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The comparison of ewe udder morphology traits of Improved Valachian, Tsigai, Lacaune breeds and their crosses

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Abstract

Morphological udder traits are very important for dairy animals. During this experiment, morphological udder traits were subjectively assessed with the use of linear scores from selected ewes (381 ewes) belonging to nine genotypes based on the basis of Improved Valachian, Tsigai and Lacaune breeds (7 udder traits; using a scale of 9 points; 1275 statements for each trait) during the milking period from 2002 to 2008. Linear udder traits were: udder depth, cistern depth, teat position, teat size, udder cleft, udder attachment and udder shape. Collected data were processed with restricted methodology and maximal probability using a MIXED procedure from the SAS statistical package. During the research, all traits were influenced by the ewe genotype ($P<0.001$), furthermore, parity and stage of lactation had its effect as well. In most cases, crosses with 25 to 75 % share of dairy breeds, such as Lacaune and East Friesian, had larger udder cisterns than purebred Tsigai ewes and Improved Valachian breed. Inconvenient teat placement was found in the purebred Lacaune ewes, which, also, had the largest udders and cisterns among studied genotypes. Tsigai crossbreds and Improved Valachian breed, together with specialized dairy breeds had larger udders than purebred ewes (Tsigai and Improved Valachian breeds), but with negative placement of teat for milking. Compliances were statistically significant ($P<0.001$) due to influences on parameters for determining the size of udder (udder depth, cistern depth, teat size and udder attachment). In conclusion, udder depth, teat position and teat size may be used as suitable characteristics for marker selection, to improve milking ability of listed breeds.

Key words: udder morphology, milk, udder scoring, lactation, sheep

Introduction

Anatomical and morphological characteristics of sheep's mammary gland, their relationship with milk production, milking-ability of the machines and manageability, have become a center of attention among farmers and scientists. Functional traits have become important for efficient breeding schemes in the dairy goat and sheep industries, mainly in Mediterranean countries, due to increased costs of production relative to milk prices and consumers demand for safe, quality food and attention to animal welfare (Barillet, 2007). Mammary morphology and morphological udder traits have been described as an important factor in the machine milkability of sheep (Kastelic and Kavčić, 1994; Dzidic et al., 2009; Prpić et al., 2012) because of the influence of applicability to machine milking (D'Alessandro et al., 2009; Makovický et al., 2012), milk yield (Nudda et al., 2002) and udder health status (Casu et al., 2010; Makovický et al., 2013a). The relevance of udder morphology is predominantly based on its relation with milking and especially with

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machine milking (Ugarte and Gabiña, 2004). Mikuš (1978) and Labussière (1988) had described the ideal morphology of mammary glands for mechanical sheep milking. In several European sheep the udder and teats are extremely variable in shape with numerous defects. Low and pendulous udders are in consideration of economic importance to the dairy man, since they are more difficult to milk when milking machines are used (Papachristoforou et al., 1982). Evaluation of udder morphology can be performed by a direct measurement of the udder (Labussière, 1988) or by a subjective assessment of udder traits using linear scales in several breeds. In dairy ewes, the most important functional traits are those related to udder morphology, and there is a need to introduce improved udder traits into sheep breeding schemes (Gutiérrez et al., 2008). Better knowledge of morphological udder trait variability should allow the identification of mammary traits most suitable for incorporation into selectional programs and optimize the udder linear score scheme for dairy sheep breeds.

The purpose of this work was to investigate the morphological traits of the mammary gland in purebred Improved Valachian (IV), Tsigai (T), Lacaune (LC) and their crosses with 25 %, 50 % and 75 % genetic proportion of LC and East Friesian (EF). Further analyses of genetic and non-genetic factors that are expected to influence the udder morphology were also done.

