



## Machine milkability of East Friesian and Lacaune dairy sheep

PAVOL MAKOVICKÝ<sup>1</sup>, MILAN MARGETÍN<sup>2</sup>, PETER MAKOVICKÝ<sup>3</sup> and MELINDA NAGY<sup>4</sup>

*J Selye University, Bratislavská cesta 3322, 945 01 Komárno, Slovak Republic*

Received: 14 June 2018; Accepted: 8 February 2019

### ABSTRACT

Udder morphology and milking characteristics are one of the factors determining milkability in dairy ewes. Udder morphology traits were measured and subjectively assessed by the use of linear scores in 150 ewes of Lacaune (LC) and East Friesian (EF) dairy breeds. Linear scores were assessed for udder depth, cistern depth, teat placement, teat length, udder attachment, udder cleft, and udder shape. Nine traits characterized by milk production and milkability were analyzed in machine milking conditions (150 measurements). Analysis of variance was done by the GLM procedure of SAS statistical package. Extraordinary great variability in all traits of linear udder evaluation was detected, as well as in traits connected with milk production and milkability. The obtained results suggest that LC breed has better milkability parameters than EF breed. The differences in milk production and analysed parameters of milkability were too large between the individual flocks.

**Key words:** Dairy sheep, East Friesian, Lacaune, Linear assessment, Milkability, Udder traits

Mammary morphology is an important factor in the machine milkability of dairy ewes (Labussière *et al.* 1981, Labussière 1988, Fernández *et al.* 1995, Ozyurek *et al.* 2018). The 4 udder traits significant for machine milking are udder depth, udder attachment, teat angle, and teat length (De la Fuente *et al.* 1996). Although these 4 linear udder traits will be sufficient to improve programs of udder morphology, phenotypic and genetic correlations showed that selection for milk yield may produce worse udder morphology which will be unsuitable for machine milking (De la Fuente *et al.* 1996). A number of linear scoring systems of udder traits have been developed in European dairy sheep to assess udder conformation (De la Fuente *et al.* 1996, Marie-Etancelin *et al.* 2005, Casu *et al.* 2006). In dairy sheep, the ideal udder conformation for machine milkability includes vertically aligned teats (Labussière 1988). Dairy ewes with pendulous udders and teats placed high on the udder are more prone to poor udder health (Casu *et al.* 2010, Makovický *et al.* 2013b, 2014). Important European dairy sheep breeds have included udder traits into their breeding programs, mainly with the aim of improving machine milkability (Marie-Etancelin *et al.* 2005, Casu *et al.* 2006). Udder and teat morphology have been shown

to be related to milk yield (Labussière 1988, Fernández *et al.* 1995) and milk flow rate (Marie *et al.* 1999, Marnet and McKusick 2001). The increasing implementation of milking machines, aimed at decreasing the tedious work of daily milking, needs study on the relationships between milking machines, udder morphology and milking ease. Marie *et al.* (1999) showed that the udder morphology traits are not very related to milking traits (milking time, milking speed) and that they can be considered as different groups of traits. Udder traits have influence on milk yield, milking ease, udder health and length of productive life.

Machine milkability is an important factor that influences the milking efficiency of a dairy breed and consequently the living standard of the farmers. Milkability can be evaluated by analysis of the milk flow curves and milk flow parameters that describe the physiological response of ewe to machine milking (Bruckmaier *et al.* 1997) and by analysis of udder morphometry (Labussière 1988, Fernández *et al.* 1995, Makovický *et al.* 2013a, 2015a,b). Milk flow kinetics is related to milk production especially in breeds that are not selected for high milk yields (Mañuhová *et al.* 2008, 2012) because of the importance of milk ejection reflex for complete milk removal (Tanèin and Bruckmaier 2001, Bruckmaier 2001a,b,c, Bruckmaier 2005). Effective milkability depends on udder morphology (Labussière 1988) and is important for sustainable milk production because it affects functional life span of the animals (Casu *et al.* 2006). Research shows that machine milking, when applied to the udder with appropriate morphology has positive effects on udder health and milk quality, namely reduction of subclinical and clinical mastitis in the animals

Present address: <sup>1,4</sup>Assistant Professor (makovicky.pavol@gmail.com, nagymelinda@gmail.com), Department of Biology, Faculty of Education. <sup>2</sup>Associate Professor (milan.margetin@uniag.sk), Department of Animal Production, Faculty of Agrobiological and Food Resources, Slovak University of Agriculture in Nitra, Nitra, Slovak Republic. <sup>3</sup>(pmakovicky@email.cz), Laboratory of Veterinary Histopathology in Komárno, Slovak Republic.

