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Udder morphology and milk yield of East Friesian sheep

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ABSTRACT

Linear scores and measures of both udder and teat shape and size (thirteen traits) were assessed in 83 ewes of Improved Valachian breed (IV) and in crossbreds with East Friesian breed (EF 25% or EF 50%). At the same time, cistern measures and cross-section areas (fourteen traits) as well as milk yield and milkability were scanned using ultrasound technique or measured in the same individuals (130 measurements in each trait). Crossbreds with EF 50% had the largest udders in terms of depth, width, and height, as determined by either a nine-point linear score or exact measurements. Additionally, these crossbreds had teats that were more horizontally placed and the most appropriate udder attachment and shape. more horizontally and most appropriate udder attachment and shape. Ultrasound scans revealed that the areas of both the left and right udder cisterns scanned by ultrasound were the highest in EF 50% crosses. Overall cistern cross-section areas scanned from the side were 2934.6 mm^2 in IV, 2932.6 mm^2 in crosses of EF 25% and 3559.4 mm^2 in crosses of EF 50% ($P<0.05$). Crossbreds of EF 50% had more appropriate machine milked milk and total milk yield (311.1 and 424.7 ml) than purebred IV (231.8 and 336.1 ml; $P>0.05$). On average, the proportion of machine-stripped milk was 33.2%, and non-significant influence of genotype was shown. Furthermore, all traits under study showed non-significant differences between crosses of EF 25% and 50%.

*Keywords***:** *Ewe, Linear score, Mammary gland, Milkability.*

INTRODUCTION

In recent years, there has been an increased interest in the anatomy and morphology of sheep udders due to their relationship with milk production and milking ability. The size and type of the udder are crucial factors in the efficiency of milking machines, reducing damage to the teats, saving labor during milking, and increasing the likelihood of remaining in breeding for a longer period.

In order to improve udder morphology and milkability, it is recommended to use linear udder traits in practice. The relationship of udder traits with milk yield in sheep has been investigated in many studies (Dzidic *et al.,* 2004; Kominakis *et al.,* 2009; Mioč *et al.,* 2009; Prpic *et al.,* 2013; Vrdoljak *et al.,* 2020; Seker *et al.,* 2022; Tolu and Yazgan, 2022; Marshall *et al.,* 2023; Smith *et al.,* 2023). Kaygisiz and Dag (2017) found generally positive and significant correlations between udder size and type of udder and milk yield. Similarly Kominakis *et al.* (2009 observed that milk yields on the day of the test were related to udder circumference, width, height and teat length. Animal selection criteria by dairy sheep farmers is usually based on milk production (quantity and composition), whereas the appraisal of udder morphology is less taken into account for optimum production (Gelasakis *et al.,* 2012). Labussiere (1988) identified udder conformation as a key functional trait for evaluating ewe milkability. This trait may also be relevant for non-dairy ewes and could impact the amount of milk available for suckling lambs. Further, defective udder conformation could increase the chances of intra-mammary infection, which may reduce the quality and quantity of milk during lactation. Udder milk flow presented useful and essential information on the course of milking including the milking efficiency and milk ejection (Bruckmaier and Blum, 1998). Udder milk flow parameters is also important for the genetic evaluation of the milkability. Additionally, milk flow traits can provide valuable information related to cow biology, milking machine performance, and health issues (Tančin *et al.,* 2003).

Understanding the milk production potential of sheep can help predict the success of lamb growth. Milk production is stimulated by oxytocin and prolactin secretion in response to teat stimulation, which increases as the number of suckling lambs increases (Dhaoui *et al.,* 2019).

According to Abecia and Palacios (2018), ewes with twin parturitions produced more milk than those with single parturitions, and the presence of female lambs had a positive effect on milk yield. Similarly, Dhaoui *et al.* (2019) found that the ewes rearing multiple lambs had higher milk yield than those rearing single lambs. The study also showed that adult ewes produced more milk than younger and older ewes. Ewes with an asymmetric udder structure produced less milk that was more concentrated compared to ewes with a symmetrical udder. The daily milk yield was affected by the lambing season.