Materials and methods

This experiment was performed during the 7-year period from 2002 to 2008 and took place in one experimental flock of dairy sheep. Purebred Improved Valachian (IV), purebred Tsigai (T) and purebred Lacaune (LC) ewes, and IV and T crosses with 25 %, 50 % and 75 % of genetically created breeds of specialized dairy breeds (SDB). Lacaune and East Friesian ewes (EF) were included in the experiment as follows: IV × SDB 25 %, IV × SDB 50 %, IV × SDB 75 %; T × SDB 25 %, T × SDB 50 %, T × SDB 75 %. Nine genotypes of ewes were compared due to the linear udder assessments (three purebreds and six groups of crossbreds).

For the whole period, the linear udder assessments at 381 ewes were surveyed. Subjective linear appraisals were done on the ewes approximately twelve hours after previous milking. Specific numbers of observations in monitored traits depending on the genotype, parity and lactation stage are shown in Table 3 and 4. Linear assessments were taken subjectively by at least 2 classifiers at each round of scoring, using a 9 point scale previously described (De la Fuente et al., 1996; Marie et al., 1999; Marie-Etancelin et al., 2003). The linear assessment scheme contained 7 udder and teat traits: udder depth (1 - low, 9 - high), cistern depth below the teat level (1 - none, 9 - high), teat position (1 - vertical, 9 - horizontal), teat size (1 - short, 9 - long), udder cleft (1 - not detectable, 9 - expressive), udder attachment (1 - narrow, 9 - wide), udder shape (1 - bad, 9 - ideal). Statistical analysis was formulated using the restricted maximum likelihood (REML) methodology (MIXED) procedure implemented in SAS/STAT v.9.2, 2002-2008.

The following statistical model with fixed and random effects was applied:

$$y_{ijklm} = \mu + Y_i + LS_j + GEN_k + P_l + an_m + a * DIM_{ijklm} + e_{ijklm}$$

where: y_{ijklm}: dependent variable or records of udder and teats scores observed phenotypic values, Y_i: year (fixed effect with width from 5 to 7; depending on the analyzed indicators from years 2002-2008), LS_j: lactation stage (fixed effect with 4 levels), from 40th to 99thlactational day, from 100th to 129th lactation day, from 130th to 159th lactation day and from 160th to 210th lactation day, GEN_k: genotype (breed group; fixed effect with 9 levels; see above for more characteristics), P_l: parity (fixed effect with 3 levels; - first, second, third and further parity), an_m: animal (random effect), DIM_{ijklm}: days in milk (covariate; 40 to 210 d in milk), e_{ijklm}: *random error.*

Results and discussion

The basic statistical characteristics of the variation of selected traits, characterizing the linear scores of ewes for IV, T, LC and their crosses with genetic proportion of LC and EF - 25 %, 50 % and 75 % are shown in Table 1. Animals were recorded repeatedly within and between lactations, therefore 1275 linear assessments were collected in total. The lowest mean value for the linear scores of ewes was found for teat size (4.49), while the most common value was set up for udder attachment (5.41).

Table 1. Basic statistical characteristics of the variation of selected ewe udder morphology traits

Traits	N**[2]	Mean	SD	CV	min.	max.
Udder depth,*[1]	1275	5.04	1.590	31.55	1	9
Cistern depth,*[1]	1275	4.99	1.959	39.26	1	9
Teat position,*[1]	1275	5.20	1.791	34.44	1	9
Teat size,*[1]	1275	4.49	1.427	31.78	1	9
Udder cleft,*[1]	1275	4.82	1.527	31.68	1	9
Udder attachment*[1]	1275	5.41	1.281	23.68	2	9
Udder shape*[1]	1275	5.28	1.549	29.34	2	9

*[1]Linear udder assessment scores (9 points scale, from 1 to 9)
**[2]Number of sets of measurements
SD - standard deviation; CV - coefficient of variability

Linear scores ranged from 1 to 9 for most traits. Mean values of all traits were about 5 while cistern's depth and teat placement had the highest variability (coefficient of variability 39.26-34.44 %).