(Pajor *et al.* 2014, 2016; Makovický *et al.* 2013b, 2014, Ayadi *et al.* 2014, Gelasakis *et al.* 2016, Swiderek *et al.* 2016, Oravcová *et al.* 2018). The improvement of udder conformation might be beneficial to milkability and animal health, but present selection on dairy production traits does not warrant a favourable trend in udder morphology. Knowledge of milk yield, milking time and udder conformation is necessary for optimal adaptation of the milking environment to the needs of the animal.

Hence the present study was undertaken to detect morphological and functional properties of the udder and milkability of the Lacaune (LC) and East Friesian (EF) ewes under the conditions of machine milking during the milking period.

## MATERIALS AND METHODS

Investigations were performed in 4 flocks of dairy sheep in Slovak Republic. The flocks of sheep were observed for udder morphological and functional properties, and milkability of two breeds of dairy ewes. The subjects of the experiment were purebred (LC) ewes from the 1st, 2nd and 3rd flock and EF ewes from the fourth flock. Experimental measurements were carried out in July and August, in the second phase of lactation. The monitored ewes in first flock (53), 2nd flock (54), 3rd flock (15) and the 4th flock (28) were on average at 162nd, 164th, 144th and 170th day of lactation respectively. Linear scores for 7 traits were assigned by one experienced technician using a 9-point scale: udder depth (1-low, 9-high), cistern depth below the teat level (1-none, 9-high), teat placement (1-vertical, 9-horizontal), teat size (1-short teats, 9-long teats), udder cleft (1-nondetectable, 9-expressive), udder attachment (1-narrow, 9-wide) and udder shape with respect to machine milking (1-bad, 9-ideal). At the same time, the udder health status (125) was subjectively assessed (using a 5-point linear scale) in 1st, 2nd and 4th flock. Before each milking, each udder was completely palpated, and also assessed for the udder asymmetry, diffuse induration, abscesses and larger or smaller cysts, which are located predominantly sagittally, near the udder cisterns. Milk yield and milk flow were measured after the attachment of teat cups to ewe udder. Ewes were milked 60 sec at least. The amount of milk extracted by the machine was recorded in 10 sec intervals until milk flow ceased for 20 sec. Machine stripping started afterwards and was recorded in 10 sec intervals. Milk yield and milk flow traits were total milk yield (TMY), machine milk yield (MMY), stripped milk yield (SMY=TMY–MMY), percentage of SMY from TMY, machine milking time, maximum flow rate, latency time, milk yield to 30 and 60 sec.

Data were processed by REML methodology using a MIXED procedure from the SAS statistical package. 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  $y_{ijklm}$ , observed trait;  $Y_i$ , year (fixed effect with 4 to

7 levels);  $LS_j$ , lactation stage, fixed effect with 4 levels (from 40<sup>th</sup> to 99<sup>th</sup> lactation day, from 100<sup>th</sup> to 129<sup>th</sup> lactation day, from 130<sup>th</sup> to 159<sup>th</sup> lactation day and from 160<sup>th</sup> to 210<sup>th</sup> lactation day);  $GEN_k$ , genotype (breed group; fixed effect with 9 levels);  $P_l$ , 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 days in milk);  $e_{ijklm}$ , random error.

The differences were statistically significant at  $P < 0.05$ ,  $P < 0.01$  and  $P < 0.001$ .

