Relationships between external and internal udder measurements and the linear scores for udder morphology traits in dairy sheep

M. Milerski[1], M. Margetín[2], A. Čapistrák[2], D. Apolen[2], J. Špánik[2], M. Oravcová[2]

[1]Research Institute of Animal Production, Prague-Uhříněves, Czech Republic
[2]Slovak Agricultural Research Authority, Nitra, Slovak Republic

ABSTRACT: Udder morphology traits were measured and subjectively assessed by the use of linear scores in 266 ewes of Tsigai (T), Improved Walachian (IW) and Lacaune (LC) dairy breeds. Animals were recorded repeatedly within and between lactations, therefore 772 sets of measurements and linear scores were collected in total. Udder measurements included: udder length, udder width, rear udder depth, cistern depth, teat length, teat angle, sum of cistern cross-section areas scanned by the ultrasound technique from the side and from the bottom in a water bath. Linear scores were assessed for: udder depth, cistern depth, teat placement, teat length, udder attachment, udder cleft, and udder shape from the aspect of machine milking. Analysis of variance was conducted by the mixed procedure of SAS statistical package. The model included effects of experimental day, parity, days in milk, random effect of animal and residual error. Subsequently, correlations between random animal effects for udder measurements and linear scores were computed for individual examined breeds separately. Subjectively assessed linear scores for udder depth, cistern depth, teat position and teat size showed high correlations with actual measurements of the respective traits on udder in all examined breeds (r_p = 0.65–0.80). Linear scores for cistern depth and teat position were highly correlated (r_p = 0.84; 0.77 and 0.90 for T; IW and LC ewes), suggesting that they are nearly identical traits. Linear score for udder shape was significantly correlated with the linear score for udder attachment in all examined breeds (r_p = 0.79; 0.80 and 0.78 for T; IW and LC). In T and IW assessments of the udder shape were also highly correlated with linear score for udder height (r_p = 0.84 resp. r_p = 0.79) while in LC this correlation was close to zero. In LC assessment of the udder shape was more dependent on teat position (r_p = –0.37) and cistern depth (r_p = –0.30).

Keywords: Tsigai; Improved Walachian; Lacaune; ewe; mammary gland; cistern

Milk yield and composition are the main selection objectives for dairy sheep. Nevertheless, it is evident that in recent years traits linked with technological aspects of milking, quality of production, functional longevity and animal welfare have been taking on a more important role within modern breeding programmes. In the last decades machine milking has been introduced more widely into dairy sheep husbandry and this fact evokes growth of attention paid by breeders and scientists to morphological and functional characteristics of udder in order to enable an easy and uniform milking routine. The ideal morphology of sheep udder for mechanical milking was described by Labousière (1988). Possibilities of applying some udder morphology characteristics as new selection criteria

Supported by the Ministry of Agriculture of the Slovak Republic (Framework project: Quality of life, health, nutrition and education: Ecologization and economic rationalization of the animal production) and by the Ministry of Agriculture of the Czech Republic (Project No. MZe 0002701401).

connected mainly with milkability are studied (Sanna et al., 2002) in order to improve the efficiency of machine milking without causing an udder injury. Linear scores for udder qualifying were used in several dairy sheep breeds in Spain (De la Fuente et al., 1996; Serrano et al., 2002), Italy (Casu et al., 2002) and France (Marie-Etancelin et al., 2003). Fernández et al. (1997), Casu et al. (2002), Serrano et al. (2002) and Legarra and Ugarte (2005) found moderate heritabilities for udder type traits, suggesting that they would respond well to selection pressure. The latest developments in dairy sheep breeding were reviewed by Sanna et al. (2002) or Ugarte and Gabiña (2004). Machine milking ability in dairy goats was studied by Katanos et al. (2005) and others.

The goal of this study was to determine the relationships between measurements of chosen udder dimensions or angles and subjective assessment of udder characteristics based on linear score in different dairy sheep breeds kept in the Slovak Republic. The knowledge of these relationships is needed to optimise the udder linear score scheme for dairy sheep in Slovakia. Linear score should characterize the udder morphology as precisely as possible, but by the use of limited scale and number of criteria in order that the system will not be too complicated and its use in practice too time consuming. The knowledge of the relationships between individual characteristics of udder morphology is important also for their including into total selection indexes or for construction of partial selection indexes for udder morphology and enables to predict future correlated responses in milk-oriented selection schemes. For selection index construction the genetic correlations between traits are needed, but reasonable estimation of genetic correlations demands large and well structured data. Unfortunately, these conditions have not been satisfied in the examined populations so far. Nevertheless, correlations between estimated random animal effects determined in this study give preliminary information on this problem.

