Estimation of carcass composition and fat depots by means of subcutaneous adipocyte area and body and tail measurements in fat-tailed Akkaraman lambs

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Abstract

This study was conducted to establish prediction equations for subcutaneous adipocyte area and body and tail measurements to estimate carcass composition and fat depots of indigenous Akkaraman lambs. As a major carcass tissue, body fat depots play an important role in deciding the optimum slaughter weight and grading of the carcass and meat quality. In this respect, forty male Akkaraman lambs were slaughtered and dissected to define the partitioning of fat among body depots after recording the body and tail measurements and taking adipose tissue samples. Mean cold carcass weight was 19.8 kg with a composition of 48.9% muscle, 30.3% fat, 19.6% bone and 1.2% waste. The dressing percentage was 48.4 %. Tail fat, subcutaneous fat and intermuscular fat were the major fat depots with overall means of 15.3%, 10.2% and 4.9%, respectively. Heart girth had the highest correlation (r = 0.91) with total body fat, while tail circumference had the highest correlation (r = 0.72) with total body fat among the tail measurements. Correlation coefficients were also high between the adipocyte area and cold carcass (r = 0.84), total body fat (r = 0.84) and carcass fat (r = 0.86) values. The established regression equations showed that tail fat (R^2 = 0.81), carcass fat (R^2 = 0.89) and total body fat (R^2 = 0.93) weights could be predicted with a high accuracy. It is concluded that carcass composition and body fat depots could be estimated with a high degree of accuracy by establishing the regression equations based on the adipocyte area and external measurements of the body and tail in Akkaraman lambs.

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Introduction

Production of safe, nutritious and uniform lean lamb is a main goal of the sheep industry. Lean lamb can be produced through the manipulation of the nutritional regimen or through a selection program. For both approaches, a knowledge of lamb carcass composition and its evolution are required. Defining the pattern of growth and distribution of fat in small ruminants is essential to understand the dynamics of body and carcass composition changes associated with production, marketing and survival during nutritionally unfavourable seasons (Negussie *et al.*, 2000). Measuring adipose cell size, for example, can be a rapid and cheap method of estimating the proportion of body fat in ewes and it may be used under experimental conditions to predict mean body fat mobilization or deposition in a relatively small group of animals. Through the use of a biopsy sample, it would also appear to be possible to repeat observations more frequently on the same animal within an experiment, thus improving the precision of the method and monitoring the evolution of adipose reserves of the body (Susmel *et al.*, 1994). The diameter of subcutaneous fat cells allows for an efficient separation of animals with different body conditions obtained after different feeding regimens, and an appreciation of the evolution of their body reserves over short periods of time, which appeared to be coherent with the expected pattern of mobilization of adipose deposits during lactation (Piasentier *et al.*, 1994). Since fat accumulation and partitioning differ among breeds, it is necessary to develop prediction equations for body fat depots for different breeds (Wright & Russel, 1984). Akkaraman fat-tailed is the main sheep breed in Turkey and this breed supplies a large proportion of the lamb's meat in this country.

The main objective of this study was to establish prediction equations from subcutaneous adipocyte area and body and tail measurements to estimate carcass composition and fat body depots of indigenous Akkaraman sheep.

