# CONTEXTUAL VOLUME GRADING VS. SPECTRAL CALIBRATION

**L.B. Christensen[1], A. Lyckegaard[2], C. Borggaard[1], R. Romvari[3], E.V. Olsen[1], W. Branscheid[4] and M. Judas[4]**

*[1]Danish Meat Research Institute, DK-4000 Roskilde. [2]Informatics and Mathematical Modelling, Technical University of Denmark, DK-2800 Lyngby. [3]University of Kaposvar, Faculty of Animal Science, H-7400 Kaposvar. [4]Bundesforschungsanstalt für Ernährung und Lebensmittel, Standort Kulmbach, D-95326 Kulmbach. Email: lbc@danishmeat.dk*

**Keywords:** CT scans, contextual volume grading, Hounsfield spectrum, lean meat weight, virtual dissection

## Introduction

The EU reference for determination of the content of lean meat in a pig carcass is based on a manual dissection of the carcass tissues into fat, bone and lean meat. The result of the grading is expressed as the lean meat weight (LMW), i.e. the weight of the total volume of lean meat in the carcass, as a percentage of carcass weight. In the EUPIGCLASS project, computer tomography scanning (CT) was investigated as a potential objective grading reference technique. Dobrowolski *et al.*, (2004), analysed the Hounsfield spectra of CT scanned carcasses to predict the dissected lean meat weight . One advantage of the spectral approach is, despite the simplicity, it achieved a high correlation (r<0.996) to the manual dissection reference. One drawback is, however, the influence from tissues like bone marrow and cartilage that have a comparable attenuation of x-rays to fat and lean meat. As the method includes no spatial information of individual tissue contributions, the presence of these tissues will limit the correlation.

Very recently, a new approach has emerged (Lyckegaard *et al.*, 2006) including the spatial information of individual voxels and their neighbours. The present paper compares this new approach to the conventional spectral analysis of CT generated data with respect to the determination of lean meat weight.

## Materials and Methods

57 pig half carcasses were CT scanned and dissected according to the EU-recommendation (data set A). A contextual volume grading model was made to estimate the total weight $W_A$ with a linear model of the form: $W_A = \beta_{fat}V_{fat} + \beta_{meat}V_{meat} + \beta_{bone}V_{bone}$, where $V_i$ denotes the volume [cm$^3$] of the i-th tissue class. From a physical point of view, $\beta_i$ is assumed to correspond to a mass density [g/cm$^3$] of each tissue class. The three volumes were found by binning all voxels into one of three classes using the Owen-Hjort-Mohn algorithm. From the Hounsfield value of each voxel, the algorithm optimises the probability of binning the voxels into one of the three classes: bone, fat or lean meat. The probability is conditional depending on the surrounding voxels. Further details on contextual volume grading may be found in (Lyckegaard *et al.*, 2006).

As contrast to the contextual volume grading, an alternative statistical model was made from the same data to estimate the LMW. The Hounsfield spectrum between -500 and 1500 HU was scaled to unit variance and then used as input for the PLS analysis to model the dissected lean meat content. Both models were validated (leave-one-out) and finally tested on a second unknown data set consisting of 25 CT scanned (in another CT scanner) and dissected carcasses (data set B).

## Results and Discussion

Data set A was generated with a voxel size of 0.0095 cm$^3$ so the volume was found by simple scaling of the number of voxels in the three tissue classes. The contextual volume grading procedure lead to the following estimation model: $W_A = 0.6542 \cdot V_{fat} + 0.7519 \cdot V_{meat} + 1.1215 \cdot V_{bone}$. The performed validation of the model resulted in a high correlation of r=0.9909 with a residual error RMSEP=584 g. The values for predicting LMW with the same model was found to be r=0.9863 with a RMSEP=1408 g. The surprisingly small coefficients for density of fat and lean meat were investigated on a second data set B, but first the alternative statistical analysis was performed on set A.