MATERIAL AND METHODS

Investigations were performed in 2002–2005 in five flocks of dairy sheep in the Slovak Republic. Totally 266 purebred Tsigai (T), Improved Walachian (IW) and Lacaune (LC) ewes were included in the experiment. Animals were recorded repeatedly within and between lactations, therefore 772 sets of measurements and linear scores were collected in total. Udder morphology measurements and subjective linear appraisals were done on the ewes approximately twelve hours after previous milking.

External udder measurements of six traits (Figure 1) were performed by one technician and they included udder length measured with a tape (UL), udder width (UW), rear udder depth (RUD), cistern depth (CD), teat length (TL), teat angle from the vertical (TA). Additionally, the measurements of udder cistern cross-section areas were carried out by the ultrasound technique from the side (SCA) according to the methodology of Ruberte et al. (1994) and from the bottom in a water bath (BCA) as was described by Bruckmaier and Blum (1992). The SonoVet2000 scanner equipped with the 170 mm linear probe working in a frequency range of 2 to 5 MHz was used for ultrasound measurements. Linear assessments were done subjectively by one experienced assessor using a nine-point scale. The linear assessment scheme contained seven characteristics of udder and teats: udder depth (1-low, 9-high), cistern depth below the teat level (1-none, 9-high), teat placement (1-vertical, 9-horizontal), teat length (1-short, 9-long), udder attachment

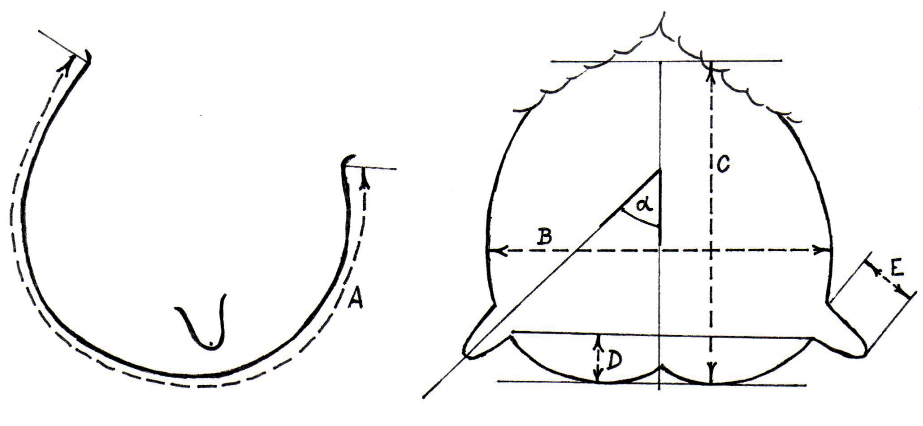

Figure 1. Udder measurements. A – udder length (UL), B – udder width (UW), C – rear udder depth (RUD), D – cistern depth (CD), E – teat length (TL), α – teat angle from the vertical (TA)

(1-narrow, 9-wide), udder cleft (1-not detectable, 9-expressive), udder shape from the aspect of machine milking (1-bad, 9-ideal).

Data were processed by REML methodology using a MIXED procedure from the SAS statistical package (SAS Institute, 2000). The following statistical model was used for all investigated traits:

$$Y_{ijkl} = \mathrm{ED}_i + \mathrm{PAR}_j + an_k + a \times \mathrm{dim}_{ijkl} + b \times \mathrm{dim}_{ijkl}^2 + e_{ijkl}$$

where:
- Y_{ijkl} = measured or assessed trait
- ED_i = experimental day (fixed effect – 12 levels for T and IW, 8 levels for LC)
- PAR_j = parity (fixed effect – 3 levels 1st, 2nd, 3rd and further lactations)
- an_k = animal (random effect)
- dim_{ijkl} = days in milk (covariable – min. = 42 days; max. = 191 days)
- e_{ijkl} = residual error

In addition to genetic effects of individuals estimated random animal effects (an_k) included also lifelong and within lactation permanent environmental effects. Pearson correlation coefficients between estimates of random animal effect (an_k) for udder measurements and for the traits of linear assessment scheme were computed by the use of CORR procedure from the SAS statistical package (SAS Institute, 2000).