Results showed that genotype (Table 2) had a significant effect on udder depth, cistern depth, teat position, udder cleft, udder attachment, udder shape ($P<0.001$), and teat size ($P<0.05$). Significant effects of genotype on linear udder scores of Churra ewes were also found by De la Fuente et al. (1996) and Fernández et al. (1997).

The highest average udder depth (5.95±0.123) was found among purebred LC ewes (Table 3).

The smallest average udder depth (3.98±0.120) was found in purebred T ewes. Similar average udder depth was indicated in Churra ewes (De la Fuente et al., 1996; Fernández et al., 1997) and in Manchega ewes (Serrano et al., 2002). On the other hand, higher values in comparison with our results were reported by Legarra and Ugarte (2005) in Latxa ewes, Gelasakis et al. (2012) in Chios ewes, Salaris et al. (2007) in Sardinian and Marie-Etancelin et al. (2005) in Lacaune ewes. Lower mean values than ours were determined by Sadeghi et al. (2013) in Lori Bakhtiari ewes.

Purebred LC ewe, as expected, also reached the largest mean CD (5.93 ± 0.176). Minimum mean CD was found in purebred IV ewes (3.66 ± 0.187).

As for the teat position, these results showed that the most favourable teat position was determined in purebred IV ewes (4.24±0.168), purebred LC (5.7 ±0.157) and crosses T x SDB (50 % SDB) (5.79±0.193). Slightly cranially oriented teats were reported in Istrian ewes by Prpić et al. (2013). Teats of Awassi ewes (Iñiguez et al., 2009), Churra ewes (Fernández et al., 1995; De la Fuente et al., 1996) East Friesian ewes (McKusick et al., 2000), Manchega ewes (Serrano et al., 2002), Latxa ewes (Legarra and Ugarte, 2005), Kıvırcık, Tahirova and Karacabey Merino Ewes (Altinçekiç and Koyuncu, 2011), Lori Bakhtiari ewes (Sadeghi et al., 2013) were further cranially oriented.

Another studied trait in this experiment was teat size. The comparison between genotype groups showed that the greatest teat size (4.83±0.131) was found in purebred Improved Valachian ewes. The smallest mean value for TS was found, as expected, in purebred T ewes (4.29±0.119). Similar results of mean teat size were found in Churra ewes (De la Fuente et al., 1996; Fernández et al., 1997), also in Manchega (Serrano et al., 2002) and Latxa ewes (Legarra and Ugarte, 2005).

As for the UC, the comparison between genotype groups shows that the greatest udder cleft was found in purebred IV ewes (5.05±0.155), in T ewes (4.78±0.141) and in purebred LC ewes (4.24±0.145). More visible udder cleft was observed in LC ewes by Marie-Etancelin et al. (2005).

The greatest UA was observed in purebred Improved Valachian ewes (5.36±0.116), in T ewes (4.94±0.105) and in purebred LC ewes (5.24±0.108). Similar mean values of udder attachments were reported in Churra ewes (De la Fuente et al., 1996; Fernández et al., 1997), Manchega ewes (Serrano et al., 2002), Latxa ewes (Legarra and Ugarte, 2005) and in Lori Bakhtiari ewes (Sadeghi et al., 2013).

Regarding udder shape, the comparison between genotype groups shows that the greatest udder shape was found in purebred LC ewes (5.62±0.132), in IV ewes (4.89±0.141) and in purebred T ewes (4.33±0.129). Similar mean values of udder attachment were reported in Churra breed (De la Fuente et al., 1996).

Parity (Table 4) had a statistically significant (P<0.001) effect on the udder depth, teat size, udder attachment (P<0.001), cistern depth (P<0.01), and teat position (P<0.05). Largest udders with the largest cisterns, teat position and teat size had sheep in their third lactation. Older ewes in most cases have significantly greater teat length than the first lactation ewes, but during the stage of lactation it became smaller. The morphological aptitude of the udder to mechanical milking became worse as parity number increased. It can be concluded that the stage of lactation is an important factor of sheep udder morphology, regardless of the genotype and the production potential of the individual ewe. Similar results were also reported by many authors (Marie et al., 1999; Peris et al., 1999; Casu et al., 2000; Fernández et al., 1995; De la Fuente et al., 1996; Seykora and McDaniel, 1986; Kretschmer and Peters, 2002a,b; Makovický et al., 2013b).

