with growth traits were moderate and muscling traits were low. The results of this study indicate that selection to increase IMF based on the CT predictions alongside maintenance or further reduction in overall carcass fat should be possible with the inclusion of both traits alongside other selection objectives within a multi trait selection index.

*Prediction of meat quality traits using post-mortem CT:* The prediction accuracy of CT for IMF found by multiple linear regression models including loin weights and tissue density values, using vacuum-packed loin cuts was moderate] (Adj $R^2$ 0.36). Prediction accuracies for other meat quality traits (mechanical tenderness and sensory taste panel traits) were low, ranging from Adj $R^2$ 0.025 to 0.098.

*Sire differences in IMF levels of crossbred lambs:* After adjusting for cold carcass weight or fat class of cross-bred slaughter lambs, significant differences ($P<0.05$) were identified between sires in terms of IMF levels found in their crossbred progeny, indicating that genetic variation exists for this trait.

## IV. CONCLUSION

Accurate estimates of IMF produced by CT (*in vivo*) are heritable and have the potential to be included into current UK sheep breeding programmes. CT scanning vacuum-packed lamb loins can be used to predict IMF alongside carcass and loin cut weights with moderate accuracy [6]. However this method cannot accurately estimate mechanical tenderness or sensory traits of the meat. The heritability of these *post-mortem* traits will be estimated once sufficient records are available from the on-going project. There may be potential to incorporate a combination of both of these CT predictors of IMF into breeding programmes for improved lamb meat quality in the slaughter generation.

## ACKNOWLEDGEMENTS

Funding for this work was gratefully received from Innovate UK and from AHDB as part of Neil Clellands PhD studies. Thanks go to staff at Wm Morrison's Woodhead Brothers abattoir and Ian Richardson and colleagues at the University of Bristol.

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