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CORRELATIONS BETWEEN UDDER TRAITS AND THEIR RELATIONSHIP WITH MILK YIELD DURING FIRST LACTATION IN SLOVENIAN ALPINE GOATS

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ABSTRACT

Udder traits were subjectively scored in 36 Slovenian Alpine goats as udder depth (UD), fore (FUA) and rear udder attachment (RUA), medial suspensory ligament (MSL), teat diameter (TD), length (TL) and position (TP), and measured as UDcm, RUAcm, TDcm, TLcm and TPcm. Phenotypic correlations among udder traits were estimated. Standardised regression coefficients were estimated for the effect of days in milk (DIM) on udder traits and daily milk yield (MY) and were tested for slope heterogeneity. Phenotypic correlations between UD and FUA, and UD and RUA were 0.25 and 0.11, respectively. Highly positive correlation was estimated between RUA and RUAcm (0.70), TD and TDcm (0.78), and TL and TLcm (0.85). Moderate correlations were estimated between days in milk and UDcm (−0.39), RUAcm (−0.34), and TDcm (−0.26), suggesting UD, RUA and TD become smaller as lactation progresses. Changes of udder traits over lactation were smaller than changes for daily milk yield. Decrease of TP, RUAcm, UDcm, TDcm, and milk yield throughout lactation was obtained. We found similar trend in changing UDcm and RUAcm with the trend of changing daily milk yield.

Key words: goats, udder traits, phenotypic correlation, milk yield, lactation period

1 INTRODUCTION

Slovenian Alpine (SA) goat is the most important goat dairy breed. There are also some other breeds used in dairy production, like Slovenian Sannen and autochthonous Dreznica goat. Although the SA counts only about 800 purebred animals, the breeding association is running a breeding programme (Kastelic *et al.*, 2010). The selection of does is based on genetic evaluation for milk traits and exterior characteristics. The present selection on dairy production traits in Slovenia does not include all udder traits, therefore, a linear scoring system (Linear Appraisal System, 2014) has been recently proposed for seven udder traits on a nine-point linear scale. The improvement of udder traits is beneficial to milking ability and animal health. Moreover, deep and well-attached udders are highly correlated with milk production in sheep (Casu *et al.*, 2000 cited in Altinçekiç and Koyuncu, 2011; Legarra and Ugarte, 2005) and goats (McLaren *et al.*, 2016). Higher and more tightly attached udders are associated with lower somatic cell scores, thus, udder depth is considered as an easy-to-collect predictor of udder health in goats (Rupp *et al.*, 2011). Vertical placed teats on the lowest part of the cistern are less subject to teat-cup falls during milking (Casu *et al.*, 2000 cited in Altinçekiç and Koyuncu, 2011).

Linear scoring system has to include udder traits which have economic impact and are at least moderately heritable. Heritabilities estimated by Manfredi *et al.*, (2001) were moderate (about 0.30) for udder traits and teat location traits and exceeds 0.40 for teat length, width, and form. Similar results were obtained by Rupp *et al.* (2011) where heritabilities ranged from 0.2 for teat angle to 0.5 for teat form and length. Estimates of heritability for rear udder attachment were from 0.23 to 0.27. Several studies reported

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negative genetic correlations between milk yield and udder depth in goats (Manfredi et. al., 2001; Rupp *et al.*, 2011; McLaren *et al.*, 2016). McLaren *et al.* (2016) obtained weaker but still negative correlations between milk yield and udder attachment (–0.28). In addition, the correlations estimated between milk yield and teat angle (–0.40) and milk yield and teat placement (–0.35) remained negative throughout lactation in goats. McLaren *et al.* (2016) suggested that breeding programs for dairy goats would benefit by taking udder traits into account in order to prevent deterioration in udder conformation. Rupp *et al.* (2011) stated that improvement of udder conformation could also reduce lactation somatic cell count in goats.

The main goals of our study were to (1) estimate phenotypic correlations among udder traits, (2) to estimate phenotypic correlations between measured and appraisal udder traits, and (3) to assess phenotypic relationship between udder traits and milk yield during the first lactation.