## RESULTS AND DISCUSSION

The lowest average value was found for udder cleft (4.33) and the highest average value was found for udder depth (5.75) (Table 1). As a general pattern, mean values of all subjectively assessed traits were about 5. Linear scores ranged from 1 to 9 for most traits. The highest variability was found for cistern depth and udder cleft (42.21% and 38.63%, respectively). Concerning the animals, the morphology and internal construction of the udder (cistern department), and the physiology of milk emission, plays an important role (Labussière 1988, Makovický *et al.* 2013a, 2015a). A good udder must have big volume, with spheroid shape and good suspension with elastic parenchyma and developed gland cistern and middle size teats. The udder and teats morphological defects decrease the milking efficiency, demand manual interventions during the milking and increase the milking time of the flock. Linear scores decreased as the stage of lactation advanced for udder height, udder attachment, and teat size, while

Table 1. Basic variation-statistical characteristic of indicators characterizing the morphology of the ewes' udder, teats and milkability

| Measurement                     | n*  | Mean   | SD     | CV    | Min. | Max.  |
|---------------------------------|-----|--------|--------|-------|------|-------|
| Udder depth                     | 150 | 5.75   | 1.57   | 27.40 | 2    | 9     |
| Cistern depth                   | 150 | 4.74   | 2.00   | 42.21 | 1    | 9     |
| Teat placement                  | 150 | 4.94   | 1.78   | 36.07 | 1    | 9     |
| Teat size                       | 150 | 4.38   | 1.47   | 33.72 | 1    | 9     |
| Udder cleft                     | 150 | 4.33   | 1.67   | 38.63 | 1    | 7     |
| Udder attachment                | 150 | 5.45   | 1.55   | 28.47 | 2    | 9     |
| Udder shape                     | 150 | 5.42   | 1.95   | 35.97 | 1    | 9     |
| Udder health status             | 125 | 1.19   | 0.56   | 47.31 | 1    | 3     |
| Total milk yield                | 134 | 433.58 | 188.53 | 43.48 | 98   | 1100  |
| Machine milk yield              | 133 | 315.67 | 170.02 | 53.86 | 38   | 870   |
| Stripping from total milk yield | 133 | 29.64  | 17.59  | 59.34 | 0    | 80.95 |
| Milking time                    | 118 | 62.47  | 29.17  | 46.70 | 22   | 164   |
| Latency time                    | 118 | 18.88  | 9.18   | 48.64 | 4    | 54    |
| Maximal milk flow rate          | 118 | 873.66 | 482.30 | 55.20 | 20   | 2700  |
| Time to maximum milk flow       | 118 | 14.56  | 8.03   | 55.21 | 0.33 | 45    |
| Milk yield in 30 sec            | 133 | 150.38 | 114.84 | 76.36 | 0    | 500   |
| Milk yield in 60 sec            | 133 | 265.35 | 146.23 | 55.10 | 20   | 811   |

\*number of sets of measurements; SD, standard deviation; CV, coefficient of variability.

Table 2. Analysis of ewes' udder linear evaluation dispersion depending on the breed and the flock

| Source of variation         | Trait                 |          |                    |       |                |         |                    |                  |
|-----------------------------|-----------------------|----------|--------------------|-------|----------------|---------|--------------------|------------------|
|                             | UD                    | CD       | TP                 | TS    | UC             | UA      | US                 | UHS              |
| No. of sets of measurements | 150                   | 150      | 150                | 150   | 150            | 150     | 150                | 125              |
| Mean                        | 5.74                  | 4.74     | 4.94               | 4.38  | 4.33           | 5.45    | 5.42               | 1.19             |
| Standard deviation          | 1.50                  | 1.95     | 1.75               | 1.43  | 1.64           | 1.49    | 1.94               | 0.53             |
| Coefficient of variability  | 26.19                 | 41.17    | 35.52              | 32.87 | 37.90          | 27.44   | 35.82              | 44.79            |
| Minimum                     | 2                     | 1        | 1                  | 1     | 1              | 2       | 1                  | 1                |
| Maximum                     | 9                     | 9        | 9                  | 9     | 7              | 9       | 9                  | 3                |
| <i>Genotype</i>             |                       |          |                    |       |                |         |                    |                  |
| Lacaune 1 (53)              | 6.26                  | 5.05     | 5.16               | 3.92  | 4.43           | 6.01    | 5.71               | 1.04             |
| Lacaune 2 (54)              | 5.64                  | 4.62     | 4.90               | 4.83  | 4.12           | 5.18    | 5.48               | 1.41             |
| Lacaune 3 (15)              | 6.00                  | 5.66     | 5.60               | 4.53  | 3.53           | 4.60    | 4.66               | –                |
| East Friesian 4 (28)        | 4.82                  | 3.85     | 4.25               | 4.28  | 4.96           | 5.35    | 5.17               | 1.00             |
| F value                     | 5.83***               | 3.56*    | 2.45 <sup>ns</sup> | 3.65* | 2.91*          | 4.76**  | 1.32 <sup>ns</sup> | 8.09***          |
| Significant differences     | 1:4***;<br>2,3:4*; 2* | 1,3:4**; | 1,3:4*;            | 1:2** | 2:4*;<br>3:4** | 1:2,3** | ns                 | 1:2***;<br>2:4** |