RESULTS AND DISCUSSION

Sample statistics of udder morphology measurements and linear scores for Tsigai (T), Improved Walachian (IW) and Lacaune (LC) ewes are summarized in Table 1. The average udder size of LC ewes was larger than in Slovak native dairy sheep breeds T and IW. Average udder depths of individual breeds were: 134 mm (T), 136 mm (IW) and 184 mm (LC). McKusick et al. (2000) measured higher average udder depth for multiparous East Friesian ewes (197 mm). Rovai et al. (1999) found average udder depth 172 mm for Manchega and 178 mm for Lacaune breed. The average cross-section areas of cistern were also much larger in LC than in T or IW for both variants of measurements, from the side and from the bottom. On the other hand, teats were positioned more horizontally in LC ewes. The

Table 1. Sample statistics of udder morphology measurements and linear scores in Tsigai, Improved Walachian and Lacaune dairy sheep breeds

Breed	Tsigai		Improved Walachian		Lacaune	
Number of sets of measurements	387		196		189	
Number of animals	123		83		60	
	mean	s.d.	mean	s.d.	Mean	s.d.
Linear udder assessment scores						
Udder depth	4.2	1.28	4.5	1.42	6.0	1.42
Cistern depth	3.8	1.73	4.1	1.84	6.0	1.73
Teat position	4.3	1.42	4.6	1.56	5.8	1.65
Teat size	4.5	1.33	4.8	1.12	4.4	1.29
Udder cleft	5.2	1.27	5.0	1.61	4.4	1.67
Udder attachment	5.0	1.14	5.3	1.24	5.4	1.42
Udder shape	4.6	1.48	4.9	1.46	5.8	1.48
Udder measurements						
Udder length (mm)	196.1	35.9	208.8	44.3	313.1	63.7
Udder width (mm)	106.7	13.8	112.1	17.9	132.2	18.2
Rear udder depth (mm)	133.7	22.6	136.1	26.7	184.2	34.5
Cistern depth (mm)	12.6	10.4	18.3	12.8	31.3	15.0
Teat length (mm)	35.3	6.7	36.5	6.0	33.6	5.1
Teat angle (°)	37.5	10.2	40.8	11.6	46.9	14.5
Cistern area from bottom (mm^2)	2 625	921	2 851	1 224	5 814	1 869
Cistern area from side (mm^2)	3 283	1 041	3 597	1 285	6 029	1 927

Table 2. Correlation coefficients between subjectively assessed linear scores and measurements of characteristics of udder morphology in Tsigai dairy ewes

Linear score	Udder measurements							
	UL	UW	RUD	CD	TL	TA	BCA	SCA
Udder depth	0.687	0.758	0.778	0.251	n.s.	n.s.	0.488	0.516
Cistern depth	0.329	n.s.	0.237	0.760	–0.205	0.614	0.281	n.s.
Teat position	0.192	n.s.	n.s.	0.666	–0.266	0.694	0.261	n.s.
Teat size	n.s.	n.s.	n.s.	n.s.	0.746	–0.175	n.s.	n.s
Udder cleft	n.s.	n.s.	n.s.	–0.238	n.s.	–0.235	n.s.	n.s.
Udder attachment	0.468	0.712	0.568	n.s.	n.s.	n.s.	0.292	0.442
Udder shape	0.577	0.727	0.671	n.s.	n.s.	–0.178	0.371	0.479

UL = udder length; UW = udder width; RUD = rear udder depth; CD = cistern depth; TL = teat length; TA = teat angle; BCA = cistern cross-section area measured from the bottom; SCA = cistern cross-section area measured from the side (valid also for Table 4 and 6)

average teat angle was 46.9° in this breed. It resulted also in higher average linear score for teat position in LC (5.8) than in T (4.3) or IW (4.6). Similar average teat angles 48.5° and 44.1° were reported in Lacaune ewes by Rovai et al. (1999) and Marie-Etacelin et al. (2003). Despite the unfavourable teat placement and higher average depth of cistern below the teat level, the average linear score for overall udder shape was higher for LC (5.80) than for T (4.61) or IW (4.92). Due to differences in the udder dimensions and shape the breeds may differ also in relationships between udder characteristics. Correlation analyses were done for the examined dairy sheep breeds separately.

