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MILKABILITY OF IMPROVED VALACHIAN, TSIGAI AND LACAUNE PUREBRED AND CROSSBRED EWES

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ABSTRACT

The objective of this study was to investigate the variation in milk yield and milk flow traits and to analyse the main factors influencing the milkability of ewes. Milk yield and milk flow traits were: milk yield to 10 s, milk yield to 30 s, milk yield to 60 s, machine milk yield, stripping yield, total milk yield, percentage milk yield to 30 s, percentage milk yield to 60 s, stripping percentage, machine milking time and average milk flow. Primiparous and multiparous Improved Valachian, Tsigai and Lacaune purebred and crossbred ewes were considered. Crossbred ewes were crosses of Improved Valachian or Tsigai ewes with Lacaune (genetic portion of Lacaune was 25, 50 and 75 %, respectively). A total of 359 to 370 ewes were measured depending on trait. Mixed model with fixed and random effects using the REML (restricted maximum likelihood) method was applied. All traits were significantly ($P<0.01$) influenced by genotype and year. Some traits were significantly ($P<0.05$ or $P<0.01$) influenced by parity, stage of lactation and interactions considered between genotype and parity and between genotype and stage of lactation. The repeatability varied from 0.23 to 0.43. Regardless of breed, mean values of machine milk yield, total milk yield and of stripping percentage were 318.3 ml, 436.6 ml and 27.7 %, respectively. Stripping percentage varied extensively, from 0 % to 95 %. The highest stripping percentage (37.8 %), the highest total milk yield (523.1 ml) and the second highest machine milk yield (330.3 ml) were found in Lacaune purebred ewes. The crossbred ewes were better than Improved Valachian and Tsigai purebred ewes in all examined traits, except for milk yield to 10 s, percentage milk yield to 30 s, percentage milk yield to 60 s, stripping percentage and machine milking time. Obtained results suggest that crossbreeding of local dairy breeds with Lacaune may be a good strategy for improvement of milkability of dairy sheep population in Slovakia.

Key words: dairy sheep; machine milking; milk yield; milk flow

INTRODUCTION

Milkability of ewes is a complex trait which can be described by milk yield (Rovai *et al*., 1999), milk flow (Mayer *et al*., 1989; Bruckmaier *et al*., 1997) and udder morphology (de la Fuente *et al*., 1996). A pattern of milk flow is influenced by milk storage in udder before milking and milk ejection (Labussiere, 1988; Bruckmaier *et al*., 1997). Udder milk consists of two fractions: cisternal and alveolar. The cisternal fraction is milk which has already been transferred from alveoli to the cistern during the interval between milkings and is immediately obtainable by the machine without milk ejection. The alveolar fraction (milk stored in the alveoli) is milk which can be removed from the udder only when milk ejection occurs during milking (Marnet and McKusick, 2001; Mačuhová *et al*., 2008). Milk flow patterns depend on physiological response of ewes to machine stimulation, milk production and teat canal characteristics (Bruckmaier *et al*., 1997; Marnet *et al*., 1999; Tančin *et al*., 2011). Two (Labussiere, 1988) and three (Dzidic *et al*., 2004) milk flow patterns were reported for ewes: one-peak, bimodal and plateau. Along with milking machine parameters (pulsation rate, milking vacuum etc.) and individual abilities of ewes, breed, parity and stage of lactation are the important factors of milkability as well. Ewes with

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well shaped udder, vertically placed teats and having high milk emission flows eject their milk rapidly with only few manual interventions during machine milking (Marie-Etancelin, 2003). When ewes are adapted to show this aptitude, sheep farm profitability may increase.

Machine milking in Slovakia has been in place since 1960s. Early works on milkability were carried out in 1970s and 1980s (Masár, 1974, 1978; Mikuš 1974, 1985). Recent results on analyses of milk yield, milk flow and udder morphology were referred by Margetín *et al.* (2003, 2004, 2005) and Milerski *et al.* (2006). Recent results on analyses of milk flow curves were referred by Mačuhová *et al.* (2007, 2009, 2010), Kulinová *et al.* (2011) and Tančin *et al.* (2011). The complex work of such scope in terms of measured ewes and genotypes as presented here has not been done in Slovakia until now.