Conclusion

Our results showed that crosses had greater prepositions for machine milking due to more suitable udders than default breeds (Tsigai and Improved Valachian). The outcome of our research also indicates that crosses of specialized dairy breeds (Lacaune and East Friesian) are more suitable for machine milking than purebred Lacaune ewes. Udder depth, teat position and teat size may be suitable selection traits to improve these breeds milking ability. In the near future, we recommend incorporating them into the routine flock recording to conduct a more accurate and efficient genetic evaluation of milk sheep in Slovakia, keeping the timelessness with the trend in all countries with advanced sheep husbandry.

Table 2. Covariance analysis of traits describing linear udder assessment traits of ewes

Source of variation	df	Trait: UD		CD		TP		TS		UC		UA		US	
		F value	P>F	F value	P>F	F value	P>F	F value	P>F	F value	P>F	F value	P>F	F value	P>F
Year	6	3.53	0.0019	5.27	<0.0001	7.74	<0.0001	4.74	<0.0001	1.76	0.1038	14.91	<0.0001	5.84	<0.0001
Lactation stage	3	0.52	0.6681	2.72	0.0436	0.81	0.4859	6.53	0.0002	2.51	0.0579	1.05	0.3717	0.88	0.4509
Genotype	8	25.70	<0.0001	16.02	< 0.0001	11.38	<0.0001	2.01	0.0421	3.42	0.0007	3.80	0.0002	10.60	<0.0001
Parity	2	50.28	<0.0001	5.02	0.0068	2.79	0.0620	26.89	<0.0001	1.43	0.2400	7.65	0.0005	0.53	0.5889
Days in milk	1	1.64	0.2003	2.14	0.1440	8.80	0.0031	0.02	0.8977	3.28	0.0704	0.05	0.8230	0.47	0.4940

UD - udder depth; CD - cistern depth; TP - teat position; TS - teat size; UC - udder cleft; UA - udder attachment; US - udder shape

Table 3. Effect of genotype on traits describing linear udder assessment traits of ewes (LSM ± SE)

Source of variation*		No. of measure-ments	UD		CD		TP	
Improved Valachian	(100)	232	4.08	0.132	3.66	0.187	4.24	0.168
IVxSDB (25 %)	(125)	68	5.17	0.234	5.58	0.324	5.55	0.296
IVxSDB (50 %)	(150)	93	5.60	0.197	5.14	0.274	5.07	0.249
IVxSDB (75 %)	(175)	82	5.74	0.207	5.48	0.292	5.66	0.263
Tsigai	(200)	289	3.98	0.120	4.06	0.170	4.34	0.152
TsxSDB (25 %)	(225)	18	5.44	0.480	4.32	0.683	5.11	0.610
TsxSDB (50 %)	(250)	170	5.26	0.152	5.70	0.215	5.79	0.193
TsxSDB (75 %)	(275)	46	5.33	0.310	5.74	0.442	5.76	0.395
Lacaune	(300)	277	5.95	0.123	5.93	0.176	5.78	0.157
Significant differences			100:125,150,175,250,275,300 +++;100:225++; 125:200+++; 125:300++; 150:200+++; 175:200+++; 200:250,275,300+++; 200:225++; 250:300+++;		100:125,150,175,250,275,300+++; 125:200+++; 150:200+++; 150:300+; 175:200+++; 200:250,275,300+++; 225:300+;		100:125,175,250,275,300+++; 100:150++; 125:200+++; 150:200,250,300+; 175:200+++; 200:250,275,300+++;	

+++ P<0.001; ++P<0.01; +P<0.05; ns - non significant effect
*Number of measurements; UD - udder depth; CD - cistern depth; TP - teat position; TS - teat size; UC - udder cleft; UA - udder attachment; US - udder shape.
SDB - specialized dairy breeds.
LSM ± SE - least square means ± standard error.

