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Non-genetic factors of udder morphology traits in Istrian ewes

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Summary

Considering the facts that Istrian sheep is Croatian indigenous breed with the highest milk production, and increasing interest of local farmers for machine milking implementation, the aim of this study was to determine the factors affecting udder morphology traits of Istrian ewes. Ninety-three purebred Istrian ewes with symmetrical udders and no signs of clinical mastitis, from second to fourth lactation, were used for this study. Average udder depth of Istrian ewes was 15.85 cm, udder width 13.05 cm, udder circumference 39.66 cm, cistern height 1.44 cm, teat position 2.85 (scored from 1 to 5), teat angle 47.32°, teat length 3.43 cm and teat width 2.03 cm. The traits related to udder size (depth, width, and circumference) were significantly ($P<0.01$) affected by lactation milk yield. These traits were also in high and positive correlations ($P<0.01$) with daily milk yield. With the increase of parity, the morphological aptitude of udder to mechanical milking become worse, with an increase ($P<0.01$) of cistern height, teat angle and position. As lactation of Istrian ewes continued morphological traits defining udder aptitude for machine milking improved (decrease of cistern height, teat angle and position). Ewes with two and more lambs had larger udder ($P<0.05$) than ewes with a single lamb.

Key words: mammary gland, udder traits, machine milking, parity, stage of lactation

Introduction

Until recently, selection of dairy sheep breeds was focused almost exclusively on increase of produced milk (Barillet, 2007) so today they produce several times more milk than breeds selected for meat and wool. However, due to the permanent striving for increase in sheep milk production, udder weight becomes too great, and suspensory system can not withstand this overweight so it ruptures more often. That significantly shortens the duration of animal's production life and adversely affects udder aptitude for machine milking. Therefore, there is an increasing interest in addition of a so-called functional udder traits in sheep breeding programs, such as udder morphology, with the aim of increase oh biological and economic efficiency of milk production, not by production increase, but reducing its costs (Barillet, 2007). In order to identify the udder and teat traits suitable for inclusion into selection programmes, there is an increased number of studies on udder morphology of dairy ewes and determination of various factors of its variability during the last decade, not only regarding udder aptitude for machine milking, but also regarding milk productivity, udder health and longevity of ewes (Carta et al., 2009).

Sheep milk production in Croatia, as well as in other Mediterranean countries, is mainly based on local breeds well adapted to karst and rocks, meagre vegetation and hot summer temperatures. Istrian sheep is the indigenous Croatian breed which originates from and is bred on the Istrian peninsula in the north of the Adriatic Sea. This breed originally belongs to a group of combined production traits sheep (milk-meat-wool), although by its milk production

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features it can be assigned to a group of typical Mediterranean dairy breeds. Despite the relatively high productivity of about 260 kg of milk per lactation (Prpić, 2011), milk of Istrian ewes is especially suitable for cheese making because of its rich chemical composition (Mioč et al., 2012).

Considering the facts that Istrian sheep is Croatian indigenous breed with the highest milk production, and increasing interest of farmers for implementation of machine milking, the aim of this study was to determine factors affecting udder morphology traits of Istrian ewes.

Material and methods

Ninety-three purebred Istrian ewes with symmetrical udders, from second to fourth lactation, were used for this study. Investigated animals were kept in similar environmental, handling and feeding conditions throughout the study period. All ewes were traditionally grazed on natural pastures almost all year round. During the summer Istrian ewes were during the day *at home in the shade* while at night they grazed on pasture. During winter and dry summer periods investigated animals were fed alfalfa/meadow hay (about 1.5 kg per head per day), with the small addition of concentrates. Before and during the breeding season, as well as few weeks before and after the parturition, ewes were supplemented with 200-500 g of concentrates (mostly ground corn and barley). Breeding season lasted for approximately two months (June and July), and, consequently, lambing time occurred in November and December.

