# CARCASS GRADING USING THE AutoFOM ULTRASOUND SYSTEM

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## Background

The AutoFOM carcass grading system introduced in 1995 by SFK-Technology in Denmark is an on-line grading system positioned directly on the slaughtering line. The system is based upon ultrasonic technology and is therefore a non destructive method providing an overall evaluation of the carcass capable of measuring up to 1,250 carcasses per hour. The AutoFOM has a number of practical advantages for the slaughtering industry compared to the current grading systems in being fully automatic, hygienic, fast and with no mechanical moving parts (meaning low maintenance costs and high up-time performance). The most extensive advantage relative to current grading system, now dominated by the insertion probe approach, is the total measurement of the carcass, which is being measured at 3.200 positions in three dimensions.

In this presentation the performance of the AutoFOM system for carcass grading using on line image analysis and multivariate data regression will be demonstrated in two tests, where the reference lean meat yields are obtained from manual cutting of the carcass.

## AutoFOM Ultrasound System

The AutoFOM system consist of four main blocks: 1) a U-shaped frame with 16 ultrasound transducers, 2) an acquisition module, 3) a data processing unit and 4) a personal computer for presentation and logging of the data. The first three main blocks are shown at figure 1. The frame consist of 16 ultrasound transducers covering the entire back of the carcass as illustrated in figure 2. All 16 transducers are sampled approximately 200 times along the length direction of the carcass for each sample 600 depth measurements are made. The transducers uses the pulse-echo ultrasound technique. Each transducer transmits a pulse every 0.1 ms and then switches to receiving mode and samples the received echoes with a sampling frequency of 5 MHz. The high intensities of the echoes occurs at intersections between different tissues; e.g. between the intersection of fat and meat at the carcass. The intensity of the received echoes as a function of time forms an A-scan, of which an example is shown in figure 3. The entire A-scans acquired of one transducer gives a two dimensional image of the length direction of the carcass.

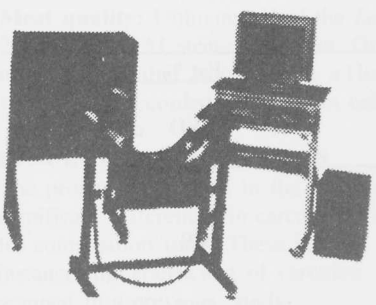

Figure 1. The AutoFOM consist of a frame with 16 transducers, an acquisition module and a workstation.

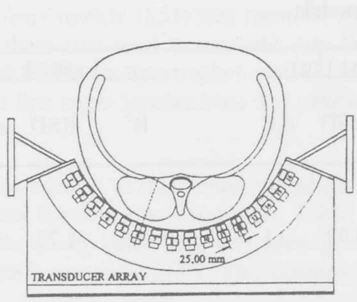


Figure 2. The frame with the 16 ultrasound transducers.

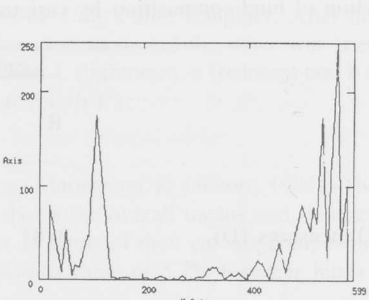


Figure 3. An A-scan is the intensity of the echoes as a function of time

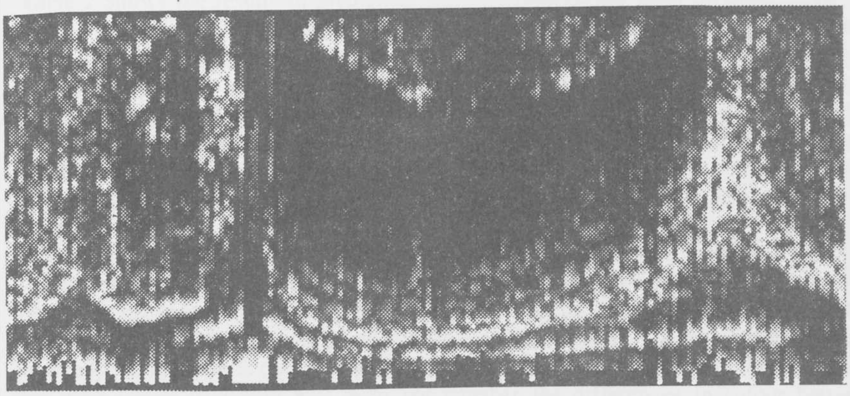

Figure 4. All A-scans performed by one ultrasound transducer are combined to an image of the length direction of the carcass.