2 MATERIAL AND METHODS

2.1 DATA

The study was conducted at the Educational and Research Animal Husbandry Centre Logatec at Biotechnical Faculty, University of Ljubljana. The data set comprised records collected for 36 Slovenian Alpine goats during first lactation for measurements and linear scores for udder traits. Rear udder attachment (RUAcm), udder depth (UDcm), teat diameter (TDcm) and teat length (TLcm) were measured using flexible canvas tape. Fore (FUA) and rear (RUA) udder attachment, udder depth (UD), medial suspensory ligament (MSL), teat placement-rear view (TP), teat diameter (TD) and length (TL) were scored subjectively using a nine-point scale.

Altogether, 36 first lactation goats were obtained three times over lactation, each scoring was repeated in five consecutive days, giving 15 measurements for each udder traits per goat with only four goats one scoring missing. In three traits (TD, TDcm, and RUAcm) one observation per each trait was excluded due to data errors. Milk yield of 34 goats was measured four times through lactation and three times for 2 goats. Therefore, 536 records for udder traits and 142 for milk yield was included. Milk yield was obtained by routine milk recording using AT4 method (ICAR Recording Guidelines, 2016).

2.2 UDDER TRAIT DEFINITIONS

The linear scoring system for dairy goats from American Dairy Goat Association (Linear Appraisal System, 2014) was followed to define udder and teat traits. Averages for twelve udder traits are given in Table 1. The term ”linear” refers to the fact that traits are scored on a linear scale from one (1 point) to the other (9 points) biological extreme. For scoring the FUA, the recorder looked at attachment strength of lateral ligaments as they extend forward and laterally to the abdominal wall. The average of FUA was 2.98 scores and was wide from expected average (5 points). An extremely loose attachment was assigned to 1 point, an extremely strong attachment to 9 point. RUA stands for width and shape of the attachment of the rear udder. An extremely narrow and pointed rear udder attachment was assigned to 1, while extremely wide to 9. The RUA average was higher (4.42) with larger standard deviation (1.62) as FUA. An udder with a weak medial suspensory ligament (MSL), without any cleft but just negative bulge presented, was assigned to 1 point, an udder with clearly defined halving to 5 points, and an udder with an extreme cleft to 9 points. The overall score of MSL (5.43) in our experiment was close to expected average. Udder depth (UD) was defined as vertical distance of udder floor above hocks, scoring 1 for very deep and 9 for extremely high udder. The average was in the middle of the scale with large standard deviation. Teat placement (TP) was viewed from the rear. Teats positioned on the outside third of udder half was assigned from 1 to 3 points. Extremely inside positioned teats were scored from 7 to 9 points while vertical positioned teats were valued between 4 and 6 points. The distribution of TP was right skewed (1.39) and the average was closer to minimum scale – extremely outside positioned teats (2.11). Teat diameter (TD) was evaluated from rear at attachment to the udder. TD was scored as very narrow (1, 2 or 3 points) to very wide (7, 8 or 9 points). The average was in the middle of the scale (5.13, Table 1) with larger standard deviation as TP. Teat length (TL) was evaluated from the rear as well and set to 1 point if very short and 9 if extremely long.

RUA, UD, TP, TD and TL were also measured by tape and indicated with RUAcm, UDcm, TPcm, TDcm and TLcm, respectively. RUAcm was measured as udder width in place where the udder was attached, as viewed from the rear. UDcm was measured as a distance from the attachment place to udder floor. TPcm was measured as a distance between teats. TPcm was determined by the centre of the teat at the point where the teat attached to the udder. TDcm was measured as the diameter of the teat at its base where it meets the left half of the udder, as viewed from the rear. TLcm was measured as a distance from the base of the teat to the end of the teat on the left half of the udder. The distributions of measured traits were symmetric with the exception of distributions of RUAcm, which was right skewed (Table 1). The results might indicate

Table 1: *Descriptive statistics for udder traits, days in milk, and milk yield in Slovenian Alpine goats*

