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In vivo measurement of breast muscle in broiler chickens by means of CT

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ABSTRACT

In this investigation 72 Arbor Acres genotype broiler chickens were subjected to CT examination at the ages of 2, 3, 4, 5, 6, 7 and 8 weeks. Trial slaughter was then performed and the weight of the filleted breast muscle was recorded. In the evaluation of the CT images produced (6-11 images per broiler) the volume of the breast muscle was determined. The largest muscle area was measured in the plane intersecting the second or the third rib (2nd and 8th week, 6.3 and 34 cm^2 respectively). The values obtained for the volume of the breast muscle increased from 21.9 cm^3 at 2 weeks to 194 cm^3 by the 8th week of life. When the weight of the filleted breast muscle was estimated on the basis of the CT images r values ranging between 0.46 and 0.88 were calculated. The results obtained indicate that the spatial configuration of the breast muscle changes with age. In the first weeks of life muscle growth in the plane intersecting the second and third rib, taken with birds examined lying in a prone position, is characteristic; with advancing age this growth shifts along the longitudinal axis of the animal in the caudal direction.
(Keywords: broiler, breast muscle, CT)

ZUSAMMENFASSUNG

Messung des Brustmuskelvolumens bei Broilern mit Computer Tomograph
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Während des Versuches wurden von 72 Broilern des Genotyps Arbo Accres im Alter von 2,3,4,5,6,7 und 8 Lebenswochen CT-Aufnahmen gemacht. Danach wurden die Versuchstiere probegeschlachtet und das Volumen des filetiert Brustmuskels gemessen. Bei der Auswertung der CT-Aufnahmen (pro Individuum 6-11 Aufnahmen) wurde das Brustmuskevolumen bestimmt. Die größte Muskeloberfläche konnte auf der Schnittebene der zweiten bzw. dritten Rippe gemessen werden (2. und 8. Woche, 6,3 und 34 cm^2). Die Werte Brustmuskelvolumens erhöhten sich von 21,9 cm^3 im Alter von 2 Wochen auf 194 cm^3 in der 8. Lebenswoche. Aufgrund der CT-Aufnahmen wurde die Masse des Brustmuskels geschätzt, die „r"-Werte lagen zwischen 0,46 und 0,48. Unseren Ergebnissen nach ist die räumliche Ausdehnung des Brustmuskels vom Lebensalter abhängig. In den ersten Wochen ist der Muskeleinbau in Höhe der zweiten und dritten Rippe (in Bauchlage untersucht) charakteristisch, mit fortschreitendem Alter verschiebt sich dieser an der Längsachse des Tieres in Richtung caudalis.
(Schlüsselwörter: Broiler, Brustmuskel, CT)

INTRODUCTION

In the field of experimental animal research there is an increasing need for the development of non-invasive methods which enable the number of animals required to be reduced without any detriment to the accuracy or authority of the conclusions reached. Therefore the further development of non-invasive *in vivo* methods for practical application is necessary. In experiments in nutrition, physiology and genetics body composition is usually determined by means of comparative slaughter followed by chemical analysis. However, this cannot be used to follow age-related changes in the same animal. *Fekete* (1992) reviewed the methods for estimating body composition in live animals.

One of these methods is X-ray computer tomography (CT), first applied in animal research by *Skjervold et al*. (1981). The Digital Imaging Centre at the Pannon University of Agriculture was put into operation in 1990 (*Horn*, 1991), and has since that time accommodated a number of experiments.

Using broilers, *Bentsen et al*. (1986; 1989), and also *Bentsen and Sehested* (1989) measured abdominal fat and breast muscle quantity by means of CT. *Svihus and Katle* (1993) examined five-week-old broilers in three consecutive years, using the method of *Bentsen* cited above. In testing the estimation of abdominal fat and breast muscle with a stock originating from the same year, independent correlations in the range of r=0.63-0.70 and 0.54-0.76 respectively between the estimated and the measured values were ascertained.