The objective of this study was to investigate the variation in milk yield and milk flow traits and to analyse the main factors influencing the milkability of ewes. A special emphasis was given on ewe genotype since milkability of Improved Valachian, Tsigai and Lacaune purebred and crossbred ewes was analysed.

MATERIAL AND METHODS

The study was performed in the experimental flock of the Animal Production Research Centre Nitra in Trenčianska Teplá between 2002 and 2008. Primiparous or multiparous Improved Valachian (IV), Tsigai (TS) and Lacaune (LC) purebred and crossbred ewes were considered. Crossbred ewes were crosses of IV or TS with LC (genetic portion of LC was 25, 50 and 75 %, respectively). Genotype acronyms for crossbred ewes were as follows: IVxLC 25 %, IVxLC 50 %, IVxLC 75 % and TSxLC 25 %, TSxLC 50 %, TSxLC 75 %. Ewes were milked twice a day. Milk yield and milk flow traits were measured during the morning milking, mostly in May and July. Machine milking was carried out in a 1x24 side by side milking parlour. Milking vacuum was 38 kPa, pulsation rate was 140 to 160 cycles/min at the ratio 1:1. Two to four measurements per lactation were taken. In ewes measured in two or more consecutive years, eight individual measurements were maximally taken.

Milk yield and milk flow were measured after the attachment of teat cups to ewe udder. A certified milkmeter (Farmtec, JSC Tabor, Czech Republic; accuracy ±10 ml) from routine milk performance testing was applied. Ewes were milked 60 s at least. The amount of milk extracted by the machine was recorded in 10 s intervals until milk flow ceased for 20 s. Machine stripping started afterwards and was recorded in 10 s intervals. Milk yield and milk flow traits were: milk yield to 10 s (MY10s), milk yield to 30 s (MY30s), milk yield to 60 s (MY60s), machine milk yield (MMY), stripping yield (SY), total milk yield (TMY = MMY + SY), percentage milk yield to 30 s (MY30sP), percentage milk yield to 60 s (MY60sP), stripping percentage (SP), machine milking time (MMT) and average milk flow (AMF). MY10s, MY30s and MY60s are the amounts of milk extracted during the first 10, 30 and 60 s of machine milking, respectively. MMY is the amount of milk extracted by the machine before milk flow ceased for 20 s. SY is the amount of milk extracted during machine stripping performed after milk flow had ceased (not earlier than 60 s from the attachment of teat cups). MY30sP, MY60sP, SP and AMF were calculated as follows: (MY30s/TMY)x100, (MY60s/TMY)x100, (SY/TMY)x100 and MMY/MMT. A total of 359 to 370 ewes were measured depending on trait. Numbers of observations by trait, and genotype, parity, stage of lactation (according to traits) are reported in Tables 1 to 4b. The lower number of observations in traits MY10s and MMT was due to the fact that these indicators were assessed only in 2002-2005 and 2002-2007 respectively.

MEANS procedure (SAS, 2009) was used to calculate basic statistics for milk yield and milk flow traits. Mixed model with fixed and random effects (MIXED procedure; SAS, 2009) was applied to assess sources of variation for milk yield and milk flow traits (SY was excluded from the analysis; interactions were omitted in the model for MY10s, MMT and MMF). The model was as follows:

$$y_{ijklm} = \mu + G_i + P_j + S_k + Y_l + G_i * S_k + G_i * P_j + a_m + e_{ijklm}$$

where:

y_{ijklm}	is individual observation of trait i.e. MY10s, MY30s, MY60s, MMY, TMY, MY30sP, MY60sP, SP, MMT, AMF
μ	is intercept
G_i	is fixed effect of genotype with 9 levels; IV, TS, LC, IVxLC 25 %, IVxLC 50 %, IVxLC 75 %, TSxLC 25 %, TSxLC 50 %, TSxLC 75 %
P_j	is fixed effect of parity with 3 levels; first, second, third and further parity
S_k	is fixed effect of stage of lactation with 4 levels; from day 40 to 99, from day 100 to 129, from day 130 to 159 and from day 160 to 210
Y_l	is fixed effect of year of experiment with 4, 6 and 7 levels, respectively, depending on trait
$G_i * S_k$	is interaction between genotype and stage of lactation
$G_i * P_j$	is interaction between genotype and parity
a_m	is random effect of animal
e_{ijklm}	is random residual error