All ewes were hand milked twice daily one day after weaning, which took place 50 days postpartum. Ewes were milked without any udder preparation or teat dipping after milking. Ewes were dried off in the period from early June to late July. Milk production records were taken during the milking period using official AT recording scheme (ICAR, 2003), or single hand milking every 30 (28-34) days (alternating morning and evening milking) without utilizing any stimuli to induce the milk-let-down. First milk recording was carried out within 5-30 days of weaning for all ewes. A total of 420 milk yield records were obtained during milking period. Ewes were milked until their milk yield dropped to 0.1 L per milking. Individual milk yield per lactation was calculated by multiplying daily milk records by the number of days since lambing, for the first period, or by the number of days since the preceding milk recording day for subsequent recording days (Thomas et al., 1999). Only lactations with at least three monthly records were included in the analysis. Date of birth, length of lactation, parity and number of lambs born for each animal were obtained from the national breeding scheme recording system (Croatian Agricultural Agency, 2012).

On the day of milk recording all ewes were examined to assess the absence of clinical mastitis signs. Animals with clinical signs of mastitis were excluded from the study.

The udder measurements and teat position scores were taken every two months during milking period (at the occasions of the first, third and fifth milk recording day), approximately 2 h prior to evening milking. Data from ewes with at least two udder measurements were included in the study. Measurements of udder morphology were made by following the protocol proposed by Labussière et al. (1981) and McKusick et al. (1999). Udder morphology traits were made by one technician using ruler, measuring tape and protractor. A maximum of three udder measurements were carried out per ewe and the mean number of udder measurements taken per lactation (per ewe) was 2.69. Measures of udder consisted of: udder depth (rear distance between the abdominal wall and the udder cleft), udder circumference (circumference of the medium area of the udder), udder width (the distance between the widest lateral points of the udder), cistern height (the distance between teat implantation line and udder floor of both udder halves), teat angle (rear view, measured in degrees from vertical), teat length (the distance between the tip of the teat and its attachment to the udder), teat width (the distance between the two lateral borders of the teat) and teat position (lateral view of right and left teat, scored with 1 = turned backwards, 2 = vertical position, 3 = a little forward, 4 = forward, and 5 = much forward).

The data were subjected to analysis of variance, using the MIXED procedure of the SAS STAT (1999) statistical software including total lactation milk yield of the ewe, parity number, stage of lactation and number of lambs born as fixed effects. The dependent variables (Y) were udder morphology traits. Total lactation milk yield was grouped into three levels: <200 kg, 200 to 300 kg and >300 kg per lactation. The parity number was divided into three groups (second, third and fourth lactation). Forty Istrian sheep were in their second lactation, twenty-four in third lactation and twenty-nine in fourth lactation. Stage of lactation was divided into three periods: early-lactation (less than 70 days), mid-lactation (from 70 to 140 days) and late-lactation (over 140 days on lactation). Number of lambs born effect corresponded to two levels defined as single or multiple lambs. Since the differences between udder halves were minimal, and the correlation coefficients between both halves were high, the measures of teat and cistern traits were expressed as the mean of halves. Data from ewes with at least three monthly milk recordings and at least two udder measurements were included in the study. Finally, the analysis of correlation among all of the variables was performed using the CORR procedure (SAS STAT, 1999). Results are presented as the least square means (LSM) and variability of the data is expressed as the S.E. of the mean response over the whole study period. For all parameters, model effects were declared significant at $P<0.05$, unless otherwise stated.

