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COMPARISON OF THE GROWTH OF FAT AND LEAN TISSUE IN YOUNG RAMS BASED ON CT SCANNING

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ABSTRACT

Ten rams of Hungarian Merino, Suffolk and Texel (altogether 30 animals) were scanned by CT in three live weight categories to study tissue growth. The results of comparison showed breed effect in the volume of lean tissue at every live weight category, however, significant differences were not detected in the fat tissue volume, only at 5–7 kg category. Therefore the fatness of Hungarian Merino lambs is not unfavourable in this early life stage. At the same time Texel lambs have significantly higher meat yields than Suffolk and Hungarian Merino lambs. According to our observation the growth coefficients (b_1) in the allometric equations for fat and lean tissue (which were 0.86–1.4 and 0.75–1.14, respectively) in Texel and Hungarian Merino rams were higher than that of Suffolk rams. Investigations will be extended up to mature size for describing tissue growth and development of lambs and detecting the divergency among the studied breeds. Moreover, further examinations with more animals are required to specify the exact growth patterns.

Key words: sheep / lambs / breeds / Hungarian Merino / Suffolk / Texel / growth / CT / fat tissue / lean tissue / meat

SPREMLJANJE RASTI MAŠČOBNEGA IN MIŠIČNEGA TKIVA PRI MLADIH OVNIH S CT MERITVAMI

IZVLEČEK

Avtorji so s pomočjo CT meritev spremljali rast tkiv pri treh različnih telesnih masah ovnov pasem madžarski merino (n=10), suffolk (n=10) in texel (n=10). Primerjava rezultatov meritev je pokazala vpliv pasme na volumen mišičnega tkiva pri vseh treh merjenih telesnih masah. Razlike v volumnu maščobnega tkiva niso bile statistično značilne, razen pri kategoriji od 5 do 7 kg. Zamaščenost jagenjčkov pasme madžarski merino je bila pri tej kategoriji primerna. V istem obdobju so imeli jagenjčki pasme texel značilno večjo vsebnost mesa v primerjavi z jagenjčki pasem suffolk in madžarski merino. Meritve kažejo, da so bili koeficienti rastnosti (b1), izračunani s pomočjo alorimetrične enačbe, za maščobno (0,86–1,4) in mišično tkivo (0,75–1,14) pri ovnih pasem texel in madžarski merino višji kot pri ovnih pasme suffolk. Avtorji bodo prihodnje raziskave razširili na proučevanje rasti tkiv in razvoja ovnov ter odkrivanje razlik med opazovanimi pasmami tudi na obdobje odrasle velikosti ovnov. Za podrobnejši in natančnejši opis rasti bo v prihodnje potrebno v raziskave vključiti večje število živali.

Ključne besede: ovce / jagnjeta / pasme / madžarski merino / suffolk / texel / rast / CT / maščobno tkivo / mišično tkivo / meso

INTRODUCTION

The sheep industry appears to have a fundamental world-wide crisis. Lewis *et al*. (1995, cited in Stanford *et al*., 1998) reported the lamb consumption has markedly declined over the past 30 years, with the exception of the major exporting countries (New-Zealand and Australia). We are a witness to a similar process in Hungarian meat consumption, which the lamb has a very low proportion in. The prices of meat increased exponentially and reason of declining consumption can also be explained by the changes in life style and delusions from misinterpretation or new scientific results.

As it is outlined by Ward *et al*. (1995) and Horn (1991) consumers require meat of favourable composition, namely with more lean and less fat (with a minimal fat level to maintain juiciness and flavour). Consistent quality and low wastage of ration (tendon, fat, meat membrane) are also required. Unfortunately, lamb is currently failing to meet these consumer demands (Ward *et al*., 1995), so to reverse this trend a solution has to be found (Stanford *et al*., 1998).

The main traits of carcass (dressing percentage, proportion of cuts) and carcass composition in sheep are moderately high heritable (Simm, 1992), therefore in these characteristics the selection based on own performance can be efficient. The methods of evaluating body composition in vivo are very effective tools in selecting for these traits, Stanford *et al*. (1998) also declared it in their exhaustive review. The first report on the use of CT in animal science was by Skjervold *et al*. (1981), who showed CT provided the most accurate technique of all in vivo measurements of body components, due to fact that between HU (Hounsfield unit) values of main tissues of the body are not overlapping (table 1) (Hounsfield, 1980, cited in Sehested, 1986).

