USING CT SCANNING TO MEASURE TISSUE VOLUME – WHAT IS THE PROBLEM?

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I. INTRODUCTION

The use of image based technology in the food industry was speeded up a decade ago with the introduction of computed tomography (CT) to assess carcass and meat quality [1], [2]. Today, CT scanning of carcasses is used as a volumetric reference of the tissue distribution to calibrate online equipment. The performance of a medical CT scanner is often assessed using a calibrating device with known densities and a predefined protocol. However, this protocol and this density correction do not necessarily reflect the acquisitions needed to measure the different tissue volumes. A recent study showed that volume measurement is affected by the scanner and the scanner settings [3]. Some of the factors influencing the uncertainty related to CT scanning are energy, current and the reconstruction algorithm (Fig. 1).

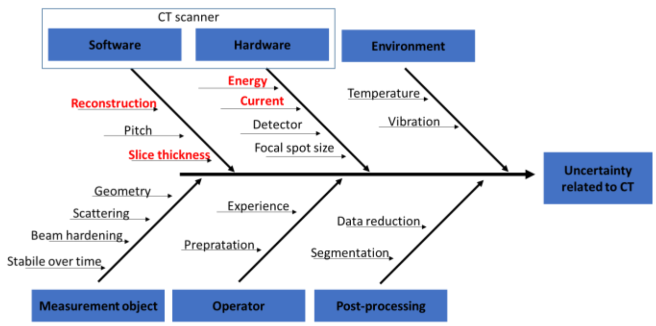

Figure 1. Cause and effect chart of factors related to the uncertainty of using CT.

The aim of this study was to investigate the source and size of the underlying measurement errors and to enable consistent volume measurements of the different tissue types, e.g. lean meat, fat and bone as well as the tissue analogies in phantoms over time and between different medical CT scanners.

II. MATERIALS AND METHODS

Twelve randomly selected pig carcasses and five volumetric measured phantoms were scanned repeatedly at two different medical CT scanners. Scanner settings defined by energy [kV] (high 135/130; low 120/110), current [mA] (high 200; low 100), slice thickness [mm] (high 10, low 4) and the reconstruction algorithm (normal and soft) formed the experimental design. A contextual segmentation algorithm was used to classify meat, fat, bone, marrow and skin from the scanned items. The difference in meat volume between the two CT scanners was investigated using phantoms, and the effect of scanner settings on meat and skin volume was investigated using both phantoms and carcasses.

The phantoms were constructed with a known lean meat percentage made in different well-defined types of polymers simulating meat, fat and bone – and traceable to a SI-unit (Fig. 2).

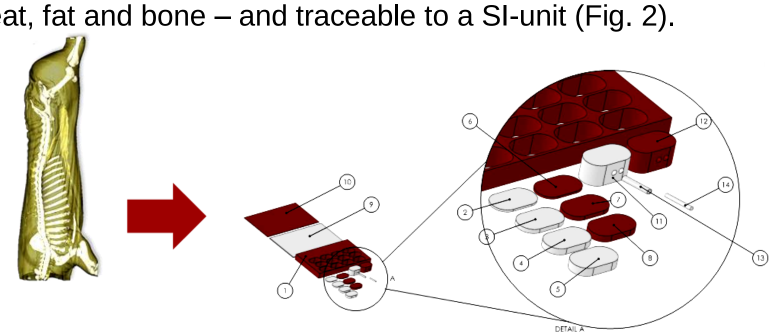

Figure 2. Illustration of a phantom (right), used to model real pig carcasses (left). Numbers represent different tissue types and different tissue thickness in the phantom.

The difference in meat and skin volume between and within the CT scanners were analyzed using an analysis of variance for main and interaction effects.

III. RESULTS AND DISCUSSION

The results showed some uncertainty related to the CT scanner (energy, current, slice thickness, reconstruction kernel). The results are shown in Table 1.

Table 1. Significant levels of the differences between the two CT scanners in the meat and skin volume measured.

Effect	Phantoms	**Effect**	Carcass meat	Carcass skin
Scanner|Phantom	***	Scanner	NS	***
Energy	***	Energy (one scanner)	NS	NS
Current	NS	Current (one scanner)	NS	NS
Scanner|Slice thickness	***	Slice thickness (one scanner)	NS	***
Scanner|Reconstruction	***	Scanner|Reconstruction	NS	***

*** indicates p-value <0.0001, NS indicates non-significant p-value >0.05, | indicates interaction

The results from the phantoms showed an effect of CT scanner and all scanner settings except for X-ray current. We also found an interaction effect between the CT scanner and the phantoms, slice thickness and the reconstruction kernel. Handling of thin complex structures such as the carcass skin also revealed an effect of the CT scanner, slice thickness and the reconstruction kernel.

Only a limited range of scanner settings, one slice thickness and a small number of carcasses (twelve carcasses) were possible to use for both CT scanners measuring the meat volume. Consequently, the same effects of settings as for phantoms could not be tested and verified on carcasses, though a tendency of difference between CT scanners was present. However, the standard error of estimated, the scanner effect for carcasses was 0.89 liter (average meat volume 25.70 liter), while it was only 0.003 liter for the phantom measurement (average meat analog volume 2.95 liter).

The phantoms were designed to stress the CT system, and it could be discussed if they were fully representative of a carcass. However, the absolute volume of meat in the carcass or phantom measurements was not evaluated in the present study. Handling of small complex structures such as skin could potentially cause a bias between different CT scanners.

IV. CONCLUSION

This study showed that the difference between the two CT scanners could not be explained by the selected settings alone. In addition, the implications from our findings indicate that care should be taken when comparing volumetric results from different CT scanners. An instrumental calibration methodology using phantoms as a standard for volume measurement needs to be fully validated.

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