Results and discussion

According to results presented in Table 1, the udder of Istrian ewes is well developed and relatively deep and wide. Compared to, for example, the ewes of Mediterranean breed Churra (Fernández et al., 1995), the udder of Istrian ewes is considerably deeper, but for about 7 cm smaller in circumference. Regarding some traits related to udder size (depth and width) and cistern height, the udder of Istrian ewes is similarly developed as udders of East Friesian crossbred dairy ewes (McKusick et al., 1999). Based on the average values of cistern height and teat angle that predetermine the aptitude of ewe udder for machine milking, it can be concluded that Istrian ewes are more convenient for machine milking than some dairy sheep breeds. Namely, on average 1.44 cm of udder depth in Istrian ewes was bellow the teat implantation line, whilst, for example, the average height of cistern in Lacaune ewes was 2.69 cm (Čapistrák et al., 2006), East Friesian ewes 2.97 cm (McKusick et al., 1999), Sarda ewes 3.19 cm (Labussière, 1988) and Awassi ewes 3.40 cm (Iñiquez et al., 2009). However, Čapistrák et al. (2006) determined lower height of cistern in Manchega ewes (0.90 cm), Tsigai ewes (1.28 cm) and Karagouniko ewes (1.31 cm) than those in presented study. Also, teats of Istrian ewes were more vertically placed (average teat angle 47.32°) than, for example, teats of East Friesian ewes (58.30°; McKusick et al., 1999) and Sarda ewes (67.20°; Labussière, 1988).

Considering the reduced cistern height, this measurement had a larger coefficient of variation (65.97 %) compared to other udder measurements presented in Table 1. According to Iñiquez et al. (2009), this suggests difficulties in recording this trait with precision.

Teats were slightly cranially oriented (teat position averaged a 2.85 score), whilst, for example, teats of Sarda (Labussière, 1988) and Churra ewes (Fernández et al., 1995) were more cranially oriented (teat position averaged from 3.6 to 3.7 score).

Table 1. Udder morphology traits of Istrian ewes (n = 93)

Trait	$\overline{x}$	SD	SE	Min	Max	CV
Udder depth, cm	15.85	2.27	0.14	10.50	25.00	14.32
Udder width, cm	13.05	1.98	0.13	11.00	20.10	15.17
Udder circumference, cm	39.66	5.58	0.35	28.00	58.50	13.42
Cistern height, cm	1.44	0.95	0.06	0.00	4.10	65.97
Teat position (score)	2.85	0.72	0.05	1.00	5.00	25.26
Teat angle, °	47.32	12.08	0.76	5.0	80.0	25.53
Teat length, cm	3.43	0.65	0.04	2.10	6.0	18.95
Teat width, cm	2.03	0.38	0.02	1.30	3.10	18.72

Table 2. Udder morphology traits of Istrian ewes with different lactation milk yield (LSM±SE)

Trait	Lactation milk yield			Level of significance
	<200 kg	200-300 kg	>300 kg	
Udder depth, cm	14.23±0.32[a]	15.58±0.28[b]	16.90±0.27[c]	**
Udder width, cm	12.08±0.28[a]	13.10±0.24[b]	13.52±0.24[b]	**
Udder circumference, cm	36.90±0.73[a]	39.29±0.64[b]	44.67±0.60[c]	**
Cistern height, cm	1.41±0.17	1.43±0.14	1.51±0.14	nz
Teat position (score)	2.78±0.11	2.81±0.09	2.83±0.09	nz
Teat angle, °	41.75±2.48[a]	43.82±2.13[a]	51.70±2.03[b]	*
Teat length, cm	3.48±0.12	3.47±0.10	3.39±0.09	nz
Teat width, cm	1.92±0.06[a]	2.01±0.06[ab]	2.13±0.05[b]	*

[a,b,c]Means with different superscripts in the same row are significantly different

*P<0.05; **P<0.01, ns: not significant

Table 3. Correlations between udder morphology traits and daily milk yield

Trait	Daily milk yield
Udder depth, cm	0.78**
Udder width, cm	0.41**
Udder circumference, cm	0.64**
Cistern height, cm	0.04
Teat position (score)	0.04
Teat angle, °	0.04
Teat length, cm	-0.05
Teat width, cm	0.16*

*P<0.05; **P<0.01

Compared with some other studied sheep breeds, it can be concluded that the teats of Istrian ewes are relatively large. Namely, Labussière (1988) found that the average teat length of Tsigai, Karagouniko, Lacaune, Sarda, Manchego and Churra ewes was from 2.61 to 3.33 cm, while the average teat width of different sheep breeds was from 1.43 to 1.77 cm (Perez Linares et al., 1983).