Materials & Methods

This study was carried out at the Sheep Research Centre of the Afyon Kocatepe University. Forty native fat-tailed single-male Akkaraman lambs were used as research material. The lambs were selected according to their body weight and health condition from a flock, and were reared by their dams until weaning at two months of age. Similar environmental and husbandry conditions were provided to the lambs. The feeding of the lambs was an *ad libitum* feeding of dry lucerne and a commercial lamb concentrate. Water was supplied *ad libitum*. During the study the lambs were kept indoors in a half-open sheep-yard, and were routinely checked for any health problems. They were drenched against internal parasites at specific intervals and vaccinated against anthrax and clostridia diseases. Body and tail measurements were performed monthly. Withers height (WH) was measured as the distance from the surface of a platform to the withers and rump height (RH) as the distance from the surface of a platform to the top of the rump. Heart girth (HG) was measured as the circumference of the chest. Chest depth (CD) was measured as the distance between the top of the withers and the bottom line of the chest. Circumference and length measures were taken with a flexible tape and calipers were used for depth measurements. Tail dimensions were taken at the largest interval for length and width and at the base to determine the thickness. Circumference was measured using a tape. Depth was measured with calipers and length and width were measured using a ruler. Subcutaneous adipose tissue samples were taken monthly via biopsy to determine the average adipocyte areas. Samples of 1 g were taken from the base of the tail, 3 cm to the left side of the central line of the tail using an 18 G x 25 cm automatic human biopsy syringes. Linear body measurements were taken together with weight measurements while the animals were immobilized. Feed was withdrawn 12 h before each session of taking measurements. Before slaughter, final body and tail measurements were recorded and adipose tissue biopsy samples were collected. Feed was withheld 12 h before slaughter but water was provided. After being transported to the slaughterhouse, the 40 lambs were slaughtered within 2 h. The slaughtering process entails the severing of the jugular vein and the carotid arteries and removal of non-carcass organs. After slaughter, the carcasses were stored overnight at 4 °C for 24 h. The weight of each cold carcass was taken before the fat-tail cut was removed. The fat-tail was then dissected from the carcass and weighed. The carcasses were split longitudinally into two equal halves using a band saw. The weights of the right and left sides were recorded. The left side was divided into six cuts (leg, shoulder, brisket, neck, back and loin), which were dissected into muscle, bone and fat (subcutaneous and intermuscular) tissue to assess the variation in composition of dissectible body components and the growth and partition of fat between body depots. Each tissue sample and fat depot were weighed separately. Weights of carcass parameters (muscle, bone, fat) were doubled to give total carcass muscle, bone and fat. Weights of the different fat depots were also summed to give total body fat (TBF). Individual body fat depots were grouped into three major classes: non-carcass fat (kidney, omental and mesenteric fats), carcass fat (CF – subcutaneous and intermuscular fats) and tail fat (TF) to assist in the analysis of differential growth and partitioning of fat among body depots. The TBF was calculated as the sum of tail fat, carcass fat and non-carcass fat depots. The subcutaneous adipose tissue samples were fixed in a bouin solution and embedded in paraffin, using standard methods (Ashwell *et al*., 1976). Paraffin blocks were then sectioned at a thickness of 5 µm and the sections were stained using triple staining according to the Crossmonn modification (Crossmonn, 1937). After staining all sections and micrometric lams were photographed, using an Olympus BX50 microscope. An Image J 1.37 software program was used to measure the adipocyte area (AA). The program was calibrated by using micrometric lam. The area of each adipocyte was calculated in a random field (about 0.36 mm^2 area). All statistical analyses including Pearson correlations and regressions were calculated using a SPSS program designed for windows (SPSS, 1998). Regression analysis was used to develop relationships between live animal traits and carcass measurements.

Results

Body weight, body measurements, tail measurements and adipocyte measurement are shown in Table 1. Among the body measurements, particularly the parameters that were correlated with the carcass components, are presented in Table 1. Body weights ranged from 35.5 to 48.9 kg. This represents the

commercial age-weight slaughter range for Akkaraman lambs. Of the tail measurements, circumference and width showed that the tail is larger in width than in length, which is a typical characteristic of the breed. Regarding the adipocyte cell dimensions, mean area for adipocyte cells was 0.005 mm^2. Cell area calculation seemed to be more accurate than the diameter parameter due to variation in size differences of adipocyte cells in samples.

In addition to carcass characteristics, the partitioning of fat among major body depots was assessed by expressing the weight of each depot as a percentage of the cold carcass and total body fat (Table 2). All carcass component values increased as slaughter weight increased. Thus, heavier body components were measured probably due to higher slaughter weights.

Correlation coefficients of final body, tail measurements, and carcass components are shown in Table 3. Significant correlations were found between body and tail measurements, and the carcass components. The high correlations between body and cold carcass weight, total body fat, heart girth and adipocyte area were particularly dramatic in terms of fat partitioning predictions. In addition, the high correlations between cold carcass and total body fat, carcass fat, heart girth and adipocyte area strengthened the validity of the regression equations. Tail fat exhibited a high correlation with tail circumference, as expected.

The prediction equations based on body and tail measurements and adipocyte areas for these Akkaraman lambs are shown in Tables 4 and 5. Body weight seems to be the main parameter in predicting the equations. The TBF appears to be easily predicted using BW and HG parameters in the regression equations, while BW and TC were the most useful parameters in estimating CF. However, prediction equations for TBF, CF and TF in which AA was included, seem to be more accurate. On the other hand, no changes occurred in CM and CB prediction equations when AA parameter was included.