By means of the correlation between variables formulated from pixel density values and the results of whole body analysis an estimation equation has been developed for the determination of body fat content. Equations constructed by MGLH and main component analysis enable a relation of r^2 value 0.71-0.93 between calculated and measured fat content to be determined *Romvári et a*l.(1994). CT has been applied in the field of broiler nutrition to determine relative tissue composition in two body segments (two treatments, at the ages of 28 and 49 days). By means of the HU index calculated, independent of body weight, groups subjected to different nutritional conditions proved, on the basis of their fat content, clearly distinguishable from each other *Romvári,* (1996).

Within the framework of the EU-financed Copernicus programme, between 1994 and 1996 long-term experiments on broilers were in progress at this faculty in the form of a Danish-Hungarian cooperation project. In addition to standard broilers specialised lines produced by the partner establishment were also subjected to comparison. CT examinations constituted a part of these comparative studies; serial images were prepared at regular intervals, at the ages of 2, 3, 4, 5, 6, 7, 8, 9, 10, 12, 14 and 16 weeks. For each bird (from a total of almost 1000 broilers, with two replicates) the cross-section of the breast muscle was determined.

The objectives set for this study were the *in vivo* estimation of the weight of the breast muscle of broiler chickens and the examination of muscle tissue development between the ages of two and eight weeks.

MATERIALS AND METHODS

The examinations were performed on Arbor Acres (AA) broilers of standard genotype (36 of each sex), within a weight range of 300 to 2000 g. The birds forming the experimental group originated from the stock used in comparative performance studies performed at the university Department of Poultry Breeding Science, and, as such, were housed in a livestock building operating under closed, intensive conditions, with deep

litter and a cubicle system, at the Experimental Livestock Production Site of the university faculty. The broilers were fed in accordance with the standard two-phase programme specified by the distributor.

At the ages of 2, 3, 4, 5, 6, 7 and 8 weeks 6 experimental birds of each sex were subjected to CT examination after being fasted for ten hours. These examinations were performed by means of the Siemens Somatom DRG equipment of the Diagnostics Centre, the slice thickness used being 8 mm and the step 8 mm; 15-25 CT images per bird were taken. The birds were examined lying in a prone position, without the use of anaesthetic.

In the evaluation of the cross-sectional images the surface area of the breast muscle was determined (involving between 6 and 11 images); pixel density data were also collected from each of the scans by means of an appropriately designed computer programme (Pannon University of Agriculture, Digital Imaging Centre, Kaposvár). Hounsfield variables were then calculated for the formulation of prediction equations, as described by *Romvári et al*. (1996). In the present work the extreme density values (corresponding to bone and air) were excluded, only those corresponding to muscle and fat being retained, i.e. the range from +200 to -200 on the Hounsfield scale (water=0). Each set of 10 consecutive HU values was taken collectively, resulting in 40 Hounsfield variables (HUv). These variables were used for the construction of three dimensional histograms (3D) from the frequency data, with negative exponential interpolation.

Subsequent to the CT examination trial slaughter was performed by cervical dislocation and the weight of the filleted breast muscle was recorded. In the evaluation of the data obtained the effect of sex was analysed by means of one-way ANOVA, and linear regression models were formulated for the purpose of defining the relations of the weight of muscle to its surface area and to its volume.

RESULTS AND DISCUSSION

Table 1 gives the mean body weight values determined for the mixed-sex groups at each examination, and also the weight of the breast muscle, filleted in the process of trial slaughter.

Table 1

Values for body weight and breast weight in the experimental stock examined, according to age group

Age (weeks) (1)	Live weight (g) (2)		Breast weight (g) (3)	
	average (4)	SD	average	SD
2	317	5.0	30	2.6
3	573	27	64	6.0
4	875	36	103	9.6
5	1303	121	172	15
6	1605	157	204	23
7	1908	135	285	16
8	2415	317	353	43