Correlation coefficients between estimations of random animal effects for udder measurements

Table 3. Correlation coefficients between subjectively assessed linear scores of udder traits in Tsigai dairy ewes

	Cistern depth	Teat position	Teat size	Udder cleft	Udder attachment	Udder hape
Udder depth	n.s.	n.s.	n.s.	n.s.	0.667	0.842
Cistern depth		0.844	–0.171	–0.279	n.s.	n.s.
Teat position			–0.236	–0.336	n.s.	–0.220
Teat size				n.s.	n.s.	n.s.
Udder cleft					0.294	0.277
Udder attachment						0.791

Table 4. Correlation coefficients between subjectively assessed linear scores and measurements of udder morphology characteristics in Improved Walachian dairy ewes

Linear score	Udder measurements							
	UL	UW	RUD	CD	TL	TA	BCA	SCA
Udder depth	0.756	0.721	0.802	0.587	n.s.	0.316	0.578	0.571
Cistern depth	0.434	0.284	0.413	0.795	–0.275	0.693	0.379	0.247
Teat position	0.325	n.s.	0.299	0.560	–0.360	0.762	0.244	n.s.
Teat size	n.s.	n.s.	n.s.	n.s.	0.654	–0.294	n.s.	n.s.
Udder cleft	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	0.215	0.269
Udder attachment	0.321	0.656	0.440	0.251	n.s.	n.s.	0.255	0.371
Udder shape	0.588	0.746	0.721	0.417	n.s.	n.s.	0.464	0.488

Table 5. Correlation coefficients between subjectively assessed linear scores of udder traits in Improved Walachian dairy ewes

	Cistern depth	Teat position	Teat size	Udder cleft	Udder attachment	Udder shape
Udder depth	0.427	0.250	–0.257	0.221	0.542	0.794
Cistern depth		0.766	–0.245	n.s.	n.s.	n.s.
Teat position			–0.384	n.s.	n.s.	n.s.
Teat size				n.s.	n.s.	n.s.
Udder cleft					0.294	0.319
Udder attachment						0.796

and linear scores are presented in Table 2, 4 and 6 for T, IW and LC, respectively. Correlation coefficients between udder linear scores mutually are summarized for individual breeds in Table 3, 5 and 7.

In all three breeds good correspondence between external udder dimensions and linear score for udder depth was found. Correlation coefficients between the linear score for udder depth and the direct measurements of the same trait on udder were r_p = 0.78 for T, r_p = 0.80 for IW and r_p = 0.76 for LC. Marie-Etacelin et al. (2003) found phenotypic correlations between these traits calculated after correction for the main sources of variation r_p = –0.60 for Lacaune and r_p = –0.72 for backcross Sarda × Lacaune ewes. They used an opposite scale for linear assessment of udder height so our findings are in agreement. The relationships between linear score and ultrasonic measurements of cistern cross-section areas were also significantly positive in all examined dairy sheep breeds.

Cistern depth and teat position or teat angle were highly correlated, suggesting that they are nearly identical traits. Correlation coefficients between linear scores for cistern depth and teat position were r_p = 0.84, r_p = 0.77 and r_p = 0.90 for T, IW and LC ewes. Both characteristics showed also similar relationships to the other udder characteristics. In T and IW they were negatively correlated with teat size; more horizontally placed teats were smaller than more vertically situated ones. Teat position and cistern depth below the teat level were also positively correlated with cistern cross-section areas measured from the bottom in all three examined breeds. Scanning of cisterns by ultrasound from below enables better scanning of the part of cisterns situated below the teat level (Bruckmaier et al., 1997) than scanning from the side. Correlation coefficients suggested that animals with higher cisterns tended to have more horizontally placed teats. A significant correlation between linear scores for teat position and udder depth was found only in IW. Other authors who used an opposite scale for teat position found higher negative correlation coefficients between these traits. Legarra and Ugarte (2005) found a genetic correlation between teat position and ud-

Table 6. Correlation coefficients between subjectively assessed linear scores and measurements of characteristics of udder morphology in Lacaune dairy ewes

Linear score	Udder measurements							
	UL	UW	RUD	CD	TL	TA	BCA	SCA
Udder depth	0.799	0.528	0.761	0.293	n.s.	n.s.	0.560	0.583
Cistern depth	0.404	n.s.	n.s.	0.765	n.s.	0.755	0.324	n.s.
Teat position	0.389	n.s.	n.s.	0.692	n.s.	0.738	0.309	n.s.
Teat size	0.356	n.s.	0.315	n.s.	0.695	n.s.	0.302	n.s.
Udder cleft	n.s.	n.s.	n.s.	–0.276	n.s.	n.s.	n.s.	n.s.
Udder attachment	n.s.	0.412	n.s.	n.s.	n.s.	–0.385	n.s.	n.s.
Udder shape	n.s.	0.574	n.s.	n.s.	n.s.	–0.305	n.s.	0.318