Fixed effects were estimated using the LSM (Least Squares Means) method. Statistical significance was tested by Fisher's F-test and differences between the estimated levels of fixed effects were tested by Scheffe's multiple range test. Ewe (σ^2_{ew}) and residual error variances (σ^2_e) were estimated using the REML (Restricted Maximum Likelihood) method. The estimated variances were used to calculate the repeatability within an individual ewe:

$r^2 = \sigma^2_{ew} / (\sigma^2_{ew} + \sigma^2_e)$.

RESULTS

Basic statistics of milk yield and milk flow traits in Slovak sheep is summarised in Table 1. MMY was 317.5 ml and took 62.3 s (MMT) on average. SY was 118.8 ml and accounted for 27.7 % of TMY. The average value of TMY (435.9 ml) was low, taking into account the fact that LC purebred ewes were also measured. Ewes with milk yield to 10, 30 and 60 s (MY10s, MY30s and MY60s) as high as 400, 840 and 1200 ml were found. Ewes able of rapid udder emptying (MY30sP or MY60sP equal to 100 %) were also found. On the contrary, ewes with no milk ejection during the first 10, 30 or 60 s of machine milking also occurred.

Analysis of variance and estimates of repeatability for milk yield and milk flow traits are shown in Tables 2a and 2b. Effects of genotype and year showed highly significant ($P<0.01$) influence on all traits under study. The effect of parity influenced significantly ($P<0.05$) MMY and MY60s, and highly significantly ($P<0.01$) MY60sP and SP. The effect of stage of lactation was highly significant ($P<0.01$) or tended to be significant ($P<0.16$). Interactions between genotype and parity and between genotype and stage of lactation were included when MY30s, MY60s, MMY, TMY, MY30sP, MY60sP and SP were analysed. Effects of interactions (with exception of interaction between genotype and stage of lactation) was highly significant ($P<0.01$), significant ($P<0.05$) or tended to be significant ($P<0.15$) in all traits, except for MY30s and MY30sP. Repeatability equal to 0.34 or higher was found for all traits under study, except for MMT (0.23). The highest value of repeatability (0.43) was found for TMY.

Least-squares means and standard errors estimated for individual levels of effects of genotype, parity and stage of lactation are summarised in Tables 3a and 3b, and Tables 4a and 4b, respectively. Primiparous ewes had milk yield and milk flow traits higher (ML10s, ML30s, ML60s, ML60sP, AMF) or as high as multiparous ewes (MY, TMY, ML30sP, MMT). The exception was SP with the opposite trend. MY10s, MY30s, MY60s, MMY, TMY, MY30sP, MMT and AMF were decreasing with

Table 1: Basic statistics for milk yield and milk flow traits

Trait	n	$\overline{x}$	s	v	min.	max.
Milk yield to 10 s (MY10s), ml	796	116.4	67.1	57.6	0	400
Milk yield to 30 s (MY30s), ml	1218	220.4	102.8	46.6	0	840
Milk yield to 60 s (MY60s), ml	1159	307.2	154.1	50.2	0	1200
Machine milk yield (MMY), ml	1218	317.5	167.4	52.7	10	1200
Total milk yield (TMY), ml	1218	435.9	197.4	45.3	30	1339
Stripping yield (SY), ml	1218	118.8	91.8	77.3	0	775
Percentage milk yield to 30 s (MY30sP), %	1218	53.7	18.5	34.5	0	100
Percentage milk yield to 60 s (MY60sP), %	1159	69.4	17.0	24.5	0	100
Stripping percentage (SP), %	1218	27.7	15.6	56.3	0	95
Machine milking time (MMT), s	1088	62.3	16.4	26.3	15	160
Average milk flow (AMF), ml/s	1088	5.2	2.6	48.8	0	17.1

n: number of observations; $\overline{x}$: mean value; s: standard deviation; v: variation coefficient

Table 2a: Analysis of variance and estimates of repeatability for milk yield and milk flow traits