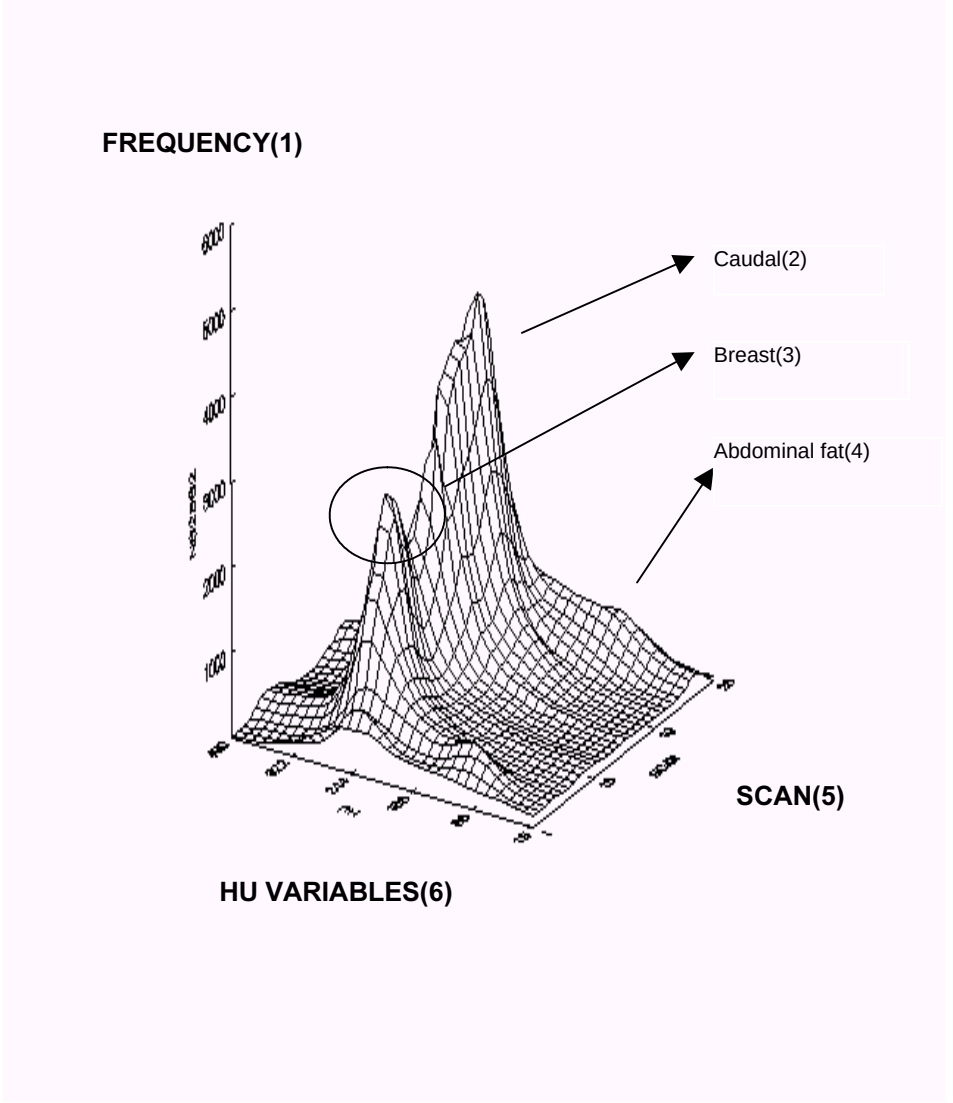
1. Tabelle: Körpergewicht und Brustgewicht im untersuchten Bestand nach Altersgruppen

Alter(1), Lebendgewicht(2), Brustgewicht(3), Durchschnitt(4)

The 3D histogram shown in *Figure 1* was produced on the basis of 24 images.