Table 4. Effect of parity and stage of lactation on traits describing linear udder assessment traits of ewes (LSM ± SE)

Source of variation		No. of measure-ments	UD		CD		TP		TS	
			LSM±SE		LSM±SE		LSM±SE		LSM±SE	
							Parity			
1st parity	(1)	432	4.67	0.092	4.86	0.128	5.16	0.117	4.16	0.094
2nd parity	(2)	402	5.18	0.095	5.08	0.129	5.19	0.119	4.71	0.097
3+	(3)	441	5.67	0.104	5.26	0.141	5.42	0.131	4.88	0.106
Significant differences			1:2,3+++;2:3+++;		1:2+; 1:3++;		1:3+; 2:3+;		1:2,3+++;	
							Lactation stage			
40th-99th day	(1)	268	5.17	0.174	4.91	0.213	5.32	0.212	4.51	0.192
100th-129th day	(2)	378	5.18	0.104	5.10	0.138	5.35	0.130	4.74	0.109
130th-159th day	(3)	349	5.23	0.107	5.22	0.141	5.26	0.134	4.72	0.113
160th-210th day	(4)	280	5.13	0.166	5.04	0.203	5.11	0.202	4.37	0.182
Significant differences			ns		ns		ns		3:4++;	

+++ P < 0.001; ++ P < 0.01; + P < 0.05; ns - non-significant effect.
*Number of measurements
LSM ± SE - least square means ± standard error
UL - udder length; UW - udder width; RUD - rear udder depth; CDE - cistern depth; TL - teat length; TA - teat angle

Trait							
TS		UC		UA		US	
score							
4.83	0.131	5.05	0.155	5.36	0.116	4.89	0.141
4.88	0.234	5.25	0.273	5.66	0.207	5.47	0.252
4.56	0.196	5.40	0.230	5.89	0.174	5.97	0.219
4.66	0.207	4.70	0.243	5.62	0.183	5.73	0.223
4.29	0.119	4.78	0.141	4.94	0.105	4.33	0.129
4.85	0.472	4.72	0.565	5.64	0.418	5.90	0.513
4.36	0.151	4.80	0.179	5.34	0.133	5.48	0.163
4.49	0.306	4.54	0.366	5.28	0.270	5.44	0.332
4.35	0.122	4.24	0.145	5.24	0.108	5.62	0.132
100:200,300++; 100:250+; 125:200,300+;		100:300+++; 125:300++; 150:175,200,250,275++; 150:300+++; 200:300++; 250:300+;		100:150+; 100:200++; 125:200++; 150:200+++; 150:250+; 150:300++; 175:200++; 200:250,300+;		100:150,300+++; 100:175,200,250++; 100:125+; 125:200+++; 150:200+++; 175:200+++; 200:225,275++; 200:250,300+++;	

(100) : Improved Valachian (IV); (125): crossbreds of IV breed with 25 % genetic proportion of specialized dairy breeds Lacaune (LC) and East Friesian (EF); (150): crossbreds of IV breed with 50 % genetic proportion of specialized dairy breeds LC and EF; (175): crossbreds of IV breed with 75 % genetic proportion of specialized dairy breeds LC and EF; (200): Tsigai (T); (225): crossbreds of T breed with 25 % genetic proportion of specialized dairy breeds LC and EF; (250): crossbreds of T breed with 50 % genetic proportion of specialized dairy breeds LC and EF; (275): crossbreds of T breed with 75 % genetic proportion of specialized dairy breeds LC and EF; (300): LC

Trait					
UC		UA		US	
LSM±SE		LSM±SE		LSM±SE	
4.94	0.108	5.64	0.083	5.48	0.100
4.79	0.110	5.34	0.086	5.38	0.103
4.77	0.121	5.34	0.094	5.41	0.113
ns		1:2+++; 1:3++;		ns	
4.62	0.197	5.55	0.171	5.54	0.198
4.83	0.120	5.45	0.097	5.36	0.115
5.00	0.124	5.47	0.100	5.40	0.119
4.88	0.187	5.29	0.162	5.40	0.188
ns		ns		ns	

