
THE PROCEEDINGS OF THE
NEW ZEALAND SOCIETY
OF
ANIMAL PRODUCTION
VOLUME 62 2002

Computer aided tomography — comprehensive body compositional data from live animals

M.J. YOUNG

Department of Animal Science
Lincoln College, Canterbury

K.L. GARDEN

Department of Electrical and Electronic Engineering
University of Canterbury, Christchurch

T.C. KNOPP

Department of Medical Physics
Christchurch Hospital, Christchurch

ABSTRACT

X-ray computer aided tomography (CAT) is shown to be a unique method of obtaining data pertaining to body composition in live animals. Comprehensive data were obtained from CAT images, dissection and chemical analysis of 5 sheep. Tissue (fat, lean and bone) volumes are accurately determined. Reference cross-sections are shown to be useful predictors of whole body composition.

Keywords Computer aided tomography; body composition; live sheep.

INTRODUCTION

X-ray computer aided tomography (CAT) combines radiographic and computer technologies to produce 2 dimensional images of body slices *in vivo* (Christensen, Curry and Dowdey, 1978). Images are made up of shades of grey corresponding to tissue density. CAT has major advantages over conventional methods of estimating body or carcass composition. Most importantly, it allows repeated measurement over time of a living animal, in a non-invasive and non-destructive manner. Repeated measurement of individuals is of recognised importance in the study of growth (Blaxter *et al.*, 1982). Additionally, CAT directly estimates tissue parameters of interest, namely volumes. It has been shown to reduce error of prediction of lean tissue composition substantially when compared with methods involving ultrasonic imaging (Simm, 1985). Images produced by CAT are superior to those of other *in vivo* methods such as ultrasonics.

Only limited use has been made of data obtained in previous CAT studies (Sehested, 1984; Standal, 1984; Simm, 1985), while in medicine CAT image assessment is largely restricted to qualitative diagnostic procedures. Since spatial resolution is of the order of 0.75 mm, the wealth of detailed information derived from CAT scanning means the potential is great for more detailed studies of an objective nature. Such technology has been applied successfully to studies of mammalian energy metabolism (Nordøy and Blix, 1985).

In order to utilise CAT data more fully, a trial was initiated to examine the accuracy with which CAT could measure or predict tissue volumes *in vivo* and allow comparison of CAT with other methods for determining body composition.

MATERIALS AND METHODS

Five sheep varying in age, sex and body weight were used. During scanning sheep were subjected to general anaesthesia and laid prone in a trough-like cradle. All sheep were scanned transversely (i.e. the image plane was perpendicular to the long axis of the body) at 5 skeletal reference points (see Table 3). Studies with frozen carcasses (J.J. Bass, unpublished data), indicated that carcass tissue volumes were accurately predicted from tissue (fat, lean and bone) areas on the exposed surface of these frozen carcass slices. All scanned slices in the study reported here were 10 mm thick. Sheep were divided into 3 subvolumes (forequarter, loin and hindquarter), for some of which all contiguous slices were scanned. This yielded a total of 8 fully scanned subvolumes from the 5 sheep. Non-carcass regions were excluded from the CAT image. This was achieved by having a human operator trace around the desired region with a cursor on the computer screen.

Software was developed to determine areas of fat, lean and bone, in CAT images (Knopp, 1985). Summation of data from contiguous slices yielded CAT tissue volumes. A large part of software development concerned procedures to overcome errors due to partial-volume effects. These occur when the smallest resolvable image unit comprises 2 or more tissues of different densities, and hence is assigned an intermediate density value by the computer during image reconstruction. Details of a correction method designed to overcome this effect are reported elsewhere (Knopp, 1985).

Animals were slaughtered within 24 h of scanning, carcasses chilled for 24 h and frozen in a position as near as possible to that in which they were scanned. Half the carcass was used to determine chemical composition by standard procedures. The other half was cut transversely with a bandsaw at the 5 reference points and the exposed tissue surfaces photographed for subsequent measurement of tissue area by planimetry (PL). Tissue volumes were also found by dissection (DIS).

CAT tissue volumes were compared with DIS tissue volumes and carcass chemical components. PL and CAT reference slice data were compared for accuracy in prediction of total DIS tissue volumes. Accuracy of CAT for registration of reference slices was examined by locating and scanning specified slices several times, separated by approximately 30 min intervals. This procedure was repeated with the additional complication of repositioning the sheep in the cradle between scans, since in practice it may be desired to scan an animal repeatedly over several days or months.

RESULTS AND DISCUSSION

Tissue volumes were accurately measured by CAT. Correlations of CAT volumes with DIS volumes were 0.997, 0.985, 0.992 for fat, lean and bone, respectively. Deviations of predicted volumes from actual volumes show the prediction error to be less than 5% for fat and lean (Table 1). Bone was less accurately predicted due to a proportionately lower volume and greater partial-volume effects. The latter occurs because bone has a much wider density range than fat or lean, hence a small amount of bone will alter the average density of an image sub-unit more than an equivalent volume of fat or lean. This accounts for the slight over-estimation of bone volumes. Under-estimation of fat may result from the difficulty with which the operator can separate internal fat in the image into that removed with the viscera and that remaining with the carcass.

TABLE 1 Percentage differences between CAT tissue volumes and dissected tissue volumes. Average difference and magnitude (sign ignored) of difference.