With the exception of genotype, the amount of milk produced is the most important factor of ewe udder size, shape, and development (Kukovics et al., 2006). Among all analyzed morphological udder traits (Table 2), the total amount of milk produced during lactation had the strongest influence on udder size measurements in a way that sheep with higher lactation milk yield had significantly (P<0.01) developed udder (larger circumference, depth and width) than those with lower milk yield. These results are in agreement with other authors (Labussière et al., 1988; Fernández et al., 1995; Emediato et al., 2008; Iñiquez et al., 2009). In parallel with the increase of lactation milk yield an increase of cistern height (P>0.05) and consequently, teat orientation cranially (P>0.05) and horizontally (P<0.05) was found.

Significant (P<0.05) and positive correlations (0.35-0.79) were found between udder size measurements (circumference, depth and width) and daily milk yield (Table 3) which is in accordance with the relationship of mentioned morphological udder traits with lactation milk yield presented in Table 2. Significant relationship between udder size

Table 4. Influence of parity on udder morphology traits of Istrian ewes (LSM±SE)

Trait	Lactation			Level of significance
	Second	Third	Fourth	
Udder depth, cm	15.51±0.21	15.94±0.26	16.07±0.25	ns
Udder width, cm	15.38[a]±0.19	15.66[a]±0.24	14.33[b]±0.22	*
Udder circumference, cm	39,91±0.53[ab]	40.80±0.70[a]	38.36±0.71[b]	*
Cistern height, cm	0,97[a]±0.10	1.28[a]±0.13	2.33[b]±0.12	**
Teat position (score)	2.62[a]±0.08	2.67[a]±0.10	3.21[b]±0.10	**
Teat angle, °	40.48±1.55[a]	47.71±1.69[b]	58.37±1.60[c]	**
Teat length, cm	3.54±0.08	3.44±0.10	3.24±0.10	ns
Teat width, cm	2.07±0.03	2.05±0.05	1.98±0.05	ns

[a,b,c]Means within the same row with different superscripts are significantly different
*P<0.05; **P<0.01, ns: not significant

Table 5. Influence of lactation stage on udder morphology of Istrian ewes (LSM±SE)

Trait	Stage of lactation			Level of significance
	Early	Mid	Late	
Udder depth, cm	16.93±0.21[a]	15.71±0.22[b]	14.52±0.22[c]	**
Udder width, cm	14.54±0.21[a]	13.08±0.20[b]	11.90±0.21[c]	**
Udder circumference, cm	44.57±0.64[a]	36.70±0.62[b]	35.11±0.64[c]	**
Cistern height, cm	1.53±0.11[a]	1.44±0.11[b]	1.37±0.12[c]	**
Teat position (score)	2.86±0.09	2.92±0.08	2.87±0.08	ns
Teat angle, °	48.81±1.65[a]	47.97±1.65[b]	46.82±1.67[c]	**
Teat length, cm	3.43±0.08[a]	3.35±0.08[b]	3.26±0.08[c]	**
Teat width, cm	2.02±0.04[a]	1.99±0.04[b]	1.93±0.04[c]	**

[a,b,c]Means with different superscripts in the same row are significantly different
**P<0.01, ns: not significant

measures and daily milk yield was also found in some other Mediterranean sheep breeds, such as Lacaune (Labussière et al., 1988), Chios (Mavrogenis et al., 1988) and Sarda (Casu et al., 1989). Except for the above mentioned measurements, teat width was the most associated with lactation (Table 2) and daily (Table 3) milk yield (P<0.05). Mavrogenis et al. (1988) and McKusick et al. (1999) also stated positive correlations between the width of teat and daily milk yield.

Mroczkowski and Borys (1998) and Rovai et al. (2003) found that udder measurements (depth, width, and circumference) increased as parity number increased, reaching the highest values in the third and the fourth lactation. A significant (P<0.05) effect of parity number on udder width and cicumference was determined in presented study (Table 4), with sheep in third lactation having the largest udder width and circumference. The morphological aptitude of the udder to mechanical milking become worse as parity number increased.

