Machine Milking Ability of Ewes of Tsigai, Improved Valachian, Lacaune Breeds and Their Crosses: Udder Morphological Traits and Milking Characteristics

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Abstract. *Good and homogenous udder morphology of dairy ewes is desirable for good milkability, udder health and animal welfare, especially if machine milking is in use. We evaluated the udder morphology and milkability of 286 ewes of eight genotypes (Tsigai, Improved Valachian, Lacaune breeds and 5 types of their crosses). The aim was to obtain an overview of the most important parameters to be evaluated for breeding dairy sheep breeds. The following traits were evaluated on a 9-point linear scale: udder depth, cistern depth, teat position, teat size, udder cleft, udder attachment and general udder shape. Selected parameters that characterise the milk yield and milkability of ewes were also recorded in individual control measurements: amount of machine milked in 30 and 60 seconds, machine milk yield, machine stripping, total milk yield and percentage thereof. Linear evaluation and precise udder measurements showed that Tsigai and Improved Valachian ewes had smaller udders with smaller cisterns and a better teat position than Lacaune ewes. The proportion of machine stripping (PMS) was best (lowest value) in the Improved Valachian ewes (26.0%) among the purebred breeds, followed by the Tsigai ewes (27.2%), and it was found to be highest in the purebred Lacaune ewes (36.3%). PMS was significantly influenced by teat size ($r = 0.177$ and 0.113, respectively; $P < 0.001$), udder attachment ($r = -0.205$; $P < 0.001$) and general udder shape ($r = -0141$; $P < 0.001$). From the study, it could be concluded that in Slovakia it will be necessary to additionally use data from linear udder evaluation (mainly udder depth, teat position, teat size and udder attachment) for breeding of dairy sheep breeds.*

Introduction

Udder morphology is an important trait to consider in both dairy and meat sheep production systems (Martinez et al., 2011; Pourlis, 2011; Pourlis, 2020; Kapusi et al., 2015; Ivanova and Raicheva, 2019; Seker et al., 2022, 2024). Udder and teat characteristics can affect milking ability (whether milked by hand, machine or lambing), disease incidence (such as mastitis) and production levels (both milk and meat) (Rovai et al., 2008; Hassoun et al., 2016; Knuth et al., 2021; Dzidic et al., 2019, 2022).

The morphology of the ewe's udder has been well studied in dairy breeds (Marie-Etancelin et al., 2005; Kominakis et al., 2009; Casu et al., 2010; Gelasakis et al., 2012; Ivancia et al., 2023), and in recent years interest has also increased in breeds reared primarily for meat production (Purfield et al., 2017; Suliman et al., 2021). Reasonably full, spherical and deep udders are often preferred as an indication of good milk production (Pieramati et al., 2011), but only up to an intermediate level: udders that become too deep are more difficult to milk, more difficult for lambs to access and often more prone to injury. The attachment of the udder at the top and the bottom to the abdomen should be wide and strong (De la Fuente et al., 1996; Fernández et al., 1997). Other examples include teat placement and size. The preferred teat placement and angle in dairy systems allow easier access for mechanical milking while still allowing lambs to suckle. In meat systems (Martinez et al., 2011; Karakus et al., 2024), the main priority is to allow lambs to suckle, but other features such as protection from the elements are sometimes also considered important. Teat size is also an important characteristic to consider, as teats that are too large or too small may not fit into the mechanical milking cup or may affect the ease with which lambs can latch on to the teat.

The evaluation of udder morphology can be carried out by both direct measurements and subjective scoring of various morphology related traits using linear scoring systems (Dzidic et al., 2004). A number

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of different scoring systems have been developed, focusing on both udder- and teat-related traits that are easy to score and repeatable, such as: udder depth, udder attachment, teat placement, teat angle and teat shape, to name a few examples (Milerski et al., 2019). In most dairy sheep breeding programmes, the four udder traits that are considered most important are udder depth, udder attachment, teat angle and teat length (De la Fuente et al., 1996; Casu et al., 2010; Gelasakis et al., 2012).