Tissue	Average difference (AD)	*t*-test AD = 0.0 (probability)	Magnitude of difference (MD)	*t*-test MD ≤ 5% (probability)
Fat	−0.9	(P = 0.70)	5.2	(P = 0.46)
Lean	0.2	(P = 0.92)	4.5	(P = 0.66)
Bone	1.9	(P = 0.58)	8.1	(P = 0.04)
Total	0.1	(P = 0.96)	3.3	(P = 0.95)
Muscle*	0.3	(P = 0.87)	2.1	(P = 0.87)

* *m. semitendinosus*

TABLE 2 Correlation between carcass chemical component weights and CAT or dissected (DIS) tissue volumes.

Volume	Chemical component			
	Fat	Protein	Water	Ash
CAT fat	0.65	—	—	—
DIS fat	0.63	—	—	—
CAT lean	—	0.42	0.58	—
DIS lean	—	0.49	0.60	—
CAT bone	—	0.41	—	0.62
DIS bone	—	0.44	—	0.61

A hindlimb muscle, *m. semitendinosus,* was delineated interactively by operator on successive computer images and its volume determined. CAT volume was highly correlated with PL volume ($r = 0.999$) with an average deviation of 0.3%. Additionally, a model of the muscle was reconstructed from CAT images and shown to bear a close resemblance to the dissected muscle.

Neither CAT or DIS tissue volumes were closely related to carcass chemical components. Neither method was superior over the other (Table 2). Since CAT yields a more direct measure of parameters of interest, namely tissue volumes, this would appear to be of little importance.

Use of reference slices, based on anatomical reference points, could facilitate accurate prediction of carcass tissue volumes with less scanning per animal. Table 3 shows the correlation of CAT and planimetry (PL) reference slice data with total tissue volumes. CAT data are shown to be more useful than PL data. This is to be expected when it is considered that CAT data are based on a 10 mm thick slice, while PL data are derived only from the surface of a slice. Thus the PL technique is subject to greater registration errors. There was considerable variation between slices in the strength of their relationship with total tissue volume. This and the difference between CAT and PL data, suggest that while the use of reference slices is a valuable technique for estimating body composition, the best reference slices need to be assessed from CAT data directly. Tissue sub-units, such as a reference muscle, may also be useful for predicting total tissue volumes since muscle volume can be accurately determined *in vivo* (Table 1). Registration errors were small, less than 3%, and while repositioning increased these errors, they were still between 2% and 4% (Table 4).

CONCLUSIONS

X-ray computer aided tomography (CAT) provides detailed, quantitative body compositional

TABLE 3 Correlation between total carcass tissue volumes and reference slice tissue areas. CAT and planimetry (PL) reference slices.

Tissue	Slice location 5th TV[1] CAT	PL	11th TV[1] CAT	PL	1st SV[1] CAT	PL	Hip joint CAT	PL	C I[1] CAT	PL
Fat	0.69	0.00	0.99	0.80	0.63	0.91	0.71	0.04	0.98	0.86
Lean	0.70	0.45	0.97	0.59	0.85	0.52	0.99	0.87	0.59	0.05
Bone	0.93	0.14	0.92	0.20	0.14	0.42	0.84	0.81	0.14	0.20

[1] TV = Thoracic vertebra; SE = Sacral vertebra; CI = Caudal ischium.

TABLE 4 Coefficients of variation (%) for CAT tissue volume determinations following reregistration or reregistration and repositioning of the live animal.

Tissue	Reregistration	Reregistration and repositioning
Fat	1.3	1.8
Lean	1.1	2.9
Bone	2.5	3.7

information for live animals. With a limited number of animals, this study has shown that CAT will accurately estimate tissue volumes and that it can be used to predict body or carcass composition by use of reference slices. Other techniques used to determine detailed body compositional information cannot be performed on the live animal, while other *in vivo* methods, such as ultrasound, cannot provide the same degree of detail possible with CAT, nor is the data as easy to manipulate or quantify. Therefore CAT is unique in that it enables detailed body compositional data to be obtained from live animals.

Clearly, application of CAT technology will accelerate progress in animal breeding programs and in research into morphology and metabolism of growth of body tissues. Every effort should be made to ensure that New Zealand is able to take advantage of such technology and thereby gain significant advances in meat animal research.

ACKNOWLEDGEMENTS

This study was funded by the Applied Biochemistry Division, DSIR, Palmerston North. The authors wish to thank Dr C.S.W. Reid and Professors R.H. Bates, A.R. Sykes and R.D. Gibson for their co-operation and encouragement during the project.

REFERENCES

Blaxter K.L.; Fowler V.R.; Gill J.C. 1982. A study of the growth of sheep to maturity. *Journal of agricultural science, Cambridge* **98:** 405-420.

Christensen E.E.; Curry T.S.; Dowdey J.E. 1978. *An introduction to the physics of diagnostic radiography.* 2nd Edition Lea and Febieger. pp. 428.

Knopp T.C. 1985. Quantitative analysis of computed tomographic images. M.Sc thesis. Otago University.

Nordøy E.S.; Blix A.S. 1985. Energy sources in fasting grey seal pups evaluated with computed tomography. *American journal of physiology* **249:** R471-R476.

Sehested E. 1984. Computerised tomography of sheep. In *In vivo measurement of body composition in meat animals.* Ed. D. Lister. Elsevier Applied Science Publishers, London. p. 67-74.

Simm G. 1985. Edinburgh School of Agriculture work on lean growth in sheep : preliminary results. In *Proceedings of the 11th workshop on overfatness and lean meat production for sheep.* p. 39-41.

Standal N. 1984. Establishment of a CT facility for farm animals. In *In vivo measurement of body composition in meat animals.* Ed. D. Lister. Elsevier Applied Science Publishers, London. p. 43-51.