Identification of possible and relevant post mortem reference methods for carcass composition

G. Daumas[1], T. Donko[2] and M. Monziols[1]

1. IFIP-Institut du Porc, Le Rheu, France.
2. Kaposvár University, Kaposvár, Hungary.

Value for Industry

- CT can provide accurate measurements of carcass and body composition of the farm animals.
- CT has a recognized potential to be a primary reference, in particular for breeding purposes.
- Building an international CT based reference would improve the comparisons, the market and the efficiency of the whole chains.

Background

CT has been used as a working standard to measure body composition for many years by a lot of researchers. In particular, this has been very efficient in sheep breeding. Ten years ago, the EUPIGCLASS project recommended the introduction of CT as a potential reference in the EU regulation for pig grading. This was a starting point of new research in this area. Several countries developed their own working standard. However, without harmonization, CT cannot be used as a stand-alone (primary) reference; costly dissections still have to be done.

To build a primary CT reference for measuring body/carcass composition is one of the main aims of COST Action FAIM. To identify possible and relevant post mortem reference methods for carcass composition is one of the milestones for FAIM in 2013.

Few methods have been proposed where CT is considered as a primary reference, i.e. without any calibration against dissection. A procedure must contain acquisition parameters and image analysis, this latter seems to have the greatest impact.

Why work is needed

In order to identify possible reference post mortem (pm) it is important to review the CT methods used for carcass composition. This is necessary to clarify the content of the CT classes and the methods for the conversion of volumes into weights.
Moreover, in order to agree on a reference, the stakeholders need to know the impact of each parameter and in particular of those having the greatest impact. It seemed thus very important to assess the effect of tissues segmentation and the effect of conversion of volumes into weights.
Finally, focusing on pig carcass composition was quite obvious, as an urgent matter under discussion at a EU level and as the segmentation is more complex due to the presence of rind. This work is an important step in order to be able to propose future coordinated research works.

The methods used

First of all, an extended literature review on CT used for measuring compositional traits was performed. Articles using CT procedures stemming from calibrations (always against dissection) were excluded. Only the articles considering CT as a primary (stand-alone) reference were taken under consideration.

Our investigation was focused on the image analysis which is considered as the main source of differences. The scope was limited to muscle segmentation by thresholding, one of the most common method, one of the simplest ones, and a good candidate for a reference. Muscle Hounsfield range and muscle density were collected for each selected article.

An arbitrary reference was chosen among these ranges and densities to facilitate comparisons. The reference was decided by the authors after taking into account the more convincing arguments.

In order to assess the effect size of HU ranges and densities, we had to use some available datasets. We chose 3 recent trials involving extreme pig carcasses or pig joints from French and Italian pigs:

- **Trial 1:**
Calibration of the French pig classification methods, carried out in 2012. It involved 250 pigs representative of the French population, including females and castrated males. The 4 main EU joints were CT scanned.
- **Trial 2:**
Experiment in course on pig genomics, including in particular Pietrain entire males. The present dataset included about 1500 pigs. Carcass side was CT scanned.
- **Trial 3:**
Calibration of the Italian pig classification methods, carried out in 2012. It involved:
- 150 heavy pigs (carcass weight in the range 115-150 kg),
- 150 light pigs (carcass weight in the range 95-110 kg).
Following Italian jointing, the 5 main joints were CT scanned.

In the 3 trials the scans were performed with the same CT scanner, the mobile IFIP CT scanner (Siemens Emotion Duo), using the same acquisition parameters: 130 kV, 40 mAs, 3 mm slice thickness, spiral scanning, FoV 500x500 mm, acquisition matrix 512x512, reconstruction filter B30S (soft tissues). Trial 3 was considered as two datasets, one for each subpopulation.

Three carcasses were selected in each of the 4 datasets on the LMP basis: the lowest LMP, the highest LMP and the LMP closest to average. For this study the sample gathered 12 pigs with a huge variability.

The number of voxels was calculated within the muscle HU range of each selected publication in each of the 12 pigs. Then, the relative difference of muscle volume was calculated with the HU range [0-120], chosen as arbitrary reference (Daumas & al., 2011). For the publications having mentioned a muscle density, this density was applied to the muscle volume to calculate the relative difference of both muscle weight and LMP with the arbitrary reference (density = 1.04; ICRU (1989). Finally, for each article was calculated the extreme relative differences as well as the median difference, both for volume and LMP.

The results obtained

From the studied literature 15 references matched the study constraints. They concerned beef, pig, lamb and sheep, and *in vivo,* carcass or cuts. These 15 references used 11 muscle HU range. Several authors used the same muscle HU ranges. Table 1 summarizes the median relative differences with the study reference of CT muscle volume, sorted by ascending order, for the 11 muscle HU ranges (codified from 1 to 11). The study reference has the code 8. The range [0-120] was proposed as a reference by Daumas and Monziols in 2011 for pig carcasses. It was used too by Brun *et al.* (2012) on beef cuts.

Most of the median relative differences ranged between -9.4 % and +6.6 %. More extreme differences were obtained for Picouet *et al*. (2010) with -13% on hams and -21% on pig carcasses.