Linear assigned udder traits	N	Mean value	SD	skewness	kurtosis	Min	Max
Fore udder attachment (FUA)*	536	2.98	0.74	−0.05	2.17	1	6
Rear udder attachment (RUA)	536	4.42	1.62	0.11	0.53	1	9
Medial suspensory ligament (MSL)	536	5.43	1.28	0.58	0.89	2	9
Udder depth (UD)	536	5.52	1.23	0.43	0.25	1	9
Teat position (TP)*	536	2.11	1.52	1.39	1.33	1	8
Teat diameter (TD)	535	5.13	2.24	−0.07	−0.98	1	9
Teat length (TL)	536	5.29	2.22	−0.02	−0.79	1	9
Measured udder traits							
Rear udder attachment (RUAcm), cm*	535	6.14	1.31	1.63	4.69	3.5	13.0
Udder depth (UDcm), cm	536	15.82	2.06	−0.16	−0.20	10.0	21.0
Teat position (TPcm), cm	536	10.22	2.78	0.03	−0.66	3.0	18.0
Teat diameter (TDcm), cm	535	2.76	1.01	0.57	0.11	0.8	6.7
Teat length (TLcm), cm	536	5.82	1.72	0.46	−0.42	2.5	10.5
Days in milk (DIM), days	678	117	40	−0.01	−1.13	49	206
Milk yield, g	142	2055	1111	0.93	1.01	100	5900

N – number of observations; SD – standard deviation;*non normal distribution

some difficulties in recording practice as RUA and TPcm were normally distributed and alternatives (RUAcm and TP) were right skewed. On the other hand, all goats assessed came from one smaller herd and it is too early to make more certain conclusions.

2.3 STATISTICAL ANALYSIS

Pearson correlation coefficients were estimated between udder type traits. As udder traits were not taken pairwise on the same day as daily milk yield but as close as possible. In addition, udder traits were assessed 5-times in consecutive days. Linear regression was used to evaluate the effect of DIM on udder traits and MY (Model 1). Test for slope heterogeneity was applied among udder traits and milk yield using standardised regression coefficients as applied in Model 2.

$$y_i = \mu + b(x_i - \overline{x}) + e_i \qquad \text{(Model 1)}$$

$$y_{ij} = \mu_i + b_i x_{ij} + e_{ij} \qquad \text{(Model 2)}$$

Standardized individual observation for dependent variable (udder type traits and daily milk yield) is presented by y_{ij}, μ_i intercept of i-th trait, b_i regression coefficient, nested within i-th trait, x_{ij} standardized covariate (days in milk) and e_{ij} residual. Statistical analyses were performed by GLM procedure using SAS/STAT® software, Version 9.4 of the SAS system for Windows (SAS Inst. Inc., 2014).

3 RESULTS AND DISCUSSION

Estimates of the phenotypic correlations (Table 2) of udder depth (UD) with fore (FUA, 0.25) or rear (RUA, 0.11) udder attachment were weak. Correlations between udder depth and udder attachment was higher (0.38) in mixed-breed dairy goats published by McLaren *et al.* (2016) and in Latxa sheep (–0.58) by Legarra and Ugarte (2005). Negative value in Latxa sheep were due to different definition of udder depth on reverse scale. Correlations were weak and negative varying from –0.11 to –0.33 between UD and teat traits TD, TL, TPcm, TDcm and TLcm, indicating that teats were longer, wider, and positioned far away from each other in deep and poorly attached udders. UD was correlated with measured TPcm (–0.33), although less correlated with subjectively scored TP (0.14). Udder length and teat distance was also uncorrelated in Black and Meriz goats as published by Merkhan and Alkass (2011). The correlation between RUA and TL (–0.14), RUA and TLcm (–0.12) and, RUAcm and TL (–0.14) were weak. TL might be shorter wherever udders were well attached. Heritability estimates of udder traits by Manfredi *et al.* (2001) were moderate, about 0.3, and teat traits (width and length) even higher (0.4). While udder depth was correlated to teat measurements (width and length), rear and front udder attachment, the selection against ‘’baggy” udder could cause correlated genetic response in other teat and udder traits. In addition, Rupp *et al.* (2011) found the genetic correlations between lactation somatic cell scores (LSCS) and type traits to be the highest for teat length