Results of studies confirmed in pigs (Skjervold *et al*., 1981) and sheep (Afonso, 1992; Jopson *et al*., 1995) that CT values could predict fat and lean tissue with high accuracy (r^2=0.75–0.93 and r^2=0.89–0.98, respectively). According to Romvári (1996) and Romvári *et al*. (2000) the CT is applicable in poultry and rabbit breeding for estimation of some slaughter traits. In spite of the 10-fold higher cost of CT as compared to ultrasound (Parratt and Simm, 1987), the genetic progress can be increased efficiently and economically in large number of animals by using CT (Simm, 1992; Jopson *et al*., 1995; Romvári *et al*., 2000; Jones *et al*., 2002). Moreover CT methodology can be used for prediction of sheep S/EUROP evaluation (Toldi *et al*., 2001).

The intensity, duration and capacity of live weight gain depend on type of breed and utility. However, it can be stated after the intensive period of muscle gain the live weight gain also slows down (Hammond, 1932). At optimal conditions the growth rate of the lambs is the highest in the first 5 month (Göhler, 1979 cited in Mezőszentgyörgyi, 2000). The study of Veress *et al*. (1995) showed that the ideal slaughter weight of sheep is at the 50–55% of mature body weight. The growth curve of lamb body components have sigmoid pattern, but the velocity and duration differ, due to the function of tissues (Hammond, 1960). Göhler (1979) found that after 4 month of age the proportion of muscle and bone decreased, while the fat increased.

The changes in proportion of body components of sheep relative to age were also studied by X-ray CT. The growth coefficients for fat areas and subcutaneous fat depth were higher, on the other hand for carcass lean tissue were smaller than for live weight (Afonso, 1992). Changes in proportion of body parts were also scanned. According to the results of Mezőszentgyörgyi (2000), the proportion of head, neck, legs and thighs decreased, whereas the proportion of long and short loin, shoulders and breasts increased between 25 kg and 45 kg weight intervals in Hungarian Merino rams. He found that CT-measured muscle area of long and short loin in Hungarian Merino did not change significantly beyond 35 kg, while it increased linearly in Suffolk sheep until 45 kg.

This is preliminary results of a study to follow the growth of lambs from the earliest possible age which has no hindering effect on lamb growing to maturing age. Our aims were to make a comparison among two meat types and Hungarian Merino rams and to describe the development of fat and muscle tissue of carcass and valuable cuts from the suckling to market weight.

MATERIALS AND METHODS

The growth of three breeds (10 Hungarian Merino, 10 Suffolk and 10 Texel rams) which are strongly differing in intensity and duration of gain, were estimated in three weight classes. The first measuring was at 5–7 kg, the second was at 15–17 kg (this category is the most common weight intending to Italian market) and the third was at 25–27 kg (the class when carcasses are dissected and sold in cuts). The lambs were reared in identical circumstances.

The most significant advantage of CT is that animals can be accurately re-measured subsequently as required, without destruction. This ability makes the CT the ideal tool to model growth exactly even in the individual (Vangen and Jopson, 1996) or in few animals.

The experiment was accomplished in the Diagnostic and Oncoradiology Institute of Kaposvár University by means of a Siemens Somatom Plus S40 CT scanner based upon serial exposures and following the CT examination protocol and animal hygienic regulations (12–24 hours starvation of animals, weighing, sedation, fixation, imaging, relaxation before transportation). The images were taken from the first cervical vertebra to the hock with 10 mm slice thickness and with varying (10–22 mm) thick imaginary slice, depending on the distance of the joint of shoulder and femur.

The archivated images (on CD-ROM) were processed by the so-called CTPC postprocessor (Berényi and Kövér, 1991). The demarcated area and its tissue division were recorded according to the density measures of table 1. With knowledge of the areas and step distances predicted volumes of tissues and meat parts were calculated.