Selection for milk yield alone leads to a deterioration in udder morphology (Bruckmaier et al., 1997), so it is important to include udder morphology traits in dairy sheep breeding programmes to prevent this. Some udder traits have also been found to be phenotypically and genetically related to milking performance and udder health; therefore, improvements in udder morphology will also help to improve milking performance and reduce the incidence of mastitis in livestock.

The impact of poor udder morphology can be significant in both dairy and meat sheep systems. Problems associated with poor morphology and milking systems include slow parlour throughput, injury due to changes in milking pressure or over milking, and infection. Similarly, in meat production systems, poor udder morphology prevents lambs from suckling properly, which affects their growth rate and can result in injury and infection to the ewe. When udder morphology is more favourable, ewes are less susceptible to infection, remain in the flock longer, culling and replacement rates are reduced and production levels in terms of milk and meat are improved (Rovai et al., 2008).

The aim of this work was to obtain an overview of the most important parameters to be evaluated for breeding dairy sheep breeds. Selected traits of linear evaluation of udder and milkability of ewes of the Tsigai, Improved Valachian, Lacaune breeds and their crosses were analysed to find out to what extent the selected traits of milk production and milkability depend on udder morphology.

Materials and methods

The udder morphology of ewes of 3 purebred breeds (Tsigai (T), Improved Valachian (IV) and Lacaune (LC)) and 5 types of their crosses (IVxLC (37.5% LC), IVxLC (50% LC), IVxLC (75% LC), TxLC (50% LC), TxLC (75% LC)) was measured during the milking period of 2002–2004 (number of ewes = 286; some ewes were measured several times).

We scored the following traits on a 9-point linear scale:

- Udder depth (UD-LA) – or udder height – measured as the distance between the posterior insertion and the base of the udder;
- Cistern depth (CD-LA), which is the distance between the base of the udder and the bottom of the cistern;
- Teat position (TP-LA), which is the angle of the teat attachment to the udder;
- Teat size (TS-LA), which is the length and diameter of the teat;
- Udder cleft (UC-LA), which is the depth of the groove between the udder halves;
- Udder attachment (UA-LA)–, which is the circumference of the udder attachment to the abdominal wall;
- General udder shape (GSU-LA), which is the overall shape of the udder, including its width and height.

We also recorded selected parameters that characterise the milk yield and milkability of ewes in individual control measurements. We studied the following parameters (in mL): amount of milk milked by machine within 30 and 60 seconds (MY30s; MY60s), machine milk yield (MMY), machine stripping (MS), total milk yield (TMY) and percentage of machine stripping (PMS), proportion of MY30s in TMY (PMY30s) and proportion of MY60s in TMY (PMY60s).

To analyse the primary data of all the variables (583 measurements for each parameter), we used the linear model with fixed effects, taking into account the factor genotype (8 levels), parity (3 levels), control year*period of milking (6 levels) and days in milk as a covariate. Partial correlation coefficients were calculated on the residuals after data adjustment by the above-mentioned linear model of covariance analysis. The SAS statistical package (SAS/STAT, 1999-2001), GLM and CORR procedures were used for the calculations.

Results

All parameters studied (Table 1) were significantly influenced by genotype ($P < 0.001$). As seen in Table 1, most parameters were also significantly influenced by the effect of parity. According to the linear evaluation, ewes in the third lactation had significantly greater udder depth (5.57 points), depth of the cistern (5.32 points), larger teats (4.90 points) and a more horizontal position of the teats (5.48 points) than ewes in the first lactation (4.51; 4.89; 4.27, respectively; $P < 0.05$ to 0.001). Ewes in the first lactation had better milk ejection (based on the amount and proportion of milk milked in 30 and 60 seconds) and lower PMS than ewes in the third lactation ($P < 0.01$ to 0.001).