Table 7. Correlation coefficients between subjectively assessed linear scores of udder traits in Lacaune dairy ewes

	Cistern depth	Teat position	Teat size	Udder cleft	Udder attachment	Udder shape
Udder depth	0.296	n.s.	0.277	n.s.	n.s.	n.s.
Cistern depth		0.903	n.s.	–0.285	–0.371	–0.300
Teat position			n.s.	n.s.	–0.426	–0.372
Teat size				n.s.	n.s.	n.s.
Udder cleft					n.s.	n.s.
Udder attachment						0.776

der depth r_g = –0.42 in Manchega ewes, Casu et al. (2002) found a genetic correlation r_g = –0.42 in Sarda dairy sheep. On the other hand, McKusick (2000) did not find a significant phenotypic correlation between udder height score and teat position score in East Friesian crossbred dairy ewes.

Linear scoring for udder cleft was slightly negatively correlated with cistern depth under the teat level in T (r_p = –0.24) and LC (r_p = –0.28) ewes, with teat position in T (r_p = –0.23) and it was positively correlated with cistern areas in IW ewes (r_p = 0.22 and r_p = 0.27) and with linear score for udder attachment in T (r_p = 0.29) and IW (r_p = 0.29). Udder attachment showed also higher correlations with udder dimensions and cistern size in Slovak native sheep breeds than in Lacaune. Correlations between linear scores for udder depth and attachment were r_p = 0.67 in T, r_p = 0.54 in IW and r_p = –0.02 (non significant) for LC. On the contrary, other authors reported high negative correlations between udder depth and attachment. Legarra and Ugarte (2005), working in Latxa breed, found a genetic correlation r_g = –0.58 between these characteristics, suggesting that weak attachments are genetically related to pendulous, deep udders. Casu et al. (2002) also found a high correlation r_g = 0.82 between these characteristics in Sarda using the opposite scale for udder depth. These opposite findings may be caused by different interpretation of udder attachment. Casu et al. (2002) defined udder attachment as the ratio between the depth and the width of the udder. In this study the udder attachment was appraised independently of udder depth as the assessment of udder base width and insertion of udder to the abdominal wall. In addition, inter-breed differences probably play their role. In Slovak native breeds animals with small and poorly attached udders were detected while in Lacaune the problems were rather with high, baggy udders of narrow base. These extremes also evoke a possibility that the relationship between udder height and attachment would not be linear along the whole range of these characteristics. In LC significantly negative correlations were found between linear score for udder attachment and teat angle (r_p = –0.35), teat position (r_p = –0.43) and cistern depth (r_p = –0.37), while in T and IW these relationships were not statistically significant.

Differences between Slovak native sheep breeds and LC were also found in the relationships of subjective appraisal of udder shape with the other udder traits. Udder shape was significantly correlated with udder width (r_p = 0.73; 0.75 and 0.57 for T; IW and LC), and especially with linear score for udder attachment (r_p = 0.79; 0.80 and 0.78 for T; IW and LC). In T and IW the assessments of udder shape were highly correlated with linear score for udder height (r_p = 0.84 and r_p = 0.79, resp.) while in LC the respective correlation coefficient was close to zero. In LC assessments of the udder shape were more dependent on the teat position, as correlation coefficients between linear score for udder shape and linear scores for teat position and cistern depth were r_p = –0.37 and r_p = –0.30. Fernández et al. (1997) found a very high genetic correlation of udder shape with teat placement (r_g = 0.96) in Churra dairy ewes while Serrano et al. (2002) with udder attachment in Manchega breed (r_g = 0.95).

CONCLUSIONS

Subjectively assessed linear scores for udder depth, cistern depth, teat position and teat size showed high correlations with actual measurements of the respective traits on udder in all three examined breeds (r_p = 0.65–0.80). It would appear that the used linear scoring system is appropriate for evaluating in dairy ewes of Tsigai, Improved Walachian and Lacaune in the Slovak Republic. Linear scores for teat position and cistern depth were highly correlated in all examined dairy sheep breeds; therefore, they may be considered the same trait in order to simplify the design of the udder assessment scheme. Nevertheless, for the final designing of linear scoring scheme in Slovakia the knowledge of relationships between udder trait assessments and milk yield and/or machine milk flow characteristics is also needed. Interbreed differences in the relationships between linear scores for udder shape and some other udder morphology characteristics were detected. This fact suggested that udder shape assessment was influenced mainly by characteristics which are far from the ideal in the investigated population, thus in Tsigai and Improved Walachian the appraisals of udder shape were highly positively correlated with linear scores for udder height while in Lacaune assessments of the udder shape were more influenced by teat position and cistern depth. The knowledge of the relationships between morphological udder traits would permit to predict future correlated responses in milk-oriented selection schemes.