Source of variance	df	MY10s		MY30s		MY60s		MMY		TMY	
		F-value	P	F-value	P	F-value	P	F-value	P	F-value	P
Genotype (G)	8	4.39	<0.0001	3.65	0.0003	10.29	<0.0001	14.10	<0.0001	30.92	<0.0001
Parity (P)	2	1.81	0.1642	0.59	0.5533	3.13	0.0441	3.49	0.0308	0.11	0.8991
Stage of lactation (S)	3	1.74	0.1586	29.99	<0.0001	56.28	<0.0001	89.16	<0.0001	125.35	<0.0001
Year	6 (3*)	13.78	<0.0001	32.13	<0.0001	24.51	<0.0001	23.30	<0.0001	32.48	<0.0001
GxS	24	-	-	1.04	0.4092	1.73	0.0169	2.46	0.0001	2.98	<0.0001
GxP	16	-	-	1.64	0.0530	1.48	0.1018	1.71	0.0406	1.54	0.0795
		Proportion of variance									
Repeatability		0.40		0.41		0.38		0.37		0.43	

df: degrees of freedom; *df for MY10s; for acronyms of traits see Table 1

Table 2b: Analysis of variance and estimates of repeatability for milk yield and milk flow traits

Source of variance	df	MY30sP		MY60sP		SP		MMT		AMF	
		F-value	P	F-value	P	F-value	P	F-value	P	F-value	P
Genotype (G)	8	16.00	<0.0001	8.65	<0.0001	7.74	<0.0001	7.40	<0.0001	5.43	<0.0001
Parity (P)	2	1.07	0.3443	8.48	0.0002	7.35	0.0007	0.44	0.6439	6.42	0.0017
Stage of lactation (S)	3	7.18	<0.0001	1.79	0.1477	4.31	0.0050	31.33	<0.0001	78.84	<0.0001
Year	6 (5*)	9.85	<0.0001	4.88	<0.0001	6.41	<0.0001	30.38	<0.0001	26.97	<0.0001
GxS	24	1.23	0.2081	1.28	0.1645	1.51	0.0569	-	-	-	-
GxP	16	2.25	0.0034	1.89	0.0187	1.37	0.1480	-	-	-	-
		Proportion of variance									
Repeatability		0.42		0.37		0.35		0.23		0.34	

df: degrees of freedom; *df for MMT and AMF; for acronyms of traits see Table 1 an increasing number of days after parturition. SP showed the opposite trend as it increased with the increasing stage of lactation. MY60sP tended to be almost stable throughout the lactation.

The lowest MY10s (84.8 ± 6.9 ml) was found in LC purebred ewes, being 30 and 34 % lower than in IV and TS purebred ewes. TSxLC 25 % crossbred ewes had the highest MY10s, being 53 % higher than in LC purebred ewes. MY10s tended to decrease with an increasing portion of LC in crossbred ewes. TSxLC 25 % and IVxLC 25 % crossbred ewes had the highest MY30s (252.6 ± 37.0 ml and 237.7 ± 16.8 ml). TS and IV purebred ewes had the lowest MY30s, which was 31 % and 17 % lower than in TSxLC 25 % and IVxLC 25 % crossbred ewes. The same trend was revealed for MY60s; it was the highest in TSxLC 25 % and IVxLC 25 % crossbred ewes (362.6 ± 50.9 ml and 328.8 ± 22.8 ml). MY10s, MY30s, MY60s seem to have a potential to characterize the intensity of milk ejection in dairy ewes: the higher amount of milk is extracted during the first 60 (10, 30) s, the higher number of ewes can be milked per unit time. TMY in crossbred ewes was found lower than in purebred LC ewes, which had the highest TMY (523.1 ± 13.7 ml). Nevertheless, TMY in crossbred IV and TS ewes was higher than in purebred IV and TS ewes. MMY in IV and TS crossbred ewes (except for TSxLC 75 %) was higher than in LC purebred ewes. The lowest MMY (226.6 ± 13.2 ml and 200.9 ± 12.1 ml) and TMY (344.7 ± 14.3 ml and 273.3 ± 13.2 ml) were found in IV and TS purebred ewes. The highest MY30sP and MY60sP were found in IV and TS purebred ewes; the lowest MY30sP and MY60sP were found in LC purebred ewes. The higher MMT in LC purebred ewes than in IV and TS purebred ewes was found (by 6 and 8 s, respectively). MMT in crossbred ewes (except for IVxLC 75 % and TSxLC 75 %) was almost the same as in LC purebred ewes. The exceptions were TSxLC 25 % crossbred ewes with slightly lower MMT than TS purebred ewes. AMF calculated as the ratio MMY/MMT showed a similar trend, being of lower values in IV and TS purebred ewes than in IV and TS crossbred ewes and in LC purebred ewes. LC purebred ewes had higher SP than TS and IV purebred ewes (by 9 and 12 percentage points, respectively). SP in IV and TS crossbred ewes tended to differ from IV and TS purebred ewes to a lower extent (by 6 percentage points at maximum). As a general pattern, the differences in milk yield and milk flow traits between various genotypes within the same group of crossbred