The udder is a crucial physiological and conformational characteristic in all dairy animals. Several authors have investigated the external udder traits in various dairy sheep breeds, including Kominakis *et al.* (2009), Altınçekiç and Koyuncu (2011), Dogan *et al*. (2013), Merkhan (2014), and Kaygisiz and Dag (2017). Altincekic and Koyuncu (2011) reported that udder measurements may be suitable selection markers for improving the milking ability of Tahirova, Kıvırcık and Karacabey Merino sheep breeds. Udder circumference showed a strong, positive correlation with udder width, udder length, and teat angle and udder volume in ewes. Martinez *et al*. (2011) revealed significant effects of breed, sheep within breed, and stage of lactation on udder traits. During lactation, there was a significant decrease in udder circumference, udder width, udder length, cistern height and teat size. The repeatability of all traits ranged from 0.17 to 0.60, with the highest repeatability observed for udder circumference. Udder circumference is a morphological trait of great interest due to its breed discriminatory power for dairy aptitude, relationship with milk yield, ease and speed of estimation, and high repeatability.

The objective of this study was to assess the udder morphology and milkability of ewes in the Improved Valachian breed and crossbreeds with 25% and 50% genetic contribution from the East Friesian breed.

MATERIALS AND METHODS

The study evaluated the functional and morphological characteristics of the udder in a selected population of sheep, specifically 83 Improved Valachian ewes (IV) and also their 25% and 50% crosses with the East Friesian breed (IVxEF) in one experimental flock of dairy sheep. The experiment included ewes in their 1st to 3rd lactation. During the milking period, 2 milk control measurements (MCM) were conducted, where MCM is defined as an evening milking followed by a morning milking. The first MCM was performed when the ewes were on average on day 124 of lactation, and at the second MCM was conducted when the ewes were on average on day 157 of lactation. At the MCM, flow meters were installed to detect milk let-down (milk yield) at 10-second intervals, to allowing us to determine the amount of milk milked in 60 seconds (MY60s), the total amount of milk milked by machine (machine milk yield – MMY), and the amount of milk obtained by machine stripping (MS). The text describes the amount of milk obtained through machine milking and stripping, including the total milk yield (TMY), the proportion of machine milk yield to total milk yield (MMY/TMY), and the proportion of milk (from TMY) milked in 30 and 60 seconds (MY30s and MY60s, respectively). It is noted that sheep were not hand stripped after machine milking.

Udder morphology, including linear assessment, was assessed during morning milking. Ultrasonography was then used to measure udder cisternae. A 9-point scale was used for linear description of the udder of all ewes included in the experiment. The following parameters were evaluated:

1. The linear assessment scheme contained 7 udder and teat traits: udder depth (1 - low, 9 - high), cistern depth below the teat level (1 - none, 9 - high), teat position (1 - vertical, 9 - horizontal), teat size (1 - short, 9 - long), udder cleft (1 - not detectable, 9 - expressive), udder attachment (1 - narrow, 9 - wide), udder shape (1 - bad, 9 - ideal). Statistical analysis was formulated using the restricted maximum likelihood (REML) methodology (MIXED) procedure implemented in SAS/ STAT v.9.2, 2002-2008.
2. External udder measurements of six traits (Milerski et al., 2006) were made by at least two technicians using ruler, measuring tape, and protractor and they included: udder length (UL), udder width (UW), rear udder depth (RUD), cistern depth (CDE), teat length (TL) and teat angle from the vertical (TA) (Figure 1).
3. Ultrasound images of the left and right udder cisterns were recorded by portable ultrasonography with a 3.5 MHz convex sector probe as previously described (Nudda *et al*., 2000). The procedure uses contact gel and places the probe directly against the upper part of the median suspensory ligament in the inguinal abdominal fold (Figure 2 and Figure 3). The operator performed an equal axis scan of the opposite side of the udder in order to obtain a sonographic image with the largest cistern size (from side method). The images were taken once for each half of the udder, 12 hours after the last milking. On the sonographic images, the length of the left (LLC1) and right (LRC1) cisterns and the width of the left (WLC1) and right (WRC1) cisterns (in millimetres) were measured from the cross sectional scans. By using digital technology the left (ALC1) and right (ARC1) cisterna areas (in mm^2) were measured, as well as the sum of the areas in both cisterns (SLRC1). For some control measurements, in addition to scanning the udder cisterns using the from side method, the sizes of the left and right udder cisterns were also investigated by scanning the entire ventral udder using the from bottom method. Udders were measured while immersed in water, with the probe held in the water against the udder wall as described (Bruckmaier *et al.,* 1997). Sonographic images obtained from bottom produced equal measurements for the udder cisterns as sonography from side (LLC2, LRC2, WLC2, WRC2, ALC2, ARC2, SLRC2).