When comparing purebred ewes of T, IV and LC breeds, LC ewes had the greatest udder depth (UD-LA = 6.19), followed by IV (4.55), and the lowest depth was found in T ewes (3.68; Table 1). The differences were highly significant ($P < 0.001$). On the other hand, the worst teat position was in LC ewes (TP-LA = 5.76), followed by IV ewes (4.58), and the best position was in T ewes (4.52). The differences between T and LC ewes were highly significant ($P < 0.001$). Teat size was significantly larger in IV

Table 1. Estimates of mean values (LSM) of selected morphological and functional traits of udder in sheep in dependence on their genotype. No = 583 measurements for each parameter

Trait	Genotype							
	IV	IVxLC (37.5% LC)	IVxLC (50% LC)	IVxLC (75% LC)	T	TxLC (50% LC)	TxLC (75% LC)	LC
UD-LA	4.55	4.37	5.76	5.76	3.68	5.18	4.86	6.19
UD (mm)	13.70	14.10	17.46	16.96	12.22	15.05	15.22	18.52
CD-LA	4.08	4.65	5.76	5.13	4.11	5.82	5.43	5.98
CD (mm)	1.91	2.16	3.50	2.94	1.59	2.91	2.33	3.36
TP-LA	4.58	4.83	5.60	5.49	4.52	5.95	5.18	5.76
TP-st.	40.99	42.65	45.79	45.94	40.06	50.51	41.95	46.27
VC-LA	4.94	5.15	4.66	4.68	4.14	4.54	4.35	4.50
TS (mm)	3.73	3.75	3.50	3.56	3.38	3.39	3.63	3.47
UC-LA	5.07	5.08	5.58	4.83	4.82	4.99	3.82	4.32
UA-LA	5.61	5.83	5.64	5.71	4.95	5.49	4.86	5.33
GSU-LA	5.24	5.67	5.83	5.89	4.15	5.68	5.34	5.73
MY30S	231.7	194.6	240.09	230.70	183.7	233.1	220.2	243.7
MY60S	305.0	273.1	351.4	343.4	210.9	288.7	321.6	345.0
MMY	307.1	279.7	378.4	371.3	211.2	302.2	361.1	355.8
MS	100.3	107.8	136.5	130.5	79.4	114.9	95.2	180.5
TMY	407.4	387.6	514.8	501.8	290.6	417.1	456.3	536.4
PMS	26.0	35.7	27.5	28.8	27.2	28.2	23.5	36.3
PMY30S	58.1	45.8	49.2	46.6	64.5	58.4	51.0	45.2
PMY60S	73.6	63.3	68.4	66.8	72.6	70.0	71.1	62.0

Abbreviations: Tsigai (T), Improved Valachian (IV), Lacaune (LC), Udder depth (UD), Linear assessment (LA), Cistern depth (CD), Teat position (TP), Teat size (TS), Udder cleft (UC), Udder attachment (UA), General udder shape (GSU), Teat angle (TA), Teat length (TL), Machine milk yield milked within 30 seconds (MY30s), Machine milk yield milked within 60 seconds (MY60s); Machine milk yield (MMY), machine stripping (MS), Total milk yield (TMY) and Percentage of machine stripping (PMS), Proportion of MY30s in TMY (PMY30s) and Proportion of MY60s in TMY (PMY60s).

ewes (TS-LA = 3.73) than in LC (3.47) and T ewes (3.38; $P < 0.001$). The crosses IV x LC and T x LC with 50% and 75% genetic content had larger udders, larger udder cisterns but a worse teat position.

LC ewes had the highest TMY (536.4 mL; Table 1) but only the fourth best MMY (355.8 mL). However, it was higher than in purebred T ewes (290.6 mL) and IV ewes (407.4 mL). Among the purebred breeds, the proportion of machine stripping (PMS) was lowest in IV ewes (26.0%), followed by T ewes (27.2%), and highest in purebred IV ewes (36.3%). The lowest value for PMS is an advantage of the breed, as a low value for this trait is expected.