Table 3a: Least squares means and standard errors of milk yield and milk flow traits by genotype

Source of variance		n *1	*2	*3	MY10s *1, ml LSM	SE	MY30s*2, ml LSM	SE	MY60s*3, ml LSM	SE	MMY*2, ml LSM	SE	TMY*2, ml LSM	SE
IV	(100)	148	218	200	128.9	7.1	196.8	9.3	271.8	12.8	226.6	13.2	344.7	14.3
IV xLC 25 %	(125)	42	68	67	124.0	13.6	237.7	16.8	328.8	22.8	339.0	24.0	428.5	25.9
IV xLC 50 %	(150)	43	93	91	128.5	13.0	225.2	13.6	325.4	18.4	348.2	19.3	468.7	20.9
IV xLC 75 %	(175)	68	82	82	111.6	10.6	219.9	14.2	344.7	19.1	367.9	20.1	498.4	21.8
TS	(200)	204	268	244	121.8	6.1	174.4	8.5	203.9	11.9	200.9	12.1	273.3	13.2
TSxLC 25 %	(225)	4	18	15	179.5	37.3	252.6	37.0	362.6	50.9	368.0	52.7	484.8	56.8
TSxLC 50 %	(250)	90	169	164	136.4	8.9	229.6	10.4	311.4	14.0	333.5	14.7	440.5	16.0
TSxLC 75 %	(275)	25	47	47	127.2	18.4	220.6	22.4	296.4	30.2	314.7	31.8	479.5	34.5
LC	(300)	172	255	249	84.8	6.9	211.4	8.9	312.7	12.1	330.3	12.6	523.1	13.7
Scheffé's multiple range tests					300:100,200,250^{+++} 300:125,150^{++} 300:175,225,275^{+}		200:125,250^{+++}; 200:150,175,300^{++}; 100:125,250^{+}; 200:225,275^{+}		200:100,125,150,175, 250, 300^{+++}; 100:175^{++}; 200:225,275^{++}; 100:125,150,250^{+}		200:125,150,175,250, 275,300^{+++}; 100:150,175,200,250, 300^{+++}; 200:225^{++}; 100:125^{++};		300:250^{+++}; 200:125,150,175,225, 250, 275,300^{+++}; 100:150,175,200,250, 275, 300^{+++}; 125:100,300^{++}; 100:125^{++}; 175:125,250^{+};300:150^{+};	

$^{+++}$ P<0.001; $^{++}$P<0.01; $^{+}$P<0.05; *1, *2, *3: number of observations (n) by trait; for acronyms of traits and genotypes see Table 1

Table 3b: Least squares means and standard errors of milk yield and milk flow traits by genotype