Table 2: *Pearson correlation coefficients among udder traits (above diagonal) with statistical significance (below diagonal)*

	FUA	RUA	MSL	UD	TP	TD	TL	RUAcm	UDcm	TPcm	TDcm	TLcm
FUA	-	0.47	−0.26	0.25	0.07	−0.20	−0.18	0.30	−0.29	−0.02	−0.18	−0.19
RUA	***	-	−0.38	0.11	0.09	−0.15	−0.14	0.74	−0.12	0.24	−0.13	−0.12
MSL	***	***	-	0.00	0.19	0.28	0.26	−0.33	0.08	−0.30	0.24	0.26
UD	***	*	ns	-	0.14	−0.16	−0.15	−0.05	−0.60	−0.33	−0.17	−0.11
TP	ns	*	***	**	-	0.12	0.14	0.12	−0.04	−0.41	0.15	0.23
TD	***	***	***	***	**	-	0.91	−0.13	−0.15	−0.29	0.78	0.83
TL	***	**	***	***	**	***	-	−0.14	−0.01	−0.28	0.67	0.86
RUAcm	***	***	***	ns	**	**	*	-	0.15	0.34	0.02	−0.08
UDcm	***	*	ns	***	**	ns	ns	**	-	0.43	0.16	−0.00
TPcm	ns	***	***	***	***	***	***	***	***	-	−0.24	−0.38
TDcm	***	*	***	***	**	***	***	ns	***	***	-	0.75
TLcm	***	*	***	*	***	***	***	ns	ns	***	***	-

FUA = Fore udder attachment; RUA = Rear udder attachment; MSL = Medial suspensory ligament; UD = Udder depth; TP = Teat position; TD = Teat diameter; TL = Teat length; RUAcm = Rear udder attachment, cm; UDcm = Udder depth, cm; TPcm = Teat position, cm; TDcm = Teat diameter, cm; TLcm = Teat length, cm; ns = not significant; * = $p < 0.05$; ** = $p < 0.01$; *** = $p < 0.001$.

(0.29), teat width (0.34), and teat form (−0.27) in the Alpine breeds. They reported that the shortest and tightest teats were associated with the lowest LSCS.

When compared linear scored udder traits with the same traits but measured, there was a highly positive correlation between RUA and RUAcm (0.74), TD and TDcm (0.78), and TL and TLcm (0.86). If RUA was assigned as extremely wide with 7, 8 or 9 points, RUAcm was extremely high as well. Subjective scores for TD and TL and measurements of TDcm and TLcm agreed very much. UD and UDcm were moderately correlated (−0.60). The correlation was negative because extremely deep udder scored with 1, 2 or 3 points were associated by extremely high udder floor. TP and TPcm were correlated below the expectations (−0.41). Udder traits by linear scoring system are offering similar conclusions like equivalent (counterpart) among measurements taken. Experienced scoring experts could achieve sufficient information about udder and teat type traits. An additional problem by measuring udder traits is to restrain an animal in a natural position long enough to make an accurate measurement, especially when the differences measured were small.

Linear regression coefficients for all udder traits and daily milk yield were estimated (Table 3). Standardized regression coefficients for all udder traits and daily milk yield were estimated to compare trends. Changes of udder traits over lactation are smaller than changes for MY. Decrease of TP, RUAcm, UDcm, TDcm, and MY throughout lactation was obtained. RUAcm was smaller for 0.37 SD (standard deviation) when lactation progressed for 1 SD. Distance from the attachment place to the floor of the udder (UDcm) decreased for 0.41 SD per 1 SD. Milk yield decreased for 0.62 SD per 1 SD longer lactation. UD and

Table 3: *Linear regression coefficients of days in milk on udder traits and daily milk yield (MY)*