Table 1. Hounsfield variables relating to certain tissues (Hounsfiled, 1980)

Values relating to different tissue types	Hounsfield variables
Fatty tissue	-200– -20
Water dense substances	-20–20
Muscle tissue	20–200
Bone tissue	600–1500

During the fattening of meat animals (eg. lamb) to market weight, growth may appear almost linear with a constant velocity, since this period is in the first part of the sigmoid curve (Swatland, 1994). To preclude the possibility of error in choice of estimate functions, we used a simple mathematical method described by Huxley (1932, cited in Kusec, 2001) for determining the allometric growth pattern (tissues and organs compare to whole body):

$$y = b_0 * x^{b_1} \quad \rightarrow \quad \log y = \log b_0 + b_1 * \log x,$$

where y = fat or lean tissue (cm^3) and x = live weight (kg).

Analyses were performed with SPSS® for Windows™ 10.0 software. Breed effect in each category was evaluated by one-way ANOVA where live weight was used as covariant. Means were compared by LSD test at $P \leq 0.05$. Allometric equations of fat and lean tissue growth was estimated by regression analysis. The regression coefficients of the parts of the breeds were compared with t-test ($P \leq 0.0025$).

RESULTS AND DISCUSSION

At the beginning of the investigations when lambs were approximately one month old Hungarian Merino lambs were significantly smaller than the meat type lambs. Live weight differences disappeared from the third scanning (table 2).

Table 2. Live weight of different breeds in each category

Live weight, kg	1. category		2. category		3. category	
	Mean	S.D.	Mean	S.D.	Mean	S.D.
Hungarian Merino	5.42[a]	0.64	16.10[ab]	2.45	24.92[a]	2.38
Suffolk	7.43[b]	2.31	16.94[a]	1.83	25.82[a]	2.49
Texel	7.39[b]	1.88	14.33[b]	1.84	25.60[a]	3.13

The letters in table show the difference between breeds at P≤0.05 significance level in each categories.

Means adjusted by covariance are shown in table 3 and 4. Suffolk rams had the largest amount of fat on the whole carcass in every categories, however, this was significant only at 5–7 kg. Morover, similar tendency can be detected on the measuring of valuable cuts (long and short loin, and leg). The Hungarian Merino lambs tend to deposit more fat on their carcass, but did not differ from the meat types significantly (P≤0.05) in the second and third live weight categories. In addition these are our principal lamb export sizes where the relatively high fat content of Hungarian Merino lambs is not unfavourable. This is an important fact, because the proportion of Hungarian Merino in national lamb production is more than 90% (Mucsi, 1997).

Table 3. Comparison of fat tissue volume of the three breeds on carcass and valuable cuts

Live weight (kg)	Breed	sum of fat tissue volume on carcass, cm^3		sum of fat tissue volume on long loin, cm^3		sum of fat tissue volume on short loin, cm^3		sum of fat tissue volume on leg, cm^3	
		Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
1. category	Hungarian Merino	147.92[a]	23.84	5.57[a]	1.03	6.87[ab]	1.60	54.73[a]	7.25
	Suffolk	345.43[b]	163.10	14.61[b]	8.97	13.62[a]	6.87	108.10[b]	43.90
	Texel	227.33[a]	94.88	8.42[a]	2.08	9.72[b]	4.41	79.40[a]	30.69
2. category	Hungarian Merino	521.23	103.63	14.53	4.56	27.55	6.77	171.24	34.27
	Suffolk	546.35	203.71	17.27	7.08	27.36	9.96	176.94	60.61
	Texel	441.00	90.20	14.67	3.07	23.10	4.29	149.44	23.03
3. category	Hungarian Merino	1011.69	287.48	32.19	9.81	53.79	16.72	321.21	85.25
	Suffolk	1066.46	428.99	38.70	19.67	58.36	24.50	331.20	121.82
	Texel	983.93	205.67	35.35	7.48	53.49	6.87	299.40	52.83

The letters in table 3 to 6 show the difference between breeds at P≤0.05 significance level in each traits.