Acknowledgements

The authors would like to thank Alex Poul and Fero Dulla for their work in the maintenance of the animals and their helpful technical assistance and Dusan Sedivy for his help with data collection during the experiments.

REFERENCES

Bruckmaier R.M., Blum J.W. (1992): B-mode ultrasonography of mammary glands of cow, goats and sheep during adrenergie agonist and oxytocin administration. J. Dairy Res., *59*, 151–159.

Bruckmaier R.M., Paul G., Mayer H., Schams D. (1997): Machine milking of Oestfriesian and Lacaune dairy sheep: udder anatomy, milk ejection and milk characteristics. J. Dairy Res., *64*, 163–172.

Casu S., Fresi P., Carta A. (2002): Estimation of the genetic parameters of udder traits in Sarda dairy sheep using a sire model with random contemporary groups. In: 7th WCGALP, Montpellier, France. CD-ROM communication 09–04.

De la Fuente L.F., Fernández G., San Primitivo F. (1996): A linear evaluation system for udder traits of dairy ewes. Livest. Prod. Sci., *45*, 171–178.

Fernández G., Baró A.P., De la Fuente L.F., San Primitivo F. (1997): Genetic parameters fot linear udder traits of dairy ewes. J. Dairy Sci., *80*, 601–606.

Katanos J., Skapetas B., Laga V. (2005): Machine milking ability and milk composition of some imported dairy goat breeds and some crosses in Greece. Czech J. Anim. Sci., *50*, 394–401.

Labousière J. (1988): Review of physiological and anatomical factors influencing the milking ability of ewes and the organization of milking. Livest. Prod. Sci., *18*, 253–274.

Legarra A., Ugarte E. (2005): Genetic parameters of udder traits, somatic cell score, and milk yield in Latxa sheep. J. Dairy Sci., *88*, 2238–2245.

Marie-Etacelin C., Casu S., Aurel M.R., Barillet F., Carta A., Deiana S., Jacquin M., Pailler F., Porte D., Tolu S. (2003): New tools to appraise udder morphology and milkability in dairy sheep. CIHEAM-Options Mediterannes, A 55, 71–80.

McKusick B.C., Marnet P.G., Berger Y.M., Thomas D.L (2000): Preliminary observation on milk flow and udder morphology traits of east Friesian crossbred dairy ewes. In: Proceedings of the 6th Great Lakes Dairy Sheep Symposium, November 2.–4., Guelph, Ontario, Canada. 101–116.

Rovai M., Such X., Piedrafita J., Caja G., Pujol M.R. (1999): Evolution of mammary morphology traits during lactation and its relationship with milk yield in Manchega and Lacaune dairy sheep. In: Barrilet F., Zervas N.P. (eds.): Milking and Milk Production of Dairy Sheep and Goats. Wageningen Pers, Wageningen. EAAP Publication No. 95, 107–109.

Ruberte J., Carretero A., Fernández M., Navarro M., Caja G., Kirchner F., Such X. (1994): Ultrasound mammography in the lactating ewe and its correspondence to anatomical section. Small Rumin. Res., *13*, 199–204.

Sanna S.R., Casu S., Carta A. (2002): Breeding programmes in dairy sheep. In: 7th WCGALP, Montpellier, France. CD-ROM communication 01–34.

SAS Institute (2000): SAS Online Doc, Version 8, SAS Institute Inc., Cary, NC.

Serrano M., Péréz-Guzmán M.D., Montoro V., Jurado J.J. (2002): Genetic analysis of udder traits in Manchega ewes. Livest. Prod. Sci., *77*, 355–361.

Ugarte E., Gabiňa D. (2004): Recent developments in dairy sheep breeding. Arch. Tierz., Special Issue, *47*, 10–17.

Received: 2006–02–13
Accepted after correction: 2006–05–15

Corresponding Author

Dr. Michal Milerski, Research Institute of Animal Production, Přátelství 815, 104 01 Prague 10-Uhříněves
Tel. +420 736 202 563, e-mail: m.milerski@seznam.cz