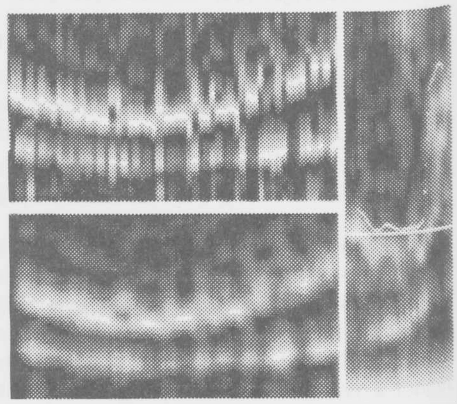

Figure 5. A horizontal averaging of the ultrasound images reduces the noise in the images. The right image has the fat profile overlaid

Figure 4 displays such an image with the left part being shoulder and the right part being the ham of the carcass. All 16 transducers forms a three dimensional image sequence with a total of 16×200 = 3,200 measuring positions on the carcass and 600 measured depths for each measuring point for the further data processing.

## Data Analysis

The data processing consist of two steps: 1) The image analysis and feature extraction and 2) The data regression and reference prediction.

### Image Processing

It has historically been recognized that the minimum depth of the subcutaneous fat is the most informative point on the carcass with respect to meat yield. Therefore the features extracted from the ultrasound images are concentrated on this region called the centerslice. The centerslice is found from a fat profile extraction algorithm, which is applied to all 16 length images. In the illustration in figure 2 the centerslice would be slice 6 or slice 11. The further data analysis is concentrated on the centerslice and its concurrent neighbors only due to the limited data processing time. Next step in the image analysis is an horizontal averaging of the images. This step reduces the noise in the ultrasound signal and highlights the fat profile without reducing the resolution in the depth direction significantly. This is illustrated in figure 5, where the top image shows a subregion of a centerimage and the bottom image shows a the same subimage after the horizontal averaging. A contour tracking algorithm is applied to the averaged images to detect the fat and meat profiles. Figure 5 (right) shows a subregion of a centerimage with the detected fat profile overlaid. The vertical overlaid line on the image is the fat depth as measured with the Aloka scanner. A total of 127 features describing the fat- and meat profiles and some significant position at the shoulder are output from the image analysis.

### Data Regression

The data regression is performed using the partial least squares (PLS) regression[1]. PLS is a linear multivariate data regression technique, which performs a decomposition of the data relative to the most informative (with respect to the reference values) direction in the 127-dimensional feature space. This pretransformation of the data prior to extraction of the regression coefficients makes the model is much more stable to noise. All data processing is performed on-line at the slaughtering line on a UNIX workstation with a processing time of approximately 3 seconds. Thus, the AutoFOM measuring principle makes it possible at a very early time in the slaughtering process to obtain grading information, which can be used for e.g. sorting the carcass before cutting.

## Results

The results presented here are from two tests in Denmark (300 carcasses) and Germany (73 carcasses). In all tests, the reference value is the total meat yield of the carcass as obtained from a manual cutting analysis of the carcass. In the German test, also the fat thickness as obtained with the manual serviced Aloka scanner is available as reference value. In all tests the performance of the prediction models are validated using cross validation, and the errors obtained in these trials has later been proven to be realistic for production conditions. The performance of the prediction is presented in table 1.

| | Germany | | Denmark | |
|---|---|---|---|---|
| | R | RMSEP | R | RMSEP |
| Meat Yield | 0.89 | 1.83% | 0.85 | 1.94% |
| Fat Thickness | 0.95 | 1.38 mm | | |

Table 1. The result of AutoFOM predictions of the cut tests in Germany and Denmark. Note that in the German test also the fat thicknesses (measured with the Aloka scanner) exist.

## Conclusion

The results of the AutoFOM predictions are satisfying compared to existing grading equipment based on insertion probes. Manually punctural based grading equipment all performed with less accuracy than the results presented here. Furthermore, the fully automatic Classification Center (KC) based on nine NIR insertion probes from the Danish Meat Research Inst.[2] was compared to the AutoFOM in the Danish test. The performance of the KC was slightly better than the results obtained on the images from the AutoFOM. This is due to the fact that the KC measures the carcass after the cutting, where the reference values are obtained as opposed to the AutoFOM, which measures the whole carcass shortly after stunning. It is worth noting, that due to the new cutting regulations[3] all carcass instrumentation obtain higher meat yield errors than obtained with the previous cutting regulation.

It is expected that the AutoFOM system including the software can be improved to reach a level similar to or better than the KC, including the unique possibility of the AutoFOM to grade the cuttings. Finally, other advantages of the AutoFOM grading system in being faster, less expensive, less maintenance requesting, of low failure rate and requiring little space on the slaughtering line makes the system a potential grading standard in future carcass grading.

## References


[1] H. Martens and T. Naes, *Multivariate Calibration*, John Wiley & Sons, ISBN: 0-471-90979-3, 1989
[2] H. Swatland, *On-Line Evaluation of Meat*, Technomic Publishing, ISBN: 1-56676-333-9, 1995
[3] EU Council Regulation, *Procedure for assessment af the Lean Meat Percentage*, EC Nr. 3220/84, 1995