In the above equations, total body fat (R^2 = 0. 93) could be predicted more accurately than carcass fat (R^2 = 0.89) and tail fat (R^2 = 0.81). On the other hand, carcass and tail fat prediction equations involved the measurement of a lower number of independent variables that might be useful under practical conditions.

Table 1 Mean (± s.e.) body weight (kg), body measurements (cm), tail measurements (cm) and adipocyte measurement (mm^2) of Akkaraman lambs

Trait	Mean ± s.e.	Min	Max
Body weight (kg)	41.6 ± 0.54	35.5	49.0
Body measurements (cm)			
Heart girth	80.2 ± 0.48	75.0	84.0
Chest depth	28.5 ± 0.29	25.0	32.0
Withers height	65.6 ± 0.33	60.0	70.0
Rump height	66.0 ± 0.17	60.0	70.0
Tail measurements (cm)			
Tail circumference	63.1 ± 0.33	60.0	68.0
Tail length	17.6 ± 0.40	14.0	22.0
Tail width	32.9 ± 0.47	27.0	39.0
Tail thickness	2.5 ± 0.04	2.0	2.9
Adipocyte area (mm^2)	0.005 ± 0.001	0.004	0.006

Discussion

In the present study the average body weight of the lambs at slaughter was 41.6 kg. Studies regarding slaughter and carcass traits of Akkaraman lambs indicated that slaughter weight varies from 35 to 50 kg (Kadak, 1983; Tekin *et al*., 1993; Tufan, 1997; Şahin & Akmaz, 2002; Ünal *et al.*, 2006a; b). Mean cold carcass weight was 19.8 kg with a composition of 48.9% muscle, 30.3% fat, 19.6% bone and 1.2% waste. The dressing percentage was 48.4% and the mean tail fat percentage was 15.3%. The average dressing percentage for Akkaraman lambs was found by other researchers to be 46.3 to 54.2%, whereas the average tail fat percentage ranged from 14.7 to 20.9% (Tekin *et al*., 1993; Tufan 1997; Esen & Yıldız, 2000) which seems to be similar to those in the present study. Tufan & Akmaz (2001) reported carcass weight, dressing percentage and ratios of muscle, fat and bone as 20.2 kg, 50.3%, 44.7%, 21.4% and 15.3%, respectively. Sahin & Akmaz (2002) measured the cold carcass weight, dressing percentage and tail fat (2.85 kg) percentage as 18.2 kg, 46.0% and 15.6%, respectively, for the same breed at a 40 kg body weight. Esen & Yıldız (2000) reported a carcass (22.1 kg) dressing percentage of 48.9% and a tail fat percentage of 17.9% for Akkaraman lambs slaughtered at 45 kg body weight. Ünal *et al*. (2006 a; b) also found the dressing percentages as 49.3% for Akkaraman lambs slaughtered at 45 kg body weight. On the other hand, Kadak (1983) recorded a dressing percentage, and muscle, fat and bone percentages of Akkaraman lambs at

Table 2 Mean (± s.e.) carcass cut and component values for Akkaraman lambs

Trait	Mean ± s.e.	Min	Max
Carcass weight (kg)	19.8 ± 0.35	16.4	24.8
Dressing percentage (%)	48.4 ± 0.31	43.3	51.7
Carcass composition (kg)			
Muscle	9.5 ± 0.22	7.39	12.6
Bone	3.76 ± 0.07	3.36	3.98
Subcutaneous fat	2.03 ± 0.05	1.42	2.67
Intermuscular fat	0.97 ± 0.02	0.60	1.19
Tail fat	3.01 ± 0.06	2.54	3.42
Carcass composition (%)			
Muscle	48.9 ± 0.43	40.93	54.4
Bone	19.6 ± 2.07	15.96	22.5
Subcutaneous fat	10.2 ± 0.15	8.55	11.4
Intermuscular fat	4.88 ± 0.11	3.33	6.05
Tail fat	15.29 ± 0.24	12.86	17.62
Fat depots (kg)			
Carcass fat	2.99 ± 0.06	2.29	3.83
Non-carcass fat	0.32 ± 0.01	0.25	0.44
Fat-tail	3.01 ± 0.06	2.54	3.42
Total body fat	6.32 ± 0.11	5.21	7.56