RESULTS AND DISCUSSON

Table 1 and Table 2 present the results of the analysis of variance of linear udder scores and exact udder measurements of ewes as a proportion of breed group. Table 1 shows that the factor "breed group" had a very high statistically significant effect on udder cleft ($P<0.001$), udder attachment ($P<0.05$) and overall udder shape ($P<0.05$).

As can be seen from Table 1, the IVxEF crosses with 50% EF genetic proportion had significantly better overall udder shape scores than the purebred IV ewes ($P<0.05$). The difference between these genotypes was demonstrated (3.98 and 4.99 points respectively, $P<0.05$). Crossbreds with 50% EF had the best attached udders and also the most cleft udders. Differences in udder morphology between IVxEF crosses with 25% EF and IV ewes were

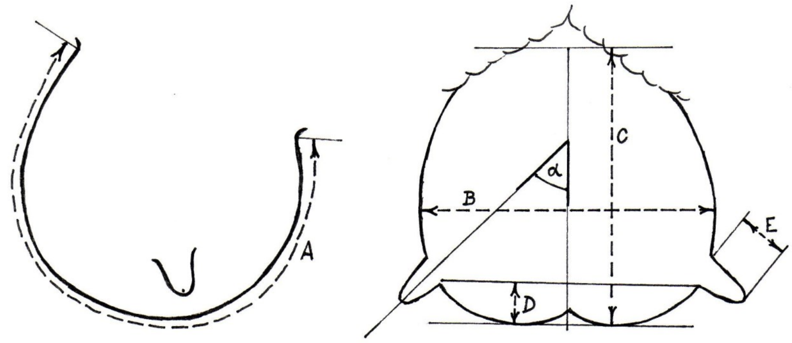

Figure 1. Morphological parameters measured on udder and teats
A: udder length (UL); B: udder width (UW); C: rear udder depth (RUD); D: cistern depth (CD); E: teat length (TL); α: teat angle from the vertical (TA).

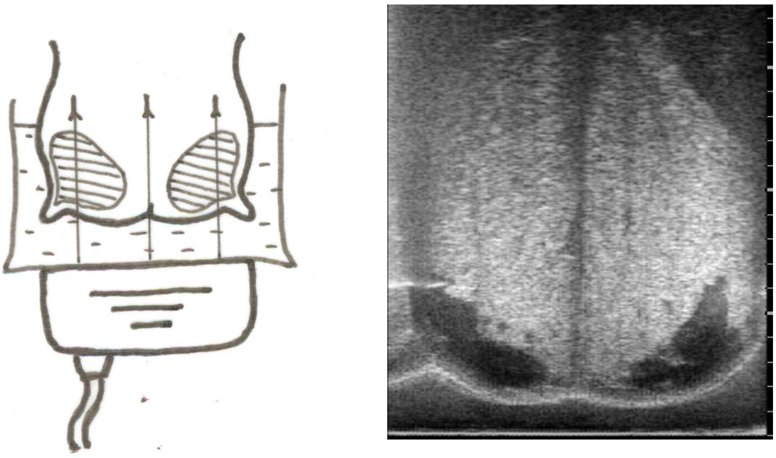

Figure 2. Ultrasonic scan of sheep udder from below (sum of cistern areas - BCA)

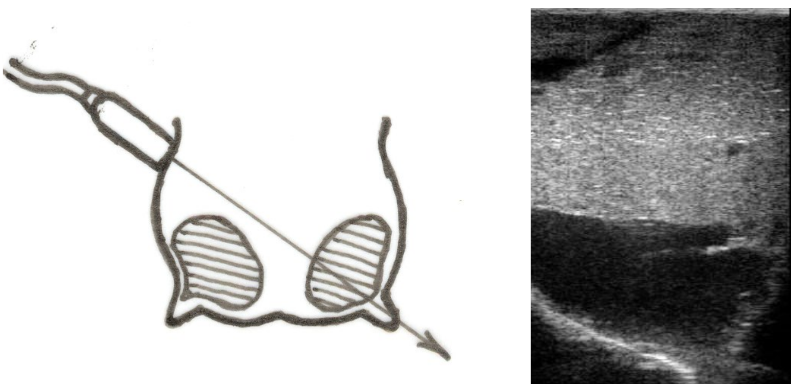

Figure 3. Ultrasonic scan of sheep udder from side (sum of both cistern areas *SCA)

not statistically significant in any of the evaluated parameters (Table 1, Table 2).