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Usporedba morfoloških odlika vimena ovaca pasmina Improved Valachian, Tsigai i Lacaune te njihovih križanaca

Sažetak

Zbog svojih specifičnih morfoloških odlika, vime je vrlo bitno u mliječnih životinja. Ovim istraživanjem je provedeno linearno ocjenjivanje vimena (*linear scoring*) ovaca različitih genotipova nastalih na temelju poboljšane Valachian pasmine te cigaja i Lacaune pasmine (ukupno 381 ovca; 7 ocjenjivanih morfoloških odlika vimena; raspon ocjena od 1 do 9; 1275 podataka za svako svojstvo). Istraživanje je provedeno tijekom razdoblja mužnje ovaca od 2002. do 2008. godine. Ocjenjivane odlike vimena su: dubina vimena, visina cisterne, položaj sisa, veličina sisa, visina intermamarnog žlijeba vimena, vezanost vimena i oblik vimena. Prikupljeni podaci su statistički obrađeni primjenom procedure MIXED statističkog paketa SAS. Tijekom istraživanja, sve istraživane odlike bile su pod utjecajem genotipa (P<0.001), kao i pod značajnim utjecajem redoslijeda i stadija laktacije. U većini slučajeva, genotipovi u kojima je udio krvi mliječnih pasmina (poput Lacaune i istočnofrizijske ovce) činio od 25 do 75 %, imali su veća vimena od čistokrvnih cigaja ovaca i poboljšane Valachian pasmine. Nepovoljan položaj sisa utvrđen je u čistokrvnih Lacaune ovaca koje su imale i najveća vimena i najviše cisterne. Križanke cigaja x poboljšana Valachian pasmina, zajedno sa specijaliziranim mliječnim pasminama, imale su veće vime od čistokrvnih ovaca (cigaja i poboljšana Valachian), ali s nepovoljnim položajem sisa za mužnju. Zaključno, dubina vimena, položaj i veličina sisa mogu se koristiti kao važni pokazatelji prikladnosti ovčjeg vimena strojnoj mužnji.

Ključne riječi: morfologija vimena, mlijeko, ocjenjivanje vimena, laktacija, ovca