Namely, ewes in fourth lactation had the deepest udder with the highest cisterns. Also, teat scores for position and horizontality increased (P<0.01) as parity increased because of the positive correlation of cistern height with teat angle (Table 7) which is in agreement with the results given by Fernández et al. (1995). Simmilar to presented results in this study, Margetín et al. (2005) found that the ewes of different genotypes in third lactation have much deeper udder with larger and more horizontally placed teats than ewes in first lactation.

According to the results of other authors (Mavrogenis et al., 1988; Fernández et al., 1995; Iñiquez et al., 2009) length and width of teat decreased as parity number increased, although the differences in teat size of Istrian ewes in second, third and fourth lactation were not significant (Table 4).

Based on numerous studies (Fernández et al., 1995; Mroczkowski and Borys, 1998; Fahr et al., 2001; Kretschmer and Peters, 2002) 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. Thus, Rovai et al. (1998) reported a significant effect of stage of lactation on all analyzed morphological traits of udder and teats in Manchega and Lacaune sheep, despite the obvius differences in their daily milk yields (0,8 : 1,4 L, respectively). The traits defining udder size showed significant (P<0.01) differences between all stages of lactation (Table 5). As lactation of Istrian ewes continued morphological traits defining udder aptitude for machine milking improved. Given the facts that the cistern height, angle and position of teats were positively correlated with the daily milk yield (Table 7), their values decreased, respectively, as lactation continued and milk production decreased.

McKusick et al. (1999) pointed out that by reduction of milk secretion, pressure in the glandular cistern is reduced due to smaller quantity of stored milk, and consequently, "force" that affects the lateral movement of teats (increase of the angle and position score of teats) ceases. Namely, the traits related to the morphology of glandular cistern (cistern height, teat position and teat angle) were mutually positively correlated (r = 0.14 to 0.83), and showed a tendency to move forward and horizontally in parallel with the increase of cistern height (Table 7).

As lactation continued, a significant (P<0.01) decrease of teat length and teat width was found. Fernández et al. (1995) explained that decrease of the teat size is caused by the reduction of milk production, similarly as in dairy cows. On the contrary, no significant effect of lactation stage on the size of teats in Merino Rambouillet sheep was found (Ochoa-Cordero et al., 2006).

Table 6. Influence of number of suckling lambs on Istrian ewe udder morphology (LSM±SE)

Trait	Number of lambs born		Level of significance
	One lamb (n = 65)	Two and more lambs (n = 28)	
Udder circumference, cm	38.50±0.45	40.63±0.74	*
Udder depth, cm	15.66±0.18	16.41±0.30	*
Udder width, cm	12.82±0.15	13.40±0.27	*
Cistern height, cm	1.37±0.08	1.53±0.13	ns
Teat position (score)	2.88±0.06	2.66±0.09	ns
Teat angle, °	46.8±1.53	48.9±2.24	ns
Teat length, cm	3.43±0.05	3.44±0.10	ns
Teat width, cm	1.99±0.03	2.12±0.06	ns

*P<0.05, ns: not significant

Table 7. Correlations between udder traits

Trait	Udder width	Udder circumference	Cistern height	Teat position	Teat angle	Teat length	Teat width
Udder depth	0.60**	0.69**	0.03	-0.10	0.05	0.19**	0.20**
Udder width	-	0.68**	-0.06	-0.15*	-0.06	0.11	0.04
Udder circumference	-	-	-0.01	-0.02	-0.07	0.14*	0.02
Cistern height	-	-	-	0.51**	0,75**	-0.04	0.17*
Teat position	-	-	-	-	0.38**	-0.14*	-0.05
Teat angle	-	-	-	-	-	-0.14*	-0.13*
Teat length	-	-	-	-	-	-	0.77**

*P<0.05; **P<0.001

The available literature on the influence of the number of suckling lambs on ewe udder morphology traits is very scarce. Sinapis et al. (2008) found that the local Greek sheep breeds with two and more lambs have larger and more developed udder than ewes with one lamb. Horstick and Distl (2002) found similar in East Friesian sheep in Germany. Also, Istrian ewes (Table 6) with two and more lambs had larger (P<0.05) udder (greater udder depth, udder width and circumference) than ewes with a single lamb. The influence of born lambs number on other analyzed morphological traits was not significant, although ewes with two and more lambs had higher cisterns and teats placed more horizontally (Table 6).