The statistical PLS model estimated the LMW with a similar high correlation of r= 0.994 and a residual error SEP = 339 g in the leave-one-out validation. The PLS analysis used the spectral range between -500 and 1500 HU. The model for predicting LMW used 3 factors. No scaling was applied to the Hounsfield spectra prior to the PLS modelling. The two analysis strategies are thus producing similar prediction quality.

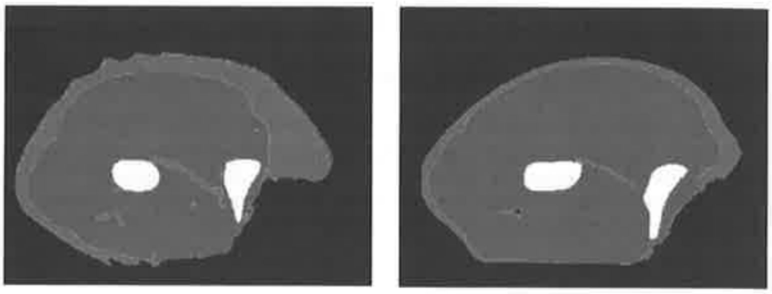

**Figure 1:** The result of the contextual volume grading procedure on a CT image from data set A (left) and data set B (right). By comparing the images, small deviations in the classification of the skin are apparent, a difference that will affect the estimated density coefficients. One other difference is the occurrence of classified intramuscular fat in the left image. The presence may be caused by artefacts from the image reconstruction algorithms, used in the specific CT scanning.

The two models were then tested on the second data set B for prediction of the LMW. The data set was generated with a slightly smaller pixel size of 0.0081cm$^3$ on a different CT scanner, so before applying the above models, both have to be scaled accordingly to achieve the tissue volumes expressed in SI units. Apart from this adaptation, no alteration whatsoever was made to any of the models.
The statistical PLS model attained a correlation between the predicted LMW and the reference value of r=0.994 with a SEP=1837g. The contextual volume grading model managed a correlation r=0.9967 but with a surprisingly high RMSEP=6991 g.
To investigate this matter, in comparison, the contextual volume grading was repeated on the second data set of 25 animals. The analysis lead to a second model $W_B = 0.9836 \cdot V_{fat} + 1.1084 \cdot V_{meat} + 1.4628 \cdot V_{bone}$ with a RMSEC=121 g. These coefficients are somewhat closer to fulfilling our expectations of the density of fat and lean meat tissue. The calculated coefficient for the bone tissue represents a mean value with a larger variation due to the inclusion of bone marrow in the bone tissue bin and to the natural density difference between cortical and trabecular bone structures.
Due to the very high correlation between the contextual volume grading result when performed on the two data sets, we believe there must be a systematic rather than random difference between the CT scanning of the two samples A and B. The difference is yet to be investigated.

## Conclusions

We have demonstrated two fundamentally different analysis of CT scanning for grading of pigs. Both the contextual volume grading and the statistical PLS approach demonstrate very high correlation to a dissected reference LMW with quite small residual error contributions.
Despite the large, yet unresolved, difference (offset) between the density constants representing the two data sets, we find the contextual volume grading a very interesting alternative to the conventional spectral analysis of the Hounsfield spectrum. Further improvements of the technique seem possible in order to avoid misclassification of skin as meat instead of fat. Figure 1 left supports the assumption.


## Acknowledgements

Data set A was provided by the EC project G6RD-CT-1999-00127 EUPIGCLASS of the Measurement and Testing activity (Competitive and Sustainable Growth programme).


## References


Dobrowolski, A., Branscheid, W., Romvari, R., Horn, P., Allen, P. (2004): X-ray computed tomography as possible reference for the pig carcass evaluation. Fleischwirtschaft 84, (3) pp. 109-112.

Lyckegaard, A., Larsen, R., Christensen, L. B., Vester-Christensen, M. and Olsen, E. V. (2006): Contextual analysis of CT scanned pig carcasses. ICoMST52, Dublin.