References

1. Altinçekiç, S.Ö., Koyuncu, M. (2011): Relationship between udder measurements and the linear scores for udder morphology traits in Kıvırcık, Tahirova and Karacabey Merino ewes. *Journal of the Faculty of Veterinary Medicine Kafkas University 17* (1), 71-76.
2. Barillet, F. (2007): Genetic improvement for dairy production in sheep and goats. *Small Ruminant Research 70* (1), 60-75.
3. Casu, S., Deiana, S., Tolu, S., Carta, A. (2000): Linear evaluation of udder morphology in Sarda dairy sheep: Relationship with milk yield, Proceedings of the 14th Congr. Naz. SIPAOC, Societa Italiana di Patologia e di Allevamento degli Ovini e dei Caprini, Perugia, Italy, 195-198.
4. Casu, S., Sechi, S., Salaris, S.L., Carta, A. (2010): Phenotypic and genetic relationships between udder morphology and udder health in dairy ewes. *Small Ruminant Research 88* (2-3), 77-83.
5. D'Alessandro, A.G., De Petro, R., Claps, S., Pizzillo, M., Martemucci, G. (2009): Yield and quality of milk and udder health in Martina Franca ass: effects of daily interval and time of machine milking. *Italian Journal of Animal Science 8* (2), 697-699.
6. De la Fuente, L.F., Fernández, G., San Primitivo, F. (1996): A linear evaluation system for udder traits of dairy ewes. *Livestock Production Science 45* (2-3), 171-178.
7. Dzidic, A., Salamon, D., Kaic, A., Salajpal, K., Kaps, M. (2009): Relationship between udder and milking traits during lactation in Istrian dairy crossbreed ewes. *Italian Journal of Animal Science 8* (3), 154-156.
8. Fernández, G., Álvarez, P., San Primitivo, F., De la Fuente, L.F. (1995): Factors affecting variation of udder traits of dairy ewes. *Journal of Dairy Science 78* (4), 842-849.
9. Fernández, G., Baró, J.A., De la Fuente, L.F., San Primitivo, F. (1997): Genetic parameters for linear udder traits of dairy ewes. *Journal of Dairy Science 80* (3), 601-605.
10. Gelasakis, A.I., Arsenos, G., Valergakis, G.E., Oikonomou, G., Kiossis, E., Fthenakis, G.C. (2012): Study of factors affecting udder traits and assessment of their interrelationships with milking efficiency in Chios breed ewes. *Small Ruminant Research 103* (2-3), 232-239.
11. Gutiérrez, G.B., El-Zarei, M.F., Álvarez, L., Bayón, Y., De La Fuente, L.F., San Primitivo, F., Arranz, J.J. (2008): Quantitative trait loci underlying udder morphology traits in dairy sheep. *Journal of Dairy Science 91* (9), 3672-3681.
12. Iñiguez, L., Hilali, M., Thomas, D.L., Jesry, G. (2009): Udder measurements and milk production in two Awassi sheep genotypes and their crosses. *Journal of Dairy Science 92* (9), 4613-4620.
13. Kastelic, D., Kavčić, S. (1994): Relationship between udder morphology, milk production and machine milking of dairy ewes. *Mljekarstvo 44* (2), 105-117.
14. Kretschmer, G., Peters, K.J. (2002a): Investigation of udder form and milkability in East Friesian milk sheep to determine recording and selection activities for improving udder shape and dairy performance - 1st communication: Recording methods and systematic effects on udder and teat traits. *Zuchtungskunde 74* (3), 194-212.
15. Kretschmer, G., Peters, K.J. (2002b): Investigation of udder form and milkability in East Friesian milk sheep to determine recording and selection activities for improving udder shape and dairy performance - 2nd communication: Phenotypic correlations between udder and teat traits and development of a linear model for udder appraisal. *Zuchtungskunde 74* (4), 300-313.
16. Labussière, J. (1988): Review of physiological and anatomical factors influencing the milking ability of ewes and the organization of milking. *Livestock Production Science 18* (3-4), 253-274.
17. Legarra, A., Ugarte, E. (2005): Genetic parameters of udder traits, somatic cell score, and milk yield in Latxa sheep. *Journal of Dairy Science 88* (6), 2238-2245.