\*\*\*P<0.001; \*\*P<0.01; \*P<0.05; ns, not significant.

linear scores increased dramatically for udder height as the parity number increased (De La Fuente *et al.* 1996, Marie *et al.* 1999, Fernández *et al.* 1995, 1997; Makovický *et al.* 2015a).

With regards to udder physiology it must be said that the animals which have developed milk ejection reflex guarantee fast emission of alveolar and cisternal milk, too. In comparison to cows, the milk ejection reflex in small ruminants is activated relatively easily. The attachment of teat cups, without applying udder stripping, is adequate for oxytocin secretion.

Indicator genotype had statistically very significant impact on the udder depth and udder health status (P<0.001), udder attachment (P<0.01) and on cistern depth, teat size and udder cleft (P<0.05) (Table 2). The total udder shape and teats positions were not significantly influenced by the

factor of breed/flock. Udder cleft in 1st flock moved at an average of 4.43 points, in the 2nd flock was 4.12 point, in the 3rd flock was 3.53 points and in 4th flock at 4.96 point. The results also show that the greatest udder cleft is characterized in the EF ewes (flock 4), suggesting that udders of EF are well attached.

Linear udder evaluation revealed that the first flock of the LC ewes had the greatest udders while the EF ewes had the smallest udders. Machine milking of ewes requires teats in vertical position to ensure the required strength of holding the teat cups. In the present study, EF ewes (flock 4) had the best built teats, and acquired for this indicator on average 4.25 point, while the LC ewes obtained in 1st flock only 5.16 points, and in 3rd stage only 5.60 points (P<0.05). The teat size at EF breeds (in 4th flock) was on average 4.28 points, at LC breed (1st flock) this value was the lowest

Table 3. Analysis of indicator dispersion characterizing ewes' milkability depending on the genotype

| Source of variation        | Trait                       |                                    |                 |                         |          |             |              |                          |                   |
|----------------------------|-----------------------------|------------------------------------|-----------------|-------------------------|----------|-------------|--------------|--------------------------|-------------------|
|                            | TMY (ml)                    | MMY (ml)                           | STMY (%)        | MT (sec)                | LT (sec) | MMF (l/min) | TMF (ml/sec) | MMY 30 sec (%)           | MMY 60 sec (%)    |
| Number of measurements     | 134                         | 133                                | 133             | 118                     | 118      | 118         | 118          | 133                      | 133               |
| Mean                       | 433.41                      | 314.33                             | 29.38           | 62.47                   | 18.88    | 0.87        | 14.56        | 150.38                   | 265.35            |
| Standard deviation         | 167.65                      | 146.24                             | 19.91           | 25.96                   | 8.53     | 0.45        | 7.64         | 105.92                   | 131.311           |
| Coefficient of variability | 38.68                       | 46.52                              | 57.56           | 41.56                   | 45.20    | 52.44       | 52.44        | 70.43                    | 49.78             |
| Minimum                    | 98                          | 38                                 | 0               | 22                      | 4        | 20          | 0.33         | 0                        | 20                |
| Maximum                    | 1100                        | 870                                | 80.95           | 164                     | 54       | 2700        | 45.00        | 500                      | 811               |
| <i>Genotype</i>            |                             |                                    |                 |                         |          |             |              |                          |                   |
| Lacaune (1)                | 522.22                      | 413.76                             | 22.37           | 66.36                   | 16.31    | 0.96        | 15.97        | 182.36                   | 349.51            |
| Lacaune (2)                | 314.02                      | 202.65                             | 35.91           | 47.26                   | 17.86    | 0.95        | 15.94        | 128.30                   | 201.97            |
| Lacaune (3)                | 458.66                      | 314.67                             | 32.65           | –                       | –        | –           | –            | 233.33                   | 286.66            |
| East Friesian (4)          | 468.32                      | 339.80                             | 28.56           | 83.16                   | 25.60    | 0.56        | 9.37         | 81.12                    | 210.96            |
| F value                    | 12.74***                    | 16.42***                           | 5.19**          | 16.35***                | 10.18*** | 7.32***     | 7.32***      | 8.72***                  | 11.57*            |
| Significant differences    | 1:2***;<br>2:4***;<br>2:3** | 1:2***;<br>2:4***;<br>1:3,4*; 2:3* | 1:2***;<br>1:3* | 1:2***;<br>2:4***; 1:4* | 1,2:4*** | 1,2:4***    | 1,2:4***     | 1,3:4***;<br>2:3**; 1:2* | 1:2,4***;<br>2:3* |