The inferior HU muscle limit comprised values between -22 and +30, while the superior limit comprised values between +76 and +200. The extreme values were thus -22 and +200, but the maximum range width was 201 HU, corresponding to the [0-200] range. The minimum range width was 54 HU, corresponding to the [23-76] range.

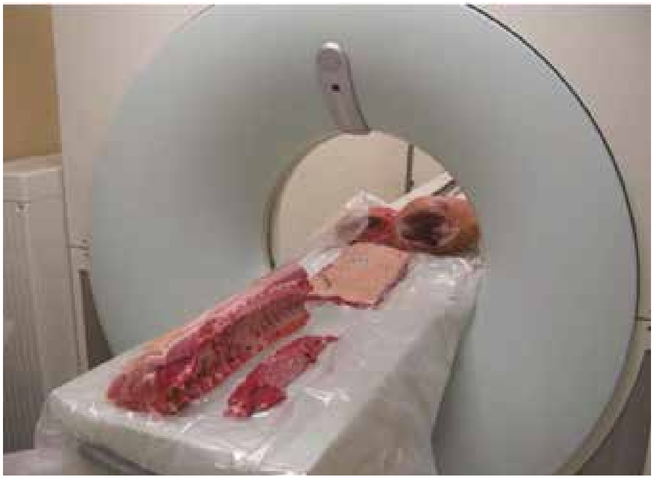

Figure 1. CT scanning the 4 main EU joints.

Table 1. Median relative differences with the study reference of CT muscle volume, sorted by ascending order, for the 11 muscle HU ranges (codified from 1 to 11), corresponding to the first author having used such a range.

				MUSCLE		Median difference
Code	**Authors**	**Species**	**Entity**	**Inf**	**Sup**	**Volumes**
1	Picouet *et al*. (2010)	Pig	Carcass	23	76	-21,1%
2	Picouet *et al*. (2010)	Pig	Ham	23	85	-12,7%
3	Navajas *et al*. (2010)	Beef	Cuts	30	133	-9,4%
4	Picouet *et al*. (2010)	Pig	Loin	7	85	-7,7%
5	Romvari *et al*. (2005)	Pig		20	200	-4,0%
6	Horn (1995)			10	150	-1,5%
7	Navajas *et al*. (2006)	Sheep	Live	-10	93	-0,5%
8	Daumas and Monziols (2011)	Pig	Carcass	0	120	0,0%
9	Monziols and Daumas (2010)	Pig	Carcass	0	200	1,8%
10	Campbell *et al*. (2003)	Sheep	Live	-17	120	4,3%
11	Kvame *et al*. (2004)	Lamb	Cuts	-22	146	6,6%

None of the authors converted the CT volumes into weights. Among the 15 articles, only 4 applied a muscle density (Md), using the 3 following references:

- Md = 1.04, citing ICRU (1989)
- Md = (HU x 0.00106) + 1.0062, citing Campbell *et al.* (2003), who cited Fullerton (1980).
- Md = (HU x 0.001413) + 0.997649, developed by Picouet *et al.* (2010).

The two last densities were a linear function of the HU values and were applied either to the average HU in the muscle range or by HU value. The latter method was applied in this comparison study. For 10 HU the variation of density was about 0.01 for both formulas. At 60 HU the "Campbell formula" gave a density of about 1.07 while the "Picouet formula" gave a density of about 1.09. Compared with the reference density of 1.04, differences are respectively of 0.03 and 0.05. For the same muscle volume, relative differences are thus about 3% and 5% respectively. Differences are lower at 50 HU.

The median relative difference of muscle weight and LMP ranged from -18 % to 9 %. The effect of using the "Campbell density" increased the relative difference of muscle volume of about 2.5 %. The effect of the "Picouet density" decreased the relative difference of muscle weight and LMP of about 3-3.5 %, compensing partially the lowest volume.

Table 2. Median relative differences with the study reference of muscle weight (and LMP), sorted by ascending order, with the codes corresponding to table 1.

					MUSCLE		Median difference	
Code	**Authors**	**Density used**	**Species**	**Entity**	**Inf**	**Sup**	**Volumes**	**Weights**
1	Picouet *et al*.(2010)	Picouet *et al*. (2010)	Pig	Carcass	23	76	-21,1%	-18,2%
2	Picouet *et al*. (2010)	Picouet *et al*.(2010)	Pig	Ham	23	85	-12,7%	-9,2%
4	Picouet *et al*. (2010)	Picouet *et al*. (2010)	Pig	Loin	7	85	-7,7%	-4,4%
8	Daumas and Monziols (2011)	ICRU (1989)	Pig	Carcass	0	120	0,0%	0,0%
9	Monziols and Daumas (2010)	ICRU (1989)	Pig	Carcass	0	200	1,8%	1,8%
11	Kvame *et al*. (2004)	Campbell *et al*. (2003)	Lamb	Cuts	-22	146	6,6%	9,0%

The scientific conclusions

Very few possible post mortem (primary) reference methods for carcass composition were identified in our literature review. We restricted this review to CT scanner and muscle volume measured by thresholding. All the authors thresholded CT scans into only 3 components: muscle, fat and bone. In pig carcasses, another tissue is present: the rind, which represents approximately 5% of the weight. Rind density is close to muscle density. Some specific approach to remove rind should be considered. Some authors applied mathematical morphology.