Figure 1

3D histogram for six-week-old broilers



1. Abbildung: 3D Histogram von einem Broiler im Alter von 6 Wochen

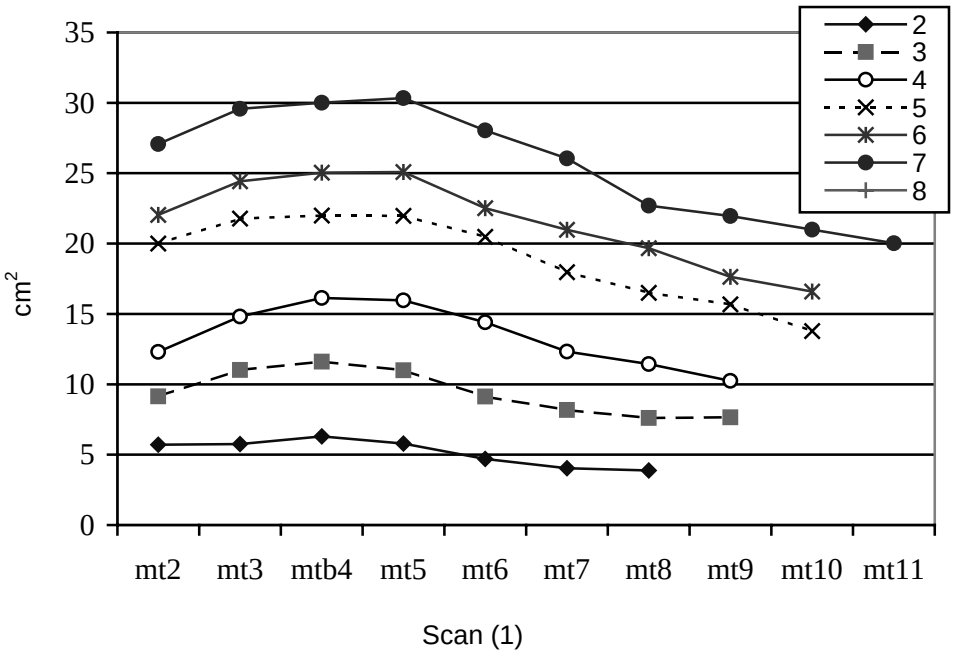
Frequenz(1), Caudales Ende(2), Brustmuskel(3), Abdominales Fett(4), Aufnahme(5), HU Variable(6)

In the muscle range on the histogram there emerge two peaks, clearly distinguishable, the first representing the area of the breast, the second that of the thigh.

In the range of the fat tissue, in addition to a fat depot in the region of the neck very pronounced abdominal fat deposition in the region of the pelvis is also evident.
On the basis of the 3D histogram, *Figure 2* illustrates changes in the mean values for breast muscle cross-sectional area for the respective age groups, in the range selected for the measurement of the breast muscle; these exhibit clearly visible maximum values. The largest muscle surface area was measured in the plane intersecting the second or the third rib, and, with the birds examined lying in prone position, the end of the clavicle (s3). It can also be observed that as age progresses the highest value shifts in the caudal direction (s4), indicating changes with the progress of time in the geometric configuration of the breast muscle.

Figure 2

Mean muscle surface area values, according to age group



2. Abbildung: Durchschnittliche Muskeloberfläche nach Altersgruppen

Aufnahme(1)

Table 2 shows the largest breast muscle surface area (maximum muscle surface) for the mixed sex groups determined at each examination, and also the breast muscle volume values calculated from all of the images evaluated.

Table 2

Muscle surface area and breast volume values for the experimental stock examined, according to age group

Age (weeks) (1)	Max. muscle surface (cm^2) (2)		Breast volume (cm^3) (3)	
	average (4)	SD	average	SD
2	6.3	0.61	21.9	2.6
3	11	0.70	49.7	6.0
4	16	1.2	76.4	6,9
5	21	1.6	118	15
6	25	1.8	135	36
7	30	1.9	169	35
8	33	3,5	194	39

2. Tabelle: Brustoberfläche und Brustvolumen im untersuchten Bestand nach Altersgruppen

Alter(Wochen)(1), Maximale Muskeloberfläche(2), Brustvolumen(3), Durchschnitt(4)

In addition, the effect of sex within the respective age groups was analysed by means of variance analysis (*Table 3*). This table illustrates quite clearly that body weight differs between the two sexes from the age of two weeks, while sex difference in breast weight and breast volume, i.e. the highest muscle cross-section values, emerges from the age of five weeks.