\*\*\*P<0.001; \*\*P<0.01; \*P<0.05; ns, not significant.

(3.92 points), in the 2nd flock the highest (4.83 points), and in 3rd flock it was 4.53 points (Table 2). Ewes udder was rated worse in terms of health in 1st flock (1.04) and 2nd flock (1.41) than at ewes EF breed – 4th flock (1.00).

Very interesting results were obtained by evaluating various indicators characterizing the milkability of ewes. In some ewes, proportion of stripping from total milk yield (STMY) was 0%, and vice versa, in worst ewe STMY was higher than 80% (80.95%) (Table 1). In some ewes, the milk yield at 30 and 60 sec was as high as 500 and 800 ml respectively while some ewes at this time did not start milking. The evaluated average of total milk yield (433.58 ml) was not high, if we take into account the fact that the studied population were also high-producer pure bred EF ewes. East Friesian ewes also have been reported to have some undesirable milking characteristics relative to LC. Bruckmaier *et al.* (1997) reported that EF ewes had a greater proportion of udder cistern located below the exit into the teat channel, delayed oxytocin release and milk letdown, slower milk flow rates during milking, and longer milking times compared to LC ewes.

The total milk yield fluctuated around an average of 433.41 ml, with a relatively large interval (98 to 1100 ml) and the machine milk yield was 314.33 ml with interval of 38 to 870 ml (Table 3). Several investigators reported that milk yield of sheep is influenced by many factors, viz. breed of ewe, parity, as well as udder measurements (Fernández *et al.* 1995, 1997; Sezenler *et al.* 2016).

Variation coefficients for all production indicators, viz. total milk yield (38.68%), machine milk yield (46.52%), STMY (57.56%), MY 60 sec (49.78%) are in all cases sufficiently high for effective selection. In ewes there is latency in milk removal when applied to the teat milking cups, but a lack of stimulation before milking, similarly as in goats, has no effect on the model curve of milk flow during milking (Bruckmaier *et al.* 1994, Marnet *et al.* 1998, 2000). Experimental ewes milked 265.35 ml of milk on an average in 60 sec. This indicator well characterizes the milking speed in dairy ewes. Large interval was found in indicators namely STMY (%) and the milk yield to 30 and 60 sec (ml). Some of the monitored ewes during the first 30 sec not started running milk (Table 3), but on average milk yield to 60 sec was 265.35 ml of total milk yield, and to 30 sec ewes milked on an average 150.38 ml. The lowest stripping from total milk was found in 1st flock (22.37%) followed by 4th flock of purebred EF ewes (28.56%). The stripping from total milk yield in 2nd and 3rd flock was similar (35.91% and 32.65%). Maximum milk flow (time to maximum milk flow in ml/s), was similar in 1st and 2nd flock (15.97 and 15.94), while in 3rd flock, this indicator was not rated. This clearly show that EF purebred ewes were characterized by poorer milkability (4th flock TMF = 9.37 ml/s) in comparison to LC purebred ewes. The highest milk yield to 60 sec (MY 60 sec) was found in 1st flock (349.51 ml), and the lowest in 2nd flock (201.97 ml). In our view the relatively large variation in this indicator is related to the fact that some holdings do not provide optimal

treatment particularly in terms of nutrition as well as prevention. Present study is the first report of EF purebred milkability and their comparison to LC ewes. The results clearly indicate that EF ewes are characterized with worse milkability compared to LC breed. In practice, the higher milk yield to 60 sec is preferable for farmers because it means more sheep milked per unit time. Highest milk yield in 30 sec was obtained in ewes of the 3rd flock which again indicates that EF ewes are worse in milk running compared to LC breed.