Source of variance		n *1	n *2	n *3	MY30sP^{*1}, % LSM	MY30sP^{*1}, % SE	MY60sP^{*2}, % LSM	MY60sP^{*2}, % SE	SP^{*1}, % LSM	SP^{*1}, % SE	MMT^{*3}, s LSM	MMT^{*3}, s SE	AMF^{*3}, ml/s LSM	AMF^{*3}, ml/s SE
IV	(100)	218	200	196	58.5	1.7	74.7	1.6	24.8	1.5	56.3	1.4	4.77	0.22
IV xLC 25 %	(125)	68	67	66	54.1	3.1	71.1	2.9	23.2	2.7	62.2	2.3	5.53	0.36
IV xLC 50 %	(150)	93	91	79	50.6	2.5	69.2	2.3	27.5	2.1	62.3	2.0	5.50	0.33
IV xLC 75 %	(175)	82	82	74	45.8	2.6	66.7	2.4	28.0	2.2	66.9	2.1	5.59	0.34
TS	(200)	268	244	250	63.9	1.6	71.4	1.5	27.9	1.3	53.4	1.2	3.94	0.20
TSxLC 25 %	(225)	18	15	12	52.6	6.7	73.7	6.5	25.3	5.9	52.6	5.2	5.48	0.83
TSxLC 50 %	(250)	169	164	149	53.9	1.9	69.9	1.8	26.7	1.6	61.3	1.5	5.24	0.23
TSxLC 75 %	(275)	47	47	37	47.8	4.1	63.1	3.8	34.1	3.5	66.0	3.1	4.86	0.51
LC	(300)	255	249	225	41.8	1.6	58.7	1.5	37.8	1.4	61.4	1.3	5.30	0.21
Scheffe's multiple range tests					300:125,250^{+++}; 200:150,175,250, 275,300^{+++}; 100:175,300^{+++}; 200:125; 100:150,300^{++} 100:200^{+},250,275^{+}; 175:125,250^{+}		300:100,125,150,200, 250^{++}; 175:300^{+}; 100:175,275^{++}; 300:225^{+}; 275:125,200^{++}; 100:150,250^{+}		300:100,125,150,175, 200, 250^{+++}; 300:225^{+++}; 275:100,125,250^{+}; 200:100^{+}		200:125,150,175,250, 275, 300^{+++}; 100:175^{+++}; 100:275,300^{++}; 225:125,150,175,275, 300^{++}; 175:250,300^{++}; 100:125,150,200,250^{+}		200:125,150,175,250, 300^{+++}; 100:200^{++}; 200:275^{++}; 100:125,150,175,300^{+}	

$^{+++}$ P<0.001; $^{++}$P<0.01; $^{+}$P<0.05; *1, *2, *3: number of observations (n) by trait; for acronyms of traits and genotypes see Table 1

ewes (either IVxLC or TSxLC) tended not to be significant; the differences in milk yield and milk flow traits between purebred and crossbred ewes (either within IVxLC and IV or within TSxLC and TS) tended to be significant.

DISCUSSION

The mean values of TMY, MMY, MY60s and SP were consistent with the findings of Margetín *et al.* (2005), who examined ewes of the same genotypes. The values differed (except for SP) from the findings of Margetín *et al*. (2004) where only IV and TS purebred ewes and their crosses with LC were considered, and also from the findings of Margetín *et al.* (2003) where only TS purebred ewes were considered. SP was considerably lower (by 17 percentage points) than SP reported for TS purebred ewes and was slightly higher (by 7 percentage points) than SP reported for East Friesian crossbred ewes (McKusick *et al*., 1996). With respect to ewes' adaptation to machine milking, SP is an important parameter affecting labour productivity and udder health and should be as low as possible.

Although studies on effects influencing milk yield and milk flow traits are reported in literature (e.g. Marie-Etancelin *et al*., 2003), only some of them focus on the same effects. Thus, limited comparisons can be done. No significant effect of parity on milk yield and milk flow traits in Slovak dairy ewes was found by Mačuhová *et al.* (2008) and Tančin *et al.* (2011). According to Tančin *et al.* (2011), the effect of month of experiment shows significant influence on most of the traits. Dzidic *et al*. (2009) confirmed significance of effect of days in milk (60-, 90- and 120-days, respectively) in Istrian dairy crossbred ewes. Regarding the effect of genotype, Mačuhová *et al.* (2007, 2008, 2009) and Tančin *et al*. (2011) showed that this effect was significant in minority of studied traits. Nevertheless, the traits tended to differ between analysed purebred and crossbred ewes. Rovai *et al.* (1999) reported significant effects of breed, parity and stage of lactation on milk yield in Manchega and LC ewes. Almost the same repeatability for TMY, MMY and MMT was reported by Tančin *et al*. (2011), whereas these authors found higher repeatability for SP (by 10 %). Marie-Etancelin *et al.* (2003) reported higher repeatability for TMY and AMF in Sarda x Lacaune backcrossed ewes (0.65 and 0.50) and LC lines (0.53 and 0.50). Casu *et al.* (2008) and Fuente *et al.* (1997) also found higher repeatability in Sarda x Lacaune backcrosses and Churra ewes, respectively.