For the udder shape traits (Table 2), breed group had a statistically significant effect on udder width (P<0.05). Crossbred ewes with 50% EF breed proportion had demonstrably greater udder width (110.55 mm) than purebred IV ewes and crossbred ewes with 25% EF breed proportion (101.46 and 101.78 mm, respectively). Crossbred ewes with 50% EF also had the greatest udder length, although the differences were not significant when compared to purebred IV ewes and crossbred ewes with 25% EF. Teat position was relatively good in ewes of the study population (39.5°).

Tables 3 and Tabl 4 show the results of the analysis of variance for the left and right udder cistern rates of ewes detected by the "from the bottom" and "from the side" methods. The data in the tables indicate that the udder measurements obtained by the "from the bottom" method are smaller than those obtained by the "from the side" method. Contrary to our results, Bruckmaier *et al*. (1997) and Margetín et al. (2002a) reported that the size of the left udder cistern is larger than that of the right cistern, regardless of the detection method. However, in our experiment, this was only true when using the "from the bottom" method. Table 3 presents the results indicating that breed group significantly affected (P<0.05) the right cistern length and right cistern width variables. The breed group factor did not have a statistically significant effect (P>0.05) on the other evaluated udder cistern size parameters detected by the "from the bottom" method. However, the F test values were relatively high in all cases (Table 3). The highest values of individual udder cistern measures in all parameters were observed in the IVxEF crosses with a 50% genetic proportion. The average left cisterna length for the whole set of ewes studied was 50.69 mm and the average right cistern length was 51.15 mm, while in crossbreds with 50% EF proportion, LLC1 and LRC1 were as high as 55.11 mm and 56.08 mm, respectively. The area of the left and right cisterns measured "from the bottom" (Table 3) was not statistically significantly affected by

Table 1. Linear evaluation of the udder of ewes depending on the breed group

Source of variance	Measurement						
	Udder depth*	Cistern depth	Teat position	Teat size	Udder cleft	Udder attachment	Udder shape
Number of control measurements	130	130	130	130	130	130	130
Total average	3.82	3.51	4.06	4.72	5.12	4.81	4.28
SD	1.242	1.540	1.273	1.200	1.388	1.316	1.547
Coefficient of variation	24.76	43.80	31.34	25.40	27.09	27.37	36.11
Minimum	1	1	2	2	1	2	1
Maximum	6	8	8	8	9	8	8
Breed group							
Improved Valachian	3.64	3.35	3.98	4.67	4.74[a]	4.74[ab]	3.98[a]
IVxEF (25%EF)	3.68	3.58	4.27	4.77	4.71[a]	4.55[a]	4.00[a]
IVxEF (50%EF)	4.23	3.68	4.06	4.93	6.12[b]	5.27[b]	4.99[b]
F test value	2.33[ns]	0.35[ns]	0.60[ns]	0.34[ns]	11.49[+++]	3.11[+]	4.66[+]

[+++] P<0.001; [++] P<0.01; [+++] P<0.05; ns – non significant (non-significant effect); a, b – differences in means marked with an unequal letter are statistically significant – also valid for Tables 2 to 5;
* Abbreviations used – see Material and methods

Table 2. Exact udder measurements of ewes (using tape measure and protractor) depending on breed group

Source of variance	Measurement					
	Udder length [mm]	Udder width [mm]	Rear udder depth [mm]	Cistern depth [mm]	Teat length [mm]	Teat angle [°]
Number of control measurements	130	130	130	130	130	130
Total average	163.46	10.9	13.8	39.5	3.7	1.5
SD	31.63	1.3	1.9	10.5	0.7	1.1
Coefficient of variation	19.35	15.35	14.01	26.49	18.01	72.57
Minimum	100	75	75	8	25	10
Maximum	280	195	170	56	50	35
			Breed group			
Improved Valachian	157.82	101.46[a]	115.04	35.64	36.04	16.96
IVxEF (25%EF)	162.19	101.78[a]	114.04	35.60	35.75	15.50
IVxEF (50%EF)	173.31	110.55[b]	120.46	33.71	35.15	17.77
F test value	1.88[ns]	3.55[+]	1.07[ns]	0.54[ns]	0.19[ns]	1.50[ns]