It is obvious from the data in table 4 that Texel rams had significantly higher meat yield in carcass and in any of the first class meat parts than Suffolk and Hungarian Merino lambs. The only exception is in the sum of lean tissue volume of short loin at 5–7 kg where the breeds were not distinct from each others (P>0.05). Lean tissue showed the tendency of being higher in Suffolk lambs than in Hungarian Merino in the first and the third category whilst the difference was proved by statistically only in the second category.

Table 4. Comparison of lean tissue volume of the three breeds on carcass and valuable cuts

Live weight, kg	Breed	sum of lean tissue volume on carcass, cm^3		sum of lean tissue volume on long loin, cm^3		sum of lean tissue volume on short loin, cm^3		sum of lean tissue volume on leg, cm^3	
		Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
1. category	Hungarian Merino	1779.72[a]	248.44	95.69[a]	19.16	111.23	15.46	679.24[a]	84.32
	Suffolk	2684.37[a]	805.32	168.31[ab]	66.68	179.46	61.18	1001.58[a]	334.14
	Texel	3007.62[b]	844.04	172.76[b]	52.59	179.16	60.31	1172.39[b]	363.34
2. category	Hungarian Merino	4578.20[a]	698.13	227.19[a]	44.03	343.63[a]	64.14	1720.58[a]	273.55
	Suffolk	5402.19[b]	740.69	289.59[b]	55.11	374.03[a]	51.40	2076.31[b]	322.17
	Texel	5582.45[c]	944.65	296.89[c]	56.91	397.25[b]	100.78	2209.85[c]	379.55
3. category	Hungarian Merino	7411.36[a]	2959.23	345.86[a]	35.25	551.55[a]	86.89	2850.74[a]	346.98
	Suffolk	8052.61[a]	2837.57	405.51[a]	97.15	556.42[a]	142.26	2984.15[a]	454.32
	Texel	9246.95[b]	4277.34	523.63[b]	70.30	713.68[b]	129.48	3768.75[b]	463.09

For the analysis of growth describing part-to-whole relationship in the range of 5–27 kg live weight, the original Huxley's monophasic form of allometric function was used, suggested by Kusec (2001). Table 5 and 6 shows the relative growth of fat and lean volumes in relation to live weight expressed as monophasic allometric coefficients (b_1).

Taking into consideration description of Hammond (1960), it can be stated that allometric coefficients of late-maturing nature fat were higher than 1 (see in table 5) and the muscle tissue grows slower than the whole body (see in table 6), thus the growth coefficients (b_1) were close to unity ($b \approx 1$). These predicted values of tissues were similar to the results of Afonso (1992) in sheep and Kusec (2001) in pigs.

Table 5. Comparison of logarithmic growth equations for fat tissue volume of investigated ram lambs

Examined part	$\log Y = \log b_0 + b_1 \log X$	Hungarian Merino	Suffolk	Texel
sum of fat tissue volume on carcass	R^2	0.93	0.73	0.92
	b_0	1.28	1.65	1.30
	b_1	**1.21[a]**	**0.93[ab]**	**1.18[b]**
sum of fat tissue volume on long loin	R^2	0.90	0.56	0.88
	b_0	0.53	0.16	–0.03
	b_1	**1.06[a]**	**0.86[b]**	**1.09[c]**
sum of fat tissue volume on short loin	R^2	0.92	0.85	0.96
	b_0	–0.13	0.06	–0.25
	b_1	**1.31[a]**	**1.17[b]**	**1.40[b]**
sum of fat tissue volume on leg	R^2	0.93	0.77	0.93
	b_0	0.92	1.18	0.94
	b_1	**1.11[a]**	**0.92[b]**	**1.08[c]**

Significant breed effect were observed between growth coefficients (see in table 5 and 6). The pattern of fat growth of both breeds (Texel and Hungarian Merino) were almost identical in this experiment. Suffolk, being a late maturing breed, had a lower b_1 values for fat and for lean tissue than the other two breeds. Most of the equations fitted closely to data of the examined parts (R^2 >0.9). Suffolk lambs, however, had lower value of R^2 (0.56–0.85) in fat tissue estimation.