Relatively large differences were found in comparison of the observed genotypes amongst flocks. Some linear udder indicators can be used in the selection of sheep for better milkability. Better milkability parameters were observed generally in the LC breed compared to EF breed. Indicators of ewes udder linear evaluation need introduction into routine genetic evaluation of dairy breeds of sheep (in line with the trends in all developed shepherd countries) in Slovakia also and should be tracked monitoring the usefulness.

#### ACKNOWLEDGEMENTS

The study was performed during the realization of the project MLIEKO 26220220098 funded by the Operational Program for Research and Development of the European Regional Development.

#### REFERENCES

- Atigui M, Hammadi M, Barmat A, Fahrati M, Khorchani T and Marnet P G. 2014. First description of milk flow traits in Tunisian dairy dromedary camels under an intensive farming system. *Journal of Dairy Research* **81**: 173–82.
- Ayadi M, Matar A M, Aljumaah R S, Alshaikh M A and Abouheif M. 2014. Factors affecting milk yield composition and udder health of Najdi ewes. *International Journal of Animal and Veterinary Advances* **6**: 28–33.
- Ambord S and Bruckmaier R M. 2009. Milk flow-controlled changes of pulsation ratio and pulsation rate affect milking characteristics in dairy cows. *Journal of Dairy Research* **76**: 272–77.
- Ambord S and Bruckmaier R M. 2010. Milk flow-dependent vacuum loss in high-line milking systems: Effects on milking characteristics and teat tissue condition. *Journal of Dairy Science* **93**: 3588–94.
- Besier J and Bruckmaier R M. 2016. Vacuum levels and milk-flow-dependent vacuum drops affect machine milking performance and teat condition in dairy cows. *Journal of Dairy Science* **99**: 3096–3102.
- Bruckmaier R M, Mayer H and Schams D. 1991. Effects of alpha- and beta-adrenergic agonists on intramammary pressure and milk flow in dairy cows. *Journal of Dairy Research* **58**: 411–19.
- Bruckmaier R M, Ritter C, Schams D and Blum J W. 1994. Machine milking of dairy goats during lactation: udder anatomy, milking characteristics, and blood concentrations of oxytocin and prolactin. *Journal of Dairy Research* **61**: 457–66.
- Bruckmaier R M, Rothenanger E and Blum J W. 1995. Milking