The proportion of milk milked within 30 and 60 seconds from TMY was highest in T ewes (64.5% and 72.6%, respectively), followed by IV ewes (58.1% and 73.6%, respectively), and lowest in LC ewes (45.2% and 62.0%, respectively).

Table 2 shows that udder depth was highly significantly correlated with machine milk (r = 0.296 and 0.314, respectively) and total milk yield (r = 0.465 and 0.518, respectively; $P < 0.001$) as well as with the amount of milk milked within 30 and 60 seconds. The proportion of machine stripping was highly significantly influenced by teat size (r = 0.177 and 0.113, respectively; $P < 0.001$). The larger the teat, the higher the proportion of machine stripping. Teat position had no effect on PMS in our experiment. In contrast, both milk yield (MMY, TMY) and milkability (MY30s, MY60s, PMS) were highly (significantly) dependent on udder attachment and general teat shape ($P < 0.001$) (Table 2). The better the teat attachment, the lower the PMS (r = –0.205; $P < 0.001$) and the better the general udder shape score, the lower the PMS (r = –0.141; $P < 0.001$). Our results show that the improvement of the native breeds T and IV by the breed LC increases not only the udder size but also the milk production (MMY and TMY) in the created crosses. However, it is mainly the teat position that deteriorates in combination with larger udder cisterns. Traits related to milkability (PMS, PMY30s, PMY60s) are slightly worse in the crosses than in purebred T and IV ewes, with the worst being in the LC breed.

Table 2. Residual correlations among traits of milkability and linear assessment and measures of udder in sheep

Trait	MY30S	MY60S	MMY	MS	TMY	PMS	PMY30S	PMY60S
UD-LA	0.227+++	0.251+++	0.296+++	0.355+++	0.465+++	0.052ns	–0.115++	–0.116++
UD-mm	0.182+++	0.265+++	0.314+++	0.429+++	0.518+++	0.079ns	–0.186+++	–0.145+++
CD-LA	0.148+++	0.156+++	0.153+++	0.77ns	0.184+++	–0.058ns	0.022ns	0.055ns
CD-mm	0.184+++	0.219+++	0.206+++	0.184+++	0.289+++	–0.028ns	–0.013ns	0.034ns
TP-LA	0.067ns	0.191+	0.094+	0.095+	0.139+++	–0.003ns	–0.043ns	–0.008ns
TP-st.	0.063ns	0.035ns	0.031ns	0.066ns	0.064ns	–0.019ns	0.034ns	0.016ns
TS-LA	0.125++	–0.137+++	–0.128++	0.134++	–0.049ns	0.177+++	–0.113++	–0.174+++
TS-mm	–0.95+	–0.148+++	–0.144+++	0.52ns	–0.107++	0.113++	–0.009ns	–0.106+
UC-LA	0.074ns	0.088+	0.079ns	–0.009ns	0.069ns	–0.057ns	0.032ns	0.062ns
UA-LA	0.345+++	0.363+++	0.334+++	–0.033ns	0.296+++	–0.205+++	0.124++	0.213+++
GSU-LA	0.402+++	0.396+++	0.383+++	0.114++	0.419+++	–0.141+++	0.095+	0.134++

Abbreviations: Udder depth (UD), Linear assessment (LA), Cistern depth (CD), Teat position (TP), Teat size (TS), Udder cleft (UC), Udder attachment (UA), General udder shape (GSU), Machine milk yield milked within 30 seconds (MY30s), Machine milk yield milked within 60 seconds (MY60s); Machine milk yield (MMY), machine stripping (MS), Total milk yield (TMY) and Percentage of machine stripping (PMS), Proportion of MY30s in TMY (PMY30s) and Proportion of MY60s in TMY (PMY60s).