Table 6. Comparison of logarithmic growth equations for lean tissue volume of investigated ram lambs

Examined part	$\log Y = \log b_0 + b_1 \log X$	Hungarian Merino	Suffolk	Texel
sum of lean tissue volume on carcass	R^2	0.98	0.97	0.99
	b_0	2.56	2.68	2.65
	$\mathbf{b_1}$	**0.93**[a]	**0.85**[ab]	**0.95**[b]
sum of lean tissue volume on long loin	R^2	0.96	0.81	0.97
	b_0	1.34	1.55	1.43
	$\mathbf{b_1}$	**0.85**[a]	**0.75**[b]	**0.92**[b]
sum of lean tissue volume on short loin	R^2	0.96	0.93	0.97
	b_0	1.28	1.44	1.26
	$\mathbf{b_1}$	**1.04**[a]	**0.92**[ab]	**1.14**[b]
sum of lean tissue volume on leg	R^2	0.98	0.96	0.98
	b_0	2.14	2.21	2.22
	$\mathbf{b_1}$	**0.93**[a]	**0.90**[b]	**0.97**[c]

The growth pattern of lean tissue on short loin relative to live weight of the three breeds are presented in Figure 1. According to the results of t-test it can be stated that the growth of Texel lambs was not different from the other two breeds, while the Hungarian Merino and Suffolk lambs significantly differed (P≤0.0025). In general the growth curve of late maturing nature Suffolk lambs were sloping more gently, than the growth curve of Texel or even the Hungarian Merino lambs. It is based on fact that Texel breed and crossbreeds ready to slaughter at the earliest age, whilst Suffolk lambs are fattened up to larger weight to achieve the highest percentage (Mucsi, 1997).

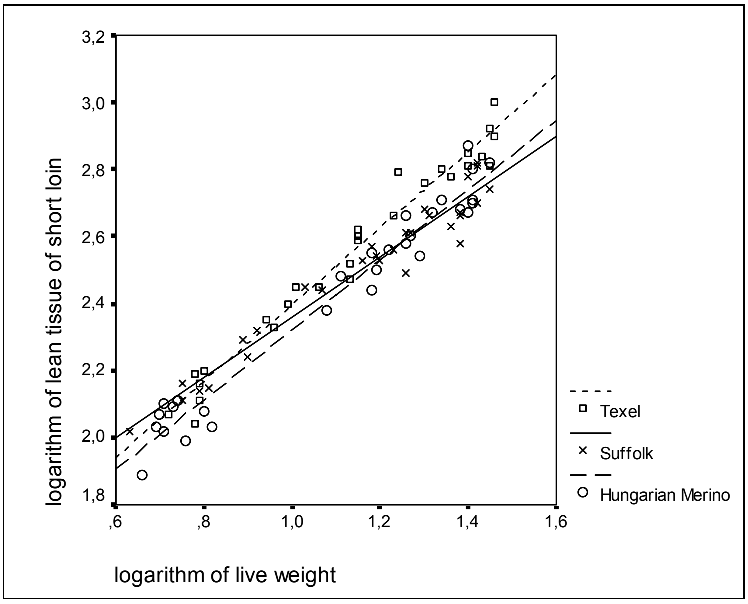

Figure 1. Growth of lean tissue of breeds on short loin.

CONCLUSIONS

The non-invasive ability of CT measure both short and long term changes in body composition accurately which makes it the ideal tool to model growth (Vangen and Jopson, 1996). The allometric equation is suitable for evaluating the growth in few live weight categories. Determination coefficients were very high ($R^2 > 0.9$), consequently the tissue volume can be predicted from live weight. The growth coefficients were obtained for fat and lean tissue 0.86–1.4 and 0.75–1.14, respectively. These b_1 values were higher in Texel and Hungarian Merino than in Suffolk rams, since they develop faster and grow up to smaller mature size.

Investigations will be extended up to mature size for describing tissue growth and development of lambs as well as the relative growth of meat parts in relation to live weight. Other equations will be tested to fit on the data of whole growth. Moreover, further examinations with larger number of animals are required to specify the exact growth patterns and to detect accurately the divergency among the studied breeds.

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