Although the rough approximation of daily milk yield requires TMY presented here to be multiplied by 2, majority of studies devoted to milk emission characteristics reported breeds with higher milk production than Slovak dairy ewes. For instance, Peris *et al.* (1995) and Fernández *et al.* (1997) found MMY in Manchega ewes as high as 899 ± 38 ml and 992 ± 33 ml, respectively. According to Marie-Etanceline et al. (2003), TMY in LC lines and Sarda x Lacaune backcrossed ewes was 815 and 781 ml, respectively. The similar value of TMY (797.5 ± 262.6 ml) and MMY equal to 676.4 ± 244.4 ml in Sarda x Lacaune backcrossed ewes were reported by Casu et al. (2008). AMF in LC lines was 5.5 ml/s (i.e. it was found similar to AMF estimated for LC in this study), whereas AMF in Sarda x Lacaune backcrossed ewes was 8.23 ml/s (Marie-Etancelin *et al.*, 2003). Similar to the increasing trend of TMY with an increasing proportion of LC breed in IV crossbred ewes, Dzidic *et al.* (2004) reported TMY in Istrian 75 % x Awasi 25 %, Istrian 50 % x Awasi 50 % and Istrian 25 % x Awasi 25 % x East Friesian 50 % crossbred ewes as high as 0.52 ± 0.1 kg, 0.58 ± 0.1 kg and 0.75 ± 0.1 kg, respectively. The high values of TMY (1.14 ± 0.3 l) and MMY (0.92 ± 0.3 l) in East-Friesian crossbred ewes were reported by McKusick *et al.* (1996). Consequently, machine milking of East-Friesian crosses took 105.9 ± 38.6 s on average (i.e. AMF in Slovak ewes was found to be 40 % lower). In Boutsiko ewes (Sinapis *et al.*, 2006), MMY from morning milking investigated in independence on milking vacuum level which was between 338.5 ± 18 ml and 390.8 ± 21.4 ml i.e. similar to MMY found in IV and TS crossbred ewes and LC purebred ewes. MMT in Boutsiko ewes was by one third to one half lower. On the contrary, AMF was by one third to one half higher.

The comparisons between purebred and crossbred ewes presented here correspond with recent studies of Mačuhová *et al.* (2009) and Tančin *et al.* (2011) in most of the traits. Mačuhová *et al.* (2009) found the highest MY30s and MY60s in TSxLC 50 % crossbred ewes and the lowest MY30s and MY60s in TS and IV purebred ewes. According to them, the highest TMY and MMY was in IVxLC 50 % crossbred ewes and the lowest TMY and MMY was in TS purebred ewes. SP and MMT were the lowest in TSxLC 50 % crossbred ewes and the highest in LC purebred ewes and IVxLC 50 % crossbred ewes. Tančin *et al.* (2011) found the lowest TMY and MMY in IV purebred ewes and the highest TMY and MMY in IVxLC 50 % crossbred ewes. IV purebred ewes had the lowest SP, whereas LC purebred ewes and TSxLC 50 % crossbred ewes had the highest SP. The authors reported the lowest MMT in TS purebred ewes and the highest MMT in TSxLC 50 % crossbred ewes. MY30s was the lowest in IV purebred ewes; the highest MY30s was found in LC purebred ewes and TSxLC 50 % crossbred ewes.