As shown in Table 7, significant (P<0.01) correlations (r = 0.60-0.69) between the traits related to udder size (depth, width, and circumference) were established. These three traits were also highly correlated in some other sheep breeds (Mavrogenis et al., 1988; Fernández et al., 1995; Iñiquez et al., 2009; Kominakis et al., 2009).

Strong correlations were found between traits related to cistern morphology, particularly between cistern height and teat angle (r = 0.75; P<0.01), then between cistern height and teat position (r = 0.51; P<0.01) and between teat angle and teat position (r = 0.38; P<0.01). Udder width was negatively correlated with traits related to cistern morphology (cistern height, teat angle and teat position), although the correlations between these traits were not significant. Also, parallel with the increase of udder width a caudal movement of teats was found (P<0.05). Udder depth was in positive correlation (P<0.01) with teat length and teat width (r = 0.19 and r = 0.20, respectively). As teat angle increased, teat length and teat width decreased (P<0.05). Also, a strong and positive correlation was found between teat length and teat width (r = 0.77; P<0.01). Fernandez et al. (1995) concluded that in sheep breeds with small glandular cistern capacity, the function of milk storage is carried out by the teats and due to accumulation of milk teat size is increased. This might explain negative correlations between the cistern height and teat width (P<0.05), as well as negative correlations between teat size measures (length and width) and teat angle and teat position (Table 7).

Conclusions

Udder depth, width and circumference were highly dependent on lactation milk yield and daily milk yield. The morphological aptitude of Istrian ewes' udder to mechanical milking become worse as parity number increased. As lactation of Istrian ewes continued morphological traits defining udder aptitude for machine milking improved. In general, based on the average values of traits that predetermine the aptitude of ewe udder for machine milking, it can be concluded that Istrian ewes are convenient for machine milking.

Negenetski čimbenici morfoloških odlika vimena istarskih ovaca

Sažetak

S obzirom na činjenicu da je istarska ovca najmliječnija hrvatska izvorna pasmina ovaca te na sve veći interes uzgajivača za primjenom strojne mužnje, cilj ovog rada bio je utvrditi čimbenike morfoloških odlika vimena istarskih ovaca. Istraživanjem su bile obuhvaćene ukupno 93 čistokrvne istarske ovce, od druge do četvrte laktacije, sa simetrično razvijenim vimenom i bez znakova kliničkog mastitisa. Prosječna dubina vimena bila je 15,85 cm, širina vimena 13,05 cm, opseg vimena 39,66 cm, visina cisterne 1,44 cm, položaj sisa 2,85 (ocjena raspona od 1 do 5), kut sise 47,32°, duljina sise 3,43 cm i širina sise 2,03 cm. Odlike vezane uz veličinu vimena (dubina, širina i opseg vimena) bile su pod značajnim utjecajem (P<0,01) količine mlijeka proizvedenoga u laktaciji. Također, ove odlike su bile u visokoj i pozitivnoj korelaciji (P<0,01) sa dnevnom proizvodnjom mlijeka. S povećanjem redoslijeda laktacije prikladnost vimena strojnoj mužnji je narušena, s posljedičnim povećanjem (P<0,01) visine cisterne, kuta i položaja sisa. S odmicanjem laktacije utvrđeno je poboljšanje prikladnosti vimena strojnoj mužnji (smanjenje visine cisterne te kuta i položaja sisa). Ovce s dvoje i više ojanjene janjadi imale su veće (P<0,05) i razvijenije vime nego ovce s jednim janjetom.

Ključne riječi: mliječna žlijezda, odlike vimena, strojna mužnja, redoslijed laktacije, stadij laktacije

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