The inferior limit of muscle volume has the greatest impact because of a noticeable proportion of mixed voxels around 0: most of these mixed voxels correspond to a mix between muscle and fat tissues. Positive limits ranged between 0 and 30. Negative limits ranged between 0 and -22. An inferior limit comprised between -20 and +20 seems a good starting point for a relevant reference.

The superior limit of muscle volume has a lowest impact, unless this limit is very low. A limit less than 100 HU should underestimate muscle volume. A high upper limit should only slightly overestimate muscle volume, because of a low proportion of bones and mixed voxels between muscle and bones in this area. For instance, a 200 HU limit only increased the muscle volume of about 2% compared to a 120 HU limit when applied on this study sample.

We only found 3 muscle density values, established by ICRU (1989), cited by Campbell *et al.* (2003) and developed by Picouet *et al.* (2010). The first one was constant (1.04) while the two others were a linear function of HU. The differences between the three densities decreased as the HU decreased. At 60 HU, a value close to muscle peak on pig carcasses, the differences with 1.04 was 3% for Campbell *et al.* (2003) and 5% for Picouet *et al.* (2010). Such high differences should motivate future investigations on the variability of muscle density. Applying a density function of HU to a HU frequency histogram seems appealing. Nevertheless, this should be decided in accordance with the muscle thresholds and the method to manage the partial voxels.

The next steps

Further studies on the analysis of CT images should investigate:

- **the variability of tissues density,**
- **how to segment the rind when present,**
- **how to manage the partial volumes, especially between muscle and fat.**

Further studies should assess the impact of CT scanners parameters. A harmonized procedure of CT scanning and of analyzing CT images should be proposed for measuring carcass composition. Then, the accuracy of this proposed CT reference should be documented.

Acknowledgements

This work has been done thanks to a financial support from Inaporc and FranceAgriMer.

References

Brun A (2012). Use of computer tomography to estimate beef cuts composition and intramuscular fat. Abstracts Book of FAIM I Conference, 51.

Campbell AW, Bain WE, McRae AF, Broad TE, Johnstone PD, Dodds KG, Veenvliet BA, Greer GJ, Glass BC, Beattie AE, Jopson NB, McEwan JC (2003). Bone density in sheep: genetic variation and quantitative trait loci localisation. Bone 33, 540–548.

Daumas G and Monziols M (2011). An accurate and simple computed tomography approach for measuring the lean meat percentage of pig cuts. Proceedings of the 57th ICoMST, 7-12 August 2011, Ghent, Belgium. Paper 061.

Horn P (1995). Using X-ray computed tomography to predict carcass leanness in pigs. Keynote lecture. Annual Meeting Proceedings of the National Swine Improvement Federation, USA, Iowa.

ICRU Report 44 (1989). Tissue Substitutes in Radiation Dosimetry and Measurement (pp. 189). Oxford University Press.

Kongsro J, Røe M, Aastveit A H, Kvaal K, Egelandsdal B (2008). Virtual dissection of lamb carcasses using computer tomography (CT) and its correlation to manual dissection. Journal of Food Engineering, 88, 86–93.

Kvame T, McEwan JC, Amer PR and Jopson NB (2004). Economic benefits in selection for weight and composition of lambs cuts predicted by computer tomography. Livestock Production Science, 90, 123–133.

Monziols M and Daumas G (2010). Comparison between computed tomography (CT) and dissection in order to measure the lean meat percentage of pig carcass cuts (in French). Journées Recherche Porcine, 42, 231-232.

Navajas EA, Glasbey C A, McLean KA, Fisher AV, Charteris AJL, Lambe N R (2006). *In vivo* measurements of muscle volume by automatic image analysis of spiral computed tomography scans. Animal Science, 82, 545–553.

Navajas EA, Lambe NR, Fisher AV, Nute GR, Bünger L, Simm G (2008). Muscularity and eating quality of lambs: Effects of breed, sex and selection of sires using muscularity measurements by computed tomography. Meat Science 79, 105–112.

Navajas EA, Glasbey CA, Fisher AV, Ross DW, Hyslop JJ, Richardson RI (2010). Assessing beef carcass tissue weights using computed tomography spirals of primal cuts. Meat Science, 84, 30–38.

Picouet PA, Teran F, Gispert M, Font-i-Furnols M (2010). Lean content prediction in pig carcasses, loin and ham by computed tomography (CT) using a density model. Meat Science, 86, 616–622.

Romvári R, Szabó A, Kárpáti J, Kovách G, Bázár G, Horn P (2005). Measurement of belly composition variability in pigs by *in vivo* computed tomographic scanning. Acta Veterinaria Hungarica, 53, 153–162.