Table3. Measurements of the left and right udder cisterns of ewes detected by the "from the bottom" method, depending on the breed group

Source of variance	Measurement						
	Length of left cistern (LLC1) [mm]	Width of left cistern (WLC1) [mm]	Area of left cistern (ALC1) [mm^2]	Length of right cistern (LRC1) [mm]	Width of right cistern (WRC1) [mm]	Area of right cistern (ARC1) [mm^2]	Sums of both cross-section areas ($\sum^1$)
Number of control measurements	130	130	130	130	130	130	130
Total average	50.69	50.69	1019.57	51.15	25.68	1026.15	2045.72
SD	11.37	8.76	500.58	11.49	9.22	522.95	987.20
Coefficient of variation	22.43	34.87	79.08	22.47	35.90	50.96	48.26
Minimum	17	8	79	0	0	0	166
Maximum	85	51	2900	76	49	2692	5312
			Breed group				
Improved Valachian	51.34	24.18	999.10	49.61[a]	25.00[a]	949.53	1948.63
IVxEF (25%EF)	49.25	24.47	968.20	50.10[a]	24.64[a]	1004.95	1973.16
IVxEF (50%EF)	55.11	28.56	1224.96	56.08[b]	30.27[b]	1231.42	2456.39
F test value	2.73[ns]	2.55[ns]	2.79[ns]	3.19[+]	4.04[+]	2.50[ns]	2.77[ns]

genotype (P>0.05), but the size of the cisterns increased with increasing proportion of EF breed. For example, ALC1 and ARC1 were 999.10 and 949.53 mm^2 respectively in purebred EF ewes, but up to 1224.96 and 1231.42 mm^2 in crossbred ewes with 50% EF (Table 3). For the traits measured "from the side", ALC2 and ARC2 were 1429.44 and 1505.18 mm^2 in purebred IV ewes and IVxEF crosses with 50% EF and 1776.81 and 1782.61 mm^2, respectively (Table 4).

On the udder cistern measurements observed by the "from the side" method (Table 4), the breed group factor had a statistically significant effect on the variables width of left cisternae (P<0.05), area of left cisternae (P<0.05) and the sum of left and right cisternae areas (∑2) (P<0.05). Table 4 again shows that as the genetic proportion of EF breed increased, the size of both udder cisterns increased. For example, WLC2 in

Table 4. Measurements of the left and right udder cistern of ewes detected by the "from the side" method depending on the breed group

Source of variance	Measurement						
	Length of left cistern (LLC2) [mm]	Width of left cistern (WLC2) [mm]	Area of left cistern (ALC2) [mm^2]	Length of right cistern (LRC2) [mm]	Width of right cistern (WRC2) [mm]	Area of right cistern (ARC2) [mm^2]	Sums of both cross-section areas (Σ^2)
Number of control measurements	130	130	130	130	130	130	130
Total average	64.81	28.82	1516.66	65.65	30.39	1562.12	3078.78
SD	12.70	6.86	574.79	12.16	7.37	619.06	1139.34
Coefficient of variation	19.60	23.81	37.90	18.53	24.24	39.63	37.01
Minimum	20	8	163	25	8	203	366
Maximum	100	47	3125	90	49	3163	6044
Breed group							
Improved Valachian	64.72	27.88^a	1429.44^a	63.62	30.59	1505.18	2934.62^a
IVxEF (25%EF)	62.72	27.81^a	1445.97^a	63.75	29.63	1486.63	2032.59^a
IVxEF (50%EF)	69.05	31.96^b	1776.81^b	68.99	32.53	1782.61	3559.42^b
F test value	2.55^{ns}	4.05$^+$	3.82$^+$	2.11^{ns}	1.58^{ns}	2.48^{ns}	3.38$^+$

purebred IV ewes was 27.88 mm and in IVxEF crosses (50% EF) was up to 31.96 mm ($P<0.05$). In crossbred ewes with 25% EF, WLC2 was similar to that of purebred IV ewes (27.81 mm).