18. Makovický, P., Nagy, M., Poráčová, J., Sedlák, V., Blaščáková, M. (2012): The milkability of sheep and the kinetics of milk ejection. *Acta Facultatis Studiorum Humanitatis et Naturae Universitatis Prešoviensis 22*, 146-153.
19. Makovický, P., Nagy, M., Makovický, P., Szinetár, C. (2013a): Milk quality comparison of the sheep breeds (Improved Valachian, Tsigai, Lacaune) and their crosses. *Magyar Allatorvosok Lapja 135* (2), 85-90.
20. Makovický, Pa., Nagy, M., Makovický, Pe. (2013b): Comparison of external udder measurements of the sheep breeds Improved Valachian, Tsigai, Lacaune and their crosses. *Chilean Journal of Agricultural Research 73* (4), 366-371.
21. Marie, C., Jacquin, M., Aurel, M.R., Pailler, F., Porte, D., Autran, P., Barillet, F. (1999): Genetic determination of the kinetics of milk secretion according to milk production potential of Lacaune sheep and phenotypic relationship to udder morphology. In Barillet, F., Zervas, N.P. (eds.) Milking and Milk Production of Dairy Sheep and Goats. EAAP Publication Nr 95, Wageningen Press, Wageningen, The Netherlands, 381-388.
22. Marie-Etancelin, C., Aurel, M.R., Barillet, F., Jacquin, M., Pailler, F., Porte, D., Casu, S., Carta, A., Deiana, S., Tolu, S. (2003): New tools to appraise udder morphology and milkability in dairy sheep. In Gabiña, D., Sanna, S. (eds.) Breeding programmes for improving the quality and safety of products. New traits, tools, rules and organization Zaragoza: CIHEAM, Options Méditerranéennes: Série A. Séminaires Méditerranéens; n. 55, 71-79.
23. Marie-Etancelin, C., Astruc, J.M., Porte, D., Larroque, H., Robert-Granié, C. (2005): Multiple-trait genetic parameters and genetic evaluation of udder-type traits in Lacaune dairy ewes. *Livestock Production Science 97* (2-3), 211-218.
24. McKusick, B.C., Marnet, P.G., Berger, Y.M., Thomas, D.L. (2000): Preliminary observations on milk flow and udder morphology traits of East Friesian crossbred dairy ewes, Proceedings of the 6th Great Lakes Dairy Sheep Symposium, Guelph, Ontario, Canada, 2-4 November 2000, Ontario, Canada, 101-116.
25. Mikuš, M. (1978): Study of the mutual relationship between dimensions of the udder with regard to improvements of sheep for machine milking, Proceedings of the 2nd Int. Symp. Machine Milking Small Ruminants, INRA-ITOVIC, Alghero, Italy, 102-112.
26. Nudda, A., Bencini, R., Mijatovic, S., Pulina, G. (2002): The yield and composition of milk in Sarda, Awassi, and Merino sheep milked unilaterally at different frequencies. *Journal of Dairy Science 85* (11), 2879-2884.
27. Papachristoforou, C., Roushias, A., Mavrogenis, A.P. (1982): The effect of milking frequency on the milk production of Chios ewes and Damascus goats. *Annales de Zootechnie 31* (1), 37-46.
28. Peris, C., Caja, G., Such, X. (1999): Relationships between udder and milking traits in Murciano-Granadina dairy goats. *Small Ruminant Research 33* (2), 171-179.
29. Prpić, Z., Mioč, B., Vnučec, I., Pavić, V., Konjačić, M. (2012): Factors affecting variability of udder morphology traits of sheep. *Stočarstvo 66* (4), 263-277.
30. Prpić, Z., Mioč, B., Vnučec, I., Držaić, V., Pavić, V. (2013): Non-genetic factors of udder morphology traits in Istrian ewes. *Mljekarstvo 63* (2), 72-80.
31. Sadeghi, S., Rafat, S.A., Ghaderi Zefrei, M., Khaligh, F., Rostami, K.H., Bohlouli, M., Bahrani Behzadi, M.R., Mohaghegh, M. (2013): Factors affecting external and internal mammary morphology traits and assessment of their interrelationships with milk yield in Lori Bakhtiari breed ewes. *Livestock Research for Rural Development 25* (3), 2013.
32. Salaris, S., Casu, S., Carta, A. (2007): Investigating the relationship between the prion protein locus and udder morphology traits and milk yield in Sardinian sheep. *Journal of Animal Science 85* (11), 2840-2845.
33. SAS Institute Inc. (2002-2008): SAS/STAT Version 9.2. Cary, NC: SAS Institute Inc.
34. Serrano, M., Pérez-Guzmán, M.D., Montoro, V., Jurado, J.J. (2002): Genetic analysis of udder traits in Manchega ewes. *Livestock Production Science 77* (2-3), 355-361.
35. Seykora, A.J., McDaniel, B.T. (1986): Genetic statistics and relationships of teat and udder traits, somatic cell counts, and milk production. *Journal of Dairy Science 69* (9), 2395-2407.
36. Ugarte, E., Gabiña, D. (2004): Recent developments in dairy sheep breeding. *Archiv Tierzucht Dummerstorf 47*, 10-17.