Table 3 Correlation coefficients of final body and tail measurements and carcass components of fat-tailed Akkaraman ram lambs

	BW	CC	TBF	CF	TF	CM	CB	TC	TW	HG	AA
BW	1	0.950**	0.903**	0.910**	0.602**	0.885**	0.851**	0.655**	0.627**	0.890**	0.797**
CC		1	0.920**	0.926**	0.700**	0.944**	0.859**	0.744**	0.725**	0.940**	0.837**
TBF			1	0.914**	0.667**	0.818**	0.816**	0.716**	0.623**	0.906**	0.839**
CF				1	0.714**	0.852**	0.805**	0.758**	0.645**	0.893**	0.857 **
TF					1	0.622**	0.576**	0.884**	0.657**	0.737**	0.758**
CM						1	0.786**	0.679**	0.676**	0.888**	0.800**
CB							1	0.593**	0.628**	0.855**	0.670**
TC								1	0.608**	0.733**	0.734**
TW									1	0.713**	0.601**
HG										1	0.453**
AA											1

** $P < 0.01$

Abbreviations: Body weight (BW); Cold carcass (CC); Total body weight (TBF); Carcass fat (CF); Tail fat (TF); Carcass muscle (CM); Carcass bone (CB); Tail circumference (TC); Tail width (TW); Heart girth (HG); Adipocytes area (AA).

Table 4 Prediction equations based on body and tail measurements for Akkaraman lambs

Established equations without considering the adipocyte area measurements	R^2	RSD
Total body fat (TBF)= -6.275 + 0.11*HG + 0.09*BW	$R^2 = 0.87$;	RSD = 0.25
Carcass fat (CF)= -3.92 + 0.08*BW + 0.06*TC	$R^2 = 0.82$;	RSD = 0.14
Tail fat (TF)= -1.987 + 0.73*TC + 0.12*TW (based on tail dimensions)	$R^2 = 0.81$;	RSD = 0.09
Tail fat (TF)= -2.500 + 0.79*TC + 0.019*CD	$R^2 = 0.78$;	RSD = 0.08
Carcass muscle (CM)= -16.474 + 0.227*HG + 0.188*BW	$R^2 = 0.83$;	RSD = 0.58
Carcass bone (CB)= -1.149 + 0.025*HG + 0.024*BW + 0.029*RH	$R^2 = 0.79$;	RSD = 0.08

Table 5 Prediction equations based on body and tail measurements and adipocyte areas for Akkaraman lambs

Established equations considering the adipocyte area measurements	R^2	RSD
Total body fat (TBF)= −5.505 + 0.053*WH + 257.53*AA + 0.060*BW+ 0.59*TC	R^2= 0.93;	RSD= 0.22
Carcass fat (CF)= -2.916 + 0.068*BW + 159.05*AA + 0.037*TC	R^2 =0.89;	RSD= 0.13
Tail fat (TF)= -1.598 + 0.067*TC + 73.08 AA	R^2 =0.81;	RSD= 0.07

a 42 kg slaughter weight to be 51.3%, 58.5%, 18.4% and 19.0%, respectively, when based on the cold carcass. The results in this study appear to be in accordance with the reported values despite the slight differences that might be due to different slaughter weights.

Although the Akkaraman breed has a typical fat tail, few studies were conducted to determine the relationships between tail dimensions and other body and carcass characteristics. Akçapınar *et al.* (2000) reported the tail circumference of 51.0 cm for Akkaraman lambs slaughtered at 36.0 kg, and indicated that tail circumference decreased in crossbreds. On the other hand, Ünal (2002) measured tail circumference as 59.1 cm for Akkaraman lambs at 36.6 kg live weight. For the same animals he also recorded wither height, heart girth, chest depth, tail width and length parameters of 65.3 cm, 85.5 cm, 31.6 cm, 26.2 cm and 25.5 cm, respectively. In another study, Ünal *et al.* (2006a; b) recorded withers height, heart girth and tail circumference as 64.3 cm, 78.1 cm and 47.8 cm, respectively, for Akkaraman lambs at a live weight of 32 kg. Esen & Yıldız (2000) reported heart girth and chest depth measurements of 70.5 cm and 26.2 cm for Akkaraman lambs slaughtered at 45 kg. The withers height, heart girth, chest depth, tail width, length and circumference in the present study on Akkaraman lambs at 41.6 kg slaughter weight were 65.6 cm, 80.2 cm, 28.5 cm, 32.9 cm, 17.6 cm and 63.1 cm, respectively. These measurements were recorded generally on animals at different live weights. Therefore, some differences could be due to individual variation and level of fattening of the animals in the different studies.