- characteristics in dairy cows of different breeds from different farms and during the course of lactation. *Journal of Animal Breeding and Genetics* **112**: 293–302.
- Bruckmaier R M and Blum J W. 1996. Simultaneous recording of oxytocin release, milk ejection and milk flow during milking of dairy cows with and without prestimulation. *Journal of Dairy Research* **63**: 201–08.
- Bruckmaier R M, Paul G, Mayer H and Schams D. 1997. Machine milking of Ostfriesian and Lacaune dairy sheep: udder anatomy, milk ejection and milking characteristics. *Journal of Dairy Research* **64**: 163–72.
- Bruckmaier R M. 2001. Milk ejection during machine milking in dairy cows. *Livestock Production Science* **70**: 121–24.
- Bruckmaier R M and Hilger M. 2001. Milk ejection in dairy cows at different degrees of udder filling. *Journal of Dairy Research* **68**: 369–76.
- Bruckmaier R M, Maëuhová J and Meyer H H D. 2001. Specific aspects of milk ejection in robotic milking: a review. *Livestock Production Science* **72**: 169–76.
- Bruckmaier R M. 2005. Normal and disturbed milk ejection in dairy cows. *Domestic Animal Endocrinology* **29**: 268–73.
- Casu S, Pernazza I and Carta A. 2006. Feasibility of a linear scoring method of udder morphology for the selection scheme of Sardinian sheep. *Journal of Dairy Science* **89**: 2200–09.
- Casu S, Sechi S, Salaris S L and Carta A. 2010. Phenotypic and genetic relationships between udder morphology and udder health in dairy ewes. *Small Ruminant Research* **88**: 77–83.
- De la Fuente L F, Fernández G and San Primitivo F. 1996. A linear evaluation system for udder traits of dairy ewes. *Livestock Production Science* **45**: 171–78.
- D•idiæ A, Knopf L and Bruckmaier R M. 2002. Oxytocin release and milk removal in machine-milked mares. *Milchwissenschaft* **57**: 423–24.
- D•idiæ A, Weiss D and Bruckmaier R M. 2004. Oxytocin release, milk ejection and milking characteristics in a single stall automatic milking system. *Livestock Production Science* **86**: 61–68.
- Fernández G, Álvarez P, San Primitivo F and De la Fuente L F. 1995. Factors affecting variation of udder traits of dairy ewes. *Journal of Dairy Science* **78**: 842–49.
- Fernández G, Baró J A, De la Fuente L F and San Primitivo F. 1997. Genetic parameters for linear udder traits of dairy ewes. *Journal of Dairy Science* **80**: 601–05.
- Gelasakis A I, Mavrogianni V S, Petridis I G, Vasileiou N G C and Fthenakis G C. 2015. Mastitis in sheep—The last 10 years and the future of research. *Veterinary Microbiology* **181**: 136–46.
- Gelasakis A I, Angelidis S, Giannakou R, Filioussis G, Kalamki M S and Arsenos G. 2016. Bacterial subclinical mastitis and its effect on milk yield in low-input dairy goat herds. *Journal of Dairy Science* **99**: 3698–3708.
- Jatsch O and Sagi R. 1979. Machine milkability as related to dairy yield and its fractions in dairy ewes. *Annales de Zootechnie* **28**: 251–60.
- Labussière J, Dotchewski D and Combaut J F. 1981. Caractéristiques morphologiques de la mamelle des brebis Lacaune. Méthodologie pour l'obtention des données. Relations avec l'aptitude à la traite. *Annales de Zootechnie* **30**: 115–36.
- Labussière J. 1988. Review of physiological and anatomical factors influencing the milkability of ewes and the organization of milking. *Livestock Production Science* **18**: 253–74.
- Maëuhová L, Uhrinèat' M, Maëuhová J, Margetín M and Tanèin V. 2008. The first observation of milkability of the sheep breeds Tsigai, Improved Valachian and their crosses with Lacaune. *Czech Journal of Animal Science* **53**: 528–36.
- Maëuhová L, Tanèin V, Uhrinèat' M and Maëuhová J. 2012. The level of udder emptying and milk flow stability in Tsigai, Improved Valachian, and Lacaune ewes during machine milking. *Czech Journal of Animal Science* **57**: 240–47.
- Makovický Pa, Nagy M and Makovický Pe. 2013. Comparison of external udder measurements of the sheep breeds Improved Valachian, Tsigai, Lacaune and their crosses. *Chilean Journal of Agricultural Research* **73**: 366–71.
- Makovický Pa, Nagy M, Makovický Pe and Szinetár Cs. 2013b. Milk quality comparison of the sheep breeds (Improved Valachian, Tsigai, Lacaune) and their crosses. *Magyar Allatorvosok Lapja* **135**: 85–90.
- Makovický Pa, Makovický Pe, Nagy M, Rimárová K and Diabelková J. 2014. Genetic parameters for Somatic cell count, LOGSCC and somatic cell score among breeds: Improved Valachian, Tsigai, Lacaune and their crosses. *Acta Veterinaria-Beograd* **64**: 386–96.
- Makovický Pa, Margetín M and Makovický Pe. 2015. Genetic parameters for the linear udder traits of nine dairy ewes—*Veterinarski Arhiv* **85**: 577–82.
- Makovický Pa, Rimárová K, Makovický Pe and Nagy M. 2015. Genetic parameters for external udder traits of different dairy ewes. *Indian Journal of Animal Sciences* **85**: 89–90.
- Marnet P G, Negrão J A and Labussière J. 1998. Oxytocin release and milk ejection parameters during milking of dairy ewes in and out natural season of lactation. *Small Ruminant Research* **28**: 183–91.
- Marnet P G and Negrão J A. 2000. The effect of a mixed management system on the release of oxytocin, prolactin and cortisol in ewes during suckling and machine milking. *Reproduction Nutrition Development* **40**: 271–81.
- Marnet P G and McKusick B C. 2001. Regulation of milk ejection and milkability in small ruminants. *Livestock Production Science* **70**: 125–33.
- Marie C, Jacquin M, Aurel M R, Pailler F, Porte D, Autran P and Barillet F. 1999. Déterminisme génétique de la cinétique d'émission du lait selon le potentiel laitier en race ovine de lacaune et relations phénotypiques avec la morphologie de la mamelle, pp. 381–88. *Milking and Milk Production of Dairy Sheep and Goats*. (Eds) Barillet F and Zervas N P. EAAP Publication Nr 95, Wageningen Press, Wageningen, The Netherlands.
- Marie-Etancelin C, Rupp R, Casu S, Carta A and Barillet F. 2001. *New objectives of selection related to udder health, morphology and milkability in dairy sheep*. 52th Annual Meeting of the European Association for Animal Production, Budapest, Hungary.
- Marie-Etancelin C, Astruc J M, Porte D, Larroque H and Robert-Granié C. 2005. Multiple-trait genetic parameters and genetic evaluation of udder-type traits in Lacaune dairy ewes. *Livestock Production Science* **97**: 211–18.
- Mavrogianni V S, Cripps P J, Papaioannou N, Taitzoglou I and Fthenakis G C. 2006. Teat disorders predispose ewes to clinical mastitis after challenge with *Mannheimia haemolytica*. *Veterinary Research* **37**: 89–105.
- Mavrogianni V S, Cripps P J and Fthenakis G C. 2007. Bacterial flora and risk of infection of the ovine teat duct and mammary gland throughout lactation. *Preventive Veterinary Medicine* **79**: 163–73.
- Mavrogianni V S, Menzies P I, Fragkou I A and Fthenakis G C.