The results of the analysis of variance of the indicators characterising the milk yield of the ewes according to the breed group are presented in Table 5. From the table it can be seen that the quantity of milk obtained by machine milking (MMY) was on average 257.48 ml and the total milk yield was 366.05 ml, with a relatively wide range (20 to 1000 ml). The amount of milk obtained by machine stripping (MS) was 108.57 ml, giving a machine stripping rate of 33.18%. This value is also in line with the work of Margetín *et al.* (2002b; 2003a,b) and the numerous works carried out in the 1960s and 1970s Tsigai and Valachian sheep from Slovakia. These publications show that the proportion of machine stripping often reaches 30 to 50%, and in some cases even more. The coefficients of variation for all production parameters (MY60s, MMY, TMY, MS) are in all cases sufficiently high for successful selection (45.89% – TMY to 65.16% – MS). In the experimental ewes, on average 64.44% of the total milk yield was milked in 60 seconds. This indicator characterises the milk let-down rate well. This percentage is quite high. This suggests that once the teat nipples were fitted, the ewes were able to produce milk relatively quickly. We found a large spread in the indicators for the proportion of machine stripping and the proportion of milk milked in 30 and 60 seconds. Some of the observed ewes did not even start milking in 60 s (Table 5), however, on average, the proportion of milk milked in 60 s of the total milk yield was the mentioned 64.44% and in 30 s ewes milked 43.49% of the milk from TMY.

Table 5 also shows that the factor breed group did not have statistically significant effect ($P>0.05$) on any of the evaluated parameters. As expected, the values for machine milk yield and total milk yield were higher in crossbreds (IV 231.75 and 336.08 ml, IVxEF 25% 245.15 and 350.80 ml, IVxEF 50% 311.07 and 424.68 ml). The proportion of machine stripping decreased as the proportion of EF increased, which is highly desirable. For example, MSR was 35.52 in IV ewes and 30.41% in IVxEF crosses with 50% EF, respectively. On the other hand, the proportion of milk milked in 60 days increased with increasing EF percentage. The proportion of milk milked in 60 seconds was 61.08% in IV ewes and up to 65.97% in IVxEF crosses with 50% EF. The more milk milked in 60 seconds, the more profitable it is for the breeder (more ewes milked per unit of time).

CONCLUSION

The results obtained in the paper show that especially crossbred ewes with 50% of EF breed proportion in the same breeding conditions have

Table 5. Indicators characterising the milk yield of ewes depending on breed group

Source of variance	Measurement						
	Milk yield in 60 s [mL]	Machine milking (MMY) [mL]	Machine stripping (MS) [mL]	Total milk yield (TMY) [mL]	Machine stripping rate (MSR) (%)	Milk yield ratio in 30s MY30s/MMY (%)	Milk yield ratio in 60s MY60s/MMY (%)
Number of control measurements	129	129	129	129	129	129	129
Total average	246.36	257.48	108.57	366.05	33.18	43.49	64.44
SD	143.54	156.20	70.74	167.98	19.16	22.06	19.52
Coefficient of variation	58.26	60.66	65.16	45.89	57.74	50.72	30.29
Minimum	0	10	10	20	3.45	0	0
Maximum	850	900	400	1000	93.33	83.33	95
Breed group							
Improved Valachian	219.83	231.75	104.33	336.08	35.52	47.91	61.08
IVxEF (25%EF)	241.92	245.15	105.65	350.80	33.25	43.09	65.45
IVxEF (50%EF)	289.14	311.07	113.61	424.68	30.41	43.19	65.97
F test value	1.76^{ns}	2.29^{ns}	0.16^{ns}	2.48^{ns}	0.50^{ns}	0.47^{ns}	0.55^{ns}

* Abbreviations used – see Material and methods

significantly higher machine and total milk yield than purebred IV ewes and crossbred IVxEF with 25% of EF breed proportion. However, the differences between breeding groups were statistically insignificant in most of the monitored parameters (large variability in the monitored parameters, smaller number of animals). Surprisingly insignificant results in comparison with purebred IV ewes were obtained for crossbred ewes with 25% EF. Crossbreds with 50% EF had larger udders, larger cisterns and relatively good milk yield (with the lowest proportion of machine stripping and the highest proportion of MY60s), based on both linear evaluation and the exact rates detected. Based on the results obtained, we recommend to continue the experimental breeding in other breeds while producing crossbreds with 50% or even higher EF. This should not only increase milk production, but may improve, at least maintain, good milk yield of EF ewes. Since the performance of crossbred ewes with a 25% EF was even worse than that of purebred IV ewes, we do not recommend continuing to produce crossbreds with this genetic proportion of the improving breed.

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CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

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