Discussion

Mačuhová et al. (2008) studied the correlation coefficients between the parameters of udder traits and milking traits of the sheep breeds Tsigai, Improved Valachian and their crosses with Lacaune. Total milk yield and machine milk yield were significantly correlated with all udder traits and milking trait parameters except machine stripping and milk flow latency. Milk flow latency showed positive correlations with milking time and negative correlations with maximum peak flow.

The positive and significant correlation was also found between the teat position and cistern depth. The same effect was also observed between the teat angle and cistern depth (mm) in the flock of Mačuhová et al. (2008), and also in Manchega (Rovai et al., 1999) and East Friesian ewes (McKusick et al., 2000).

However, udders with deeper cisterns and larger teat angles may have a problem with cups falling off during milking (Labussiere, 1988) and an increase in stripping milk yield due to a part of the cisternal milk which is located below the opening into the teat canal and cannot be reached without machine stripping (Mačuhová et al., 2008; Bruckmaier et al., 1997; Carta et al., 1999). However, this may prolong the milking time and thus reduce the efficiency of machine milking. The ewes in the study by Mačuhová et al. (2008) were not high-yielding ewes, but positive correlations of total milk yield with cistern depth and teat position were observed in these sheep. This may indicate that further breeding for higher milk production may lead to deterioration of udder morphology (Mačuhová et al., 2008).

In a study by Beal et al. (1990), the correlation of average weigh-suckle-weigh and average MMY estimates of milk production with preweaning calf gain were high and similar (greater than 0.75) in beef cows. Inclusion of milk composition did not improve the multiple correlation of MMY-estimated milk production and calf gain.

Peris et al. (1996) studied the milkability of Murciano-Granadina dairy goats. As in sheep, milk flow and total machine milk (but not milking time) were influenced by parity, with second and third lactation goats having higher values. Positive correlations were found between daily milk yield and milk flow characteristics. Residual milk was positively correlated with machine stripping, but not with machine milk yield.

Rovai et al. (2008) found that Lacaune ewes had greater udder depth and cistern height, whereas Manchega ewes had longer and wider teats. Özyürek (2020) investigated the relationship between lactation traits, milk components and udder morphology in 34 Morkaraman and 32 Awassi sheep. While breed had a statistically significant effect on lactation milk yield and lactation length, age had a statistically significant effect on all lactation traits ($P< 0.05$). In contrast to Morkaraman, a positive correlation was found between udder circumference and both lactation milk yield and average daily milk yield, and also between udder length and both lactation milk yield and average daily milk yield in Awassi. There was a higher correlation between udder traits and lactation traits in Awassi than in Morkaraman (Özyürek, 2020). Similar to the findings of this study, Şeker et al. (2022) reported positive correlations between the lactation period and milk yield values of Awassi ewes. Except for the correlation coefficient between daily average milk yield and the lactation period in this study, all correlation coefficients calculated were found to be positive and statistically significant.

Arcos-Álvarez et al. (2020) found an acceptable correlation (r = 0.60) between udder measurements, udder volume and daily milk yield in Pelibuey sheep. When direct measurements of milk production are not possible in practice, the measurement of udders and their volume could be a viable alternative to estimate milk yield production as an indirect method. Özyürek (2020) recommended new studies on the rate of milking from the alveolar and cistern areas in machine milking.

Conclusion

Linear evaluation and precise udder measurements showed that Tsigai and Improved Valachian ewes had smaller udders with smaller cisterns and a better teat position than Lacaune ewes. The proportion of machine stripping (PMS) was best in the Improved Valachian ewes (26.0%) among the purebred breeds, followed by the Tsigai ewes (27.2%), and highest in the purebred Lacaune ewes (36.3%). PMS was significantly influenced by teat size, udder attachment and general udder shape. It could be concluded that in Slovakia it will be necessary to additionally use data from linear udder evaluation (mainly udder depth, teat position, teat size and udder attachment) for breeding of dairy sheep breeds.

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