2011. Principles of mastitis treatment in sheep and goats. *Veterinary Clinics of North America: Food Animal Practice* **27**: 115–20.
- Oravcová M, Maèuhová L and Tanèin V. 2018. The relationship between somatic cells and milk traits, and their variation in dairy sheep breeds in Slovakia. *Journal of Animal and Feed Sciences* **27**: 97–104.
- Ozyurek S, Turkyilmaz D, Yaprak M and Esenbuga N. 2017. Determination of morphological and linear udder traits in Morkaraman, Tuj and Awassi sheep. *Indian Journal of Animal Research* **52**: 424–30.
- Pajor F, Egerer A, Sramek A, Weidel W, Polgár J P, Bárdos L and Póti P. 2014. Effect of teat morphology on the hygienically traits of goat milk. *Magyar Allatorvosok Lapja* **136**: 535–40.
- Pajor F, Weidel W, Polgár J P, Bárdos L, Póti P and Bodnár A. 2016. Effect of pathogen udder bacteria species on the somatic cell count of goat milk. *Magyar Allatorvosok Lapja* **138**: 541–47.
- Sagi R and Morag M. 1974. Udder conformation, milk yield and milk fractionation in the dairy ewes. *Annales de Zootechnie* **23**: 185–92.
- Sezenler T, Ceyhan A, Yuksel M A, Onaldi A T and Yildirim M. 2016. Effect of parity and type of lambing on performance and udder traits of Bandirma ewes. *Indian Journal of Animal Sciences* **86**: 572–77.
- Swiderek W P, Charon K M, Winnicka A, Gruszczynska J and Pierzchala M. 2016. Physiological threshold of somatic cell count in milk of Polish heath sheep and Polish lowland sheep. *Annals of Animal Science* **16**: 155–70.
- Tanèin V and Bruckmaier R M. 2001. Factors affecting milk ejection and removal during milking and suckling of dairy cows. *Veterinary Medicine-Czech* **46**: 108–18.
- Tanèin V, Ipema B, Hogewerf P and Maèuhová J. 2006. Sources of variation in milk flow characteristics at udder and quarter levels. *Journal of Dairy Science* **89**: 978–88.
- Tanèin V, Uhrinèat' M, Maèuhová L and Bruckmaier R M. 2007. Effect of pre-stimulation on milk flow pattern and distribution of milk constituents at a quarter level. *Czech Journal of Animal Science* **52**: 117–21.