	FUA†	RUA	MSL	UD	TP†	TD	TL	RUAcm†	UDcm	TPcm	TDcm	TLcm	MY
$\hat{b}$	0.001	0.001	0.001	0.005	−0.008	0.003	0.007	−0.012	−0.021	−0.006	−0.007	0.000	−17.212
SEE	0.001	0.002	0.001	0.001	0.002	0.003	0.003	0.001	0.002	0.003	0.001	0.002	1.961
Sig.	ns	ns	ns	**	***	ns	**	***	***	ns	***	ns	***
$\hat{b}_i$	0.03	0.03	0.03	0.16	−0.22	0.06	0.13	−0.37	−0.41	−0.08	−0.27	0.00	−0.62
SEE	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.09
Sig.	ns	ns	ns	**	***	ns	**	***	***	ns	***	ns	***

FUA = Fore udder attachment; RUA = Rear udder attachment; MSL = Medial suspensory ligament; UD = Udder depth; TP = Teat position; TD = Teat diameter; TL = Teat length; RUAcm = Rear udder attachment, cm; UDcm = Udder depth, cm; TPcm = Teat position, cm; TDcm = Teat diameter, cm; TLcm = Teat length, cm; MY = Milk Yield; $\hat{b}$ = estimated regression coefficients; $\hat{b}_i$ = estimated standardized regression coefficients; SEE = standard error; Sig = significance; ns = not significant; * = $p < 0.05$; ** = $p < 0.01$; *** = $p < 0.001$; † = non normal distribution.

Table 4: *Estimated differences in standardized trend between udder traits and daily milk yield (MY)*

	FUA[†]	RUA	MSL	UD	TP[†]	TD	TL	RUAcm[†]	UDcm	TPcm	TDcm	TLcm
diff.	0.65	0.64	0.65	0.78	0.41	0.68	0.75	0.25	0.20	0.54	0.34	0.62
SEE	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
Sig.	***	***	***	***	***	***	***	*	*	***	**	***

FUA = Fore udder attachment; RUA = Rear udder attachment; MSL = Medial suspensory ligament; UD = Udder depth; TP = Teat position; TD = Teat diameter; TL = Teat length; RUAcm = Rear udder attachment, cm; UDcm = Udder depth, cm; TPcm = Teat position, cm; TDcm = Teat diameter, cm; TLcm = Teat length, cm; MY = Milk Yield; diff. = estimated difference in standardized regression coefficients; SEE = standard error; Sig = significance; ns = not significant; * = $p < 0.05$; ** = $p < 0.01$; *** = $p < 0.001$; [†] = non normal distribution.

TL showed positive trend, although increase was small (0.16 SD and 0.13 SD, respectively).

Differences in slope among MY and udder traits were obtained using test for slope heterogeneity. The smallest difference in trend was observed between UDcm and MY, on the other hand, the highest difference in trend was obtained with subjectively scored UD, while UD and UDcm were in negatively correlation. Results confirmed the strongest relationship of daily milk production with udder depth predicting the cistern volume. These results are in agreement with literature (Manfredi et. al., 2001; Rupp *et al.*, 2011; McLaren *et al.*, 2016). Moreover, RUAcm was decreasing similarly to decrease of MY, with estimated difference in standardized regression coefficient 0.25. When lactation progressed, daily milk yield was smaller and rear udder attachment was shorter. Other traits showed independent trend comparing to milk production.

4 CONCLUSION

There was weak relationship between udder depth and fore udder attachment and, udder depth and rear udder attachment. Stronger correlation was evaluated for days in milk with some measured udder traits, suggesting that with progressed lactation the measurements of udder depth, rear udder attachment, and teat diameter become smaller. Negative values of standardised regression coefficient of udder traits in relationship with days in milk confirmed the negative trend.

The correlations between linear scored udder traits and their measured counterparts were highly positive, suggesting that linear scoring system could be appropriate substitution for measuring system.

For most of the udder traits we did not find similarities in trends with milk yield, with exception for UDcm and RUAcm. With decreasing of milk yield UDcm and RUAcm decreased similar.

The current results are not enough informative for general application of the tested scoring system into selection programs. As more data become available, future estimates may become more accurate, particularly in terms of the standard errors associated with the estimates observed and the fact that the data originated from just one farm.

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