Table 3

Effect of sex on the parameters examined

Age (weeks) (1)	2	3	4	5	6	7	8
Live weight (2)	NS	***	***	***	***	***	***
Breast weight (3)	NS	NS	NS	*	**	NS	**
Max. muscle surface(4)	NS	NS	NS	***	**	*	*
Breast volume (5)	*	NS	NS	*	*	*	*

* P<0.1, ** P<0.05, *** P<0.01

3. Tabelle: Einfluss des Geschlechts auf die untersuchten Parameter

Alter(Wochen)(1), Lebendgewicht(2), Brustgewicht(3), Maximale Muskeloberfläche(4), Brustvolumen(5)

The weight of the filleted breast muscle was estimated by means of a linear regression model; breast muscle volume calculated on the basis of the CT images, i.e. the highest muscle cross-sectional area value, was used as the independent variable (*Table 4*).

Table 4

The r values determined for the estimation of breast muscle weight

Age (weeks) (1)	Volume (2)	Max. surface (3)
2	0.40	0.33
3	0.63	0.66
4	0.46	0.49
5	0.73	0.76
6	0.68	0.83
7	0.62	0.65
8	0.51	0.58

4. Tabelle: Die r-Werte für die Einschätzung des Brustmuskelgewichts

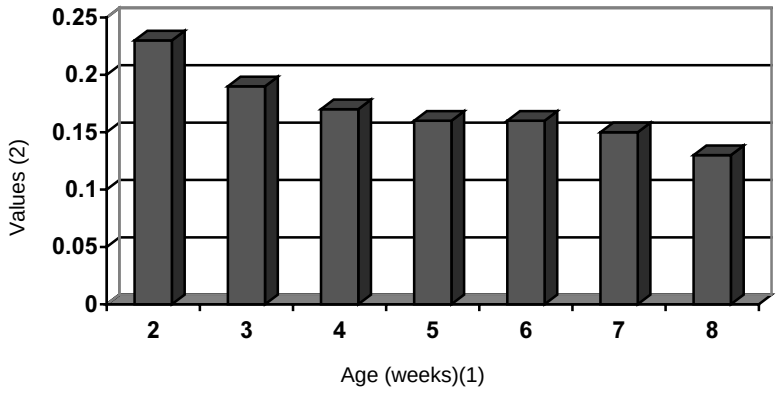
Alter (Wochen)(1), Volumen(2), Max.Oberfläche(3)

The low correlation values obtained at the age of two weeks can be explained primarily by the low body weight of the birds. This weight range (250–350 g) is near the lower limit of the CT examination. In the interpretation of the data obtained the relatively low number of samples for each group (n=12) should also be taken into account.

The ratio of maximum muscle surface area to values for muscle surface area totalled for each image, and also changes in this ratio, are illustrated in figure 3. It can be observed that with progressing age this value decreases, indicating changes in the spatial configuration of the breast muscle.

Figure 3

Ratio of max. muscle surface area to totalled muscle cross-section



3. Abbildung: Verhältnis der maximalen Muskeloberfläche und des gesamten Muskelquerschnittes

Alter (Wochen)(1), Werte(2)

On the basis of the evaluation of the cross-sectional images and the relations depicted in figures 2 and 3 it can be ascertained that the spatial configuration of the breast muscle changes with age. In the first weeks of life muscle growth in the plane intersecting the second and third rib, taken with birds examined lying in a prone position, is characteristic; with advancing age this growth shifts along the longitudinal axis of the animal in the caudal direction.

CONCLUSIONS

By means of non-invasive CT examination the weight of the breast muscle can, where body weight is above 500 g, be determined with an appropriate degree of accuracy.

Estimation determined with a single image, based on the highest muscle cross-section value, produces results similar to those obtained by estimation of volume on the basis of 6 to 11 images.

CT provides an unequalled possibility for the geometric configuration of the breast muscle to be examined by means of repeated imaging of the same animal. Thus, an objective set for further study is the 3D portrayal of the breast muscle, and, on the basis of this, the comparison of muscle development in different genotypes.

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