Using the size or number of the adipocytes in estimating the growth and proportion of fat in sheep, has been studied by several researches (Piasentier *et al*., 1994; Susmel *et al*., 1994; Purroy *et al*., 1995). Most of these researchers considered the cell diameter as a parameter to represent the adipocyte cell size. In this study we initially tried to use the diameter, but variations the size of cells forced us to use cell area. Because the results were more accurate and satisfactory, we preferred area as a parameter to represent cell size. In addition, similar to the findings of mentioned researchers, we measured positive correlations between adipocyte size and proportion of fat in the carcass (Table 3).

With regard to individual fat depots, results presented in Table 2 show that in Akkaraman lambs in general, tail fat, subcutaneous fat and intermuscular fat were the major depots with overall means of 15.3%, 10.2% and 4.9%, respectively. It was obvious that the tail fat represented the largest proportion of the total dissectible fat. The tail fat (3.01 kg) was significantly correlated with CF (r = 0.71) and TBF (r = 0.67) (Table 3). This result is confirmed by several studies in the past (Atti & Khaldi, 1988; Atti & Hamouda, 2004).

Considering the correlations between total body fat and all of the external body measurements, heart girth was found to have the highest correlation (r = 0.91), while tail circumference had the highest correlation (r = 0.72) of the tail measurements. Similar results were seen between carcass fat and the other measurements. Heart girth (r = 0.89) and tail circumference (r = 0.76) also had the highest correlations with carcass fat. In addition, the relationships between body weight and heart girth (r = 0.89), carcass fat (r = 0.91) and adipocyte area (r = 0.80) were also high. The correlations between tail dimensions and tail fat, TC (r = 0.88) and TW (r = 0.66) were the highest. This is in agreement with previous reports (Zamiri & Izadifard, 1997; Atti & Hamouda, 2004).

Atti & Hamouda (2004) reported that tail fat (R^2 = 0.75), carcass fat (R^2 = 0.69) and total body fat (R^2 = 0.69) of Barbarine sheep could be estimated by using only tail measures as independent variables, and could be improved by including BW parameter in the prediction equations. On the other hand, Zamiri & Izadifard (1997) established prediction equations for fat tail weight using fat-tail dimensions of Mehraban and Ghezel sheep and stated that fat tail weight in live fat-tailed sheep could be estimated by measuring fat-tail dimensions. The regression equation we established for tail fat weight prediction based on tail dimensions (R^2= 0, 81) for Akkaraman sheep is more accurate than the findings for Barbarine (R^2 = 0.75) (Atti & Hamouda, 2004) and Ghezel sheep (R^2 = 0.69), and similar to the results for Mehraban sheep (R^2 = 0.83) (Zamiri & Izadifard, 1997). In addition, the equations we established include body (BW, CD, RH, HG and WH) and tail measurements (TC), and improved by the inclusion of AA. This approach could contribute in further relevant studies. Regarding the carcass and total body fat depots, it seems as if the accuracy of our prediction equations (R^2 = 0.82 for carcass fat and R^2 = 0.87 for total body fat) is better than that of reported values.

Relationships between body measurements and carcass content are widely reported (Kirton *et al*., 1983; Zamiri & Izadifard, 1997; Atti & Hamouda, 2004) but the inclusion of adipocyte area as an independent variable significantly improved the precision of carcass traits estimation. The positive

relationship between variations of body fat content and cell area of subcutaneous adipose tissue showed that this parameter could be used in estimating the fat content of the live animals, as confirmed by the others (Purroy *et al*., 1995; Hood, 1982). The adipocyte area showed a significantly correlation with cold carcass (r = 0.84) as well as with TBF (r = 0.84) and CF (r = 0.86) in this study. The presence of adipocyte area attracts attention in the prediction equations. The results also support the utilization of these measurements for selection to reduce meat adiposity in Akkaraman lambs with an acceptable precision.

Conclusion

It is concluded that prediction equations can be established from subcutaneous adipocyte area and body and tail measurements to estimate carcass composition and fat body depots of indigenous Akkaraman sheep. Thus, the assessment of the animals could be easier in breeding and nutrition experiments without slaughtering of the animals.

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