The comparisons between IV and TS purebred ewes and their crosses with LC breed indicate that

Table 4a: Least squares means and standard errors of milk yield and milk flow traits by parity and stage of lactation

Source of variance		n *1	n *2	n *3	MY10s*1, ml LSM	MY10s*1, ml SE	MY30s*2, ml LSM	MY30s*2, ml SE	MY60s*3, ml LSM	MY60s*3, ml SE	MMY*2, ml LSM	MMY*2, ml SE	TMY*2, ml LSM	TMY*2, ml SE
Parity														
1	(1)	434	289	425	133.1	6.0	225.1	5.8	329.2	9.8	340.8	9.7	442.0	10.4
2	(2)	348	242	321	124.7	6.3	217.3	9.5	297.4	14.2	317.1	13.8	436.3	14.4
3+	(3)	436	265	413	123.2	6.7	213.7	10.6	292.4	14.4	298.2	15.1	435.5	16.3
Scheffe's multiple range tests					ns		ns		$1{:}2{,}3^{+}$		$1{:}3^{+}$		ns	
Stage of lactation														
Day 40 to 99	(1)	261	173	251	131.5	6.7	262.69	9.2	415.5	13.6	448.1	13.4	593.0	14.0
Day 100 to 129	(2)	366	271	357	130.3	6.0	236.15	7.7	320.7	11.2	339.3	11.2	465.6	11.8
Day 130 to 159	(3)	335	217	316	127.3	6.3	188.90	7.5	238.6	10.5	243.9	10.9	352.2	11.5
Day 160 to 210	(4)	256	135	235	118.8	7.1	187.02	9.0	250.9	13.4	243.4	13.1	341.0	13.7
Scheffe's multiple range tests					$1{:}4^{+}$; $2{:}4^{+}$		$1{:}3{,}4^{+++}$; $2{:}3{,}4^{+++}$;		$1{:}2{,}3{,}4^{+++}$; $2{:}3{,}4^{+++}$ $1{:}2^{++}$		$1{:}2{,}3{,}4^{+++}$; $2{:}3{,}4^{+++}$		$1{:}2{,}3{,}4^{+++}$; $2{:}3{,}4^{+++}$	

$^{+++}$ P<0.001; $^{++}$P<0.01; $^{+}$P<0.05; ns: not significant; *1, *2, *3: number of observation (n) by trait; for acronyms of traits see Table 1

Table 4b: Least squares means and standard errors of milk yield and milk flow traits by parity and stage of lactation

Source of variance		n *1	n *2	n *3	MY30sP^{*1}, % LSM	SE	MY60sP^{*3}, % LSM	SE	SP^{*1}, % LSM	SE	MMT^{*2}, s LSM	SE	AMF^{*2}, ml/s LSM	SE
Parity														
1	(1)	434	424	398	53.5	1.3	73.3	1.2	25.0	1.1	60.5	0.98	5.49	0.15
2	(2)	348	321	326	52.6	1.7	68.2	1.8	27.9	1.6	59.7	1.18	5.01	0.18
3+	(3)	436	413	364	50.3	1.9	64.8	1.8	32.2	1.7	60.6	1.21	4.91	0.19
Scheffe's multiple range tests					ns		1:3^{+++}; 1:2^{++}		1:3^{+++} 2:1,3^{+}		ns		1:2,3^{++}	
Stage of lactation														
Day 40 to 99	(1)	261	251	261	47.4	1.7	70.5	1.7	25.3	1.5	66.2	1.2	6.57	0.18
Day 100 to 129	(2)	366	357	346	52.0	1.4	69.0	1.4	27.6	1.3	61.8	1.1	5.41	0.16
Day 130 to 159	(3)	335	316	283	54.5	1.4	66.7	1.3	30.3	1.2	57.5	1.1	4.39	0.17
Day 160 to 210	(4)	256	235	198	54.7	1.6	68.8	1.7	30.2	1.5	55.5	1.3	4.26	0.19
Scheffe's multiple range tests					1:2,3,4^{+++}; 2:3^{+}		1:3^{+}		1:3,4^{++}; 2:3,4^{+}		1:2,3,4^{+++}; 2:3,4^{+++}		1:2,3,4^{+++}; 2:3,4^{+++}	

$^{+++}$ P<0.001; $^{++}$P<0.01; $^{+}$P<0.05; ns: not significant; *1, *2, *3: number of observation (n) by trait; for acronyms of traits see Table 1

crossbred ewes showed a good potential to benefit from desired traits of both local and LC breeds. As a partial disadvantage may be considered an increase in MMT and SP, nevertheless these seem to be balanced with better TMY, MMY, AMF, MY30s and MY60s. Knowledge gained from the analyses of milk yield and milk flow traits in various ewes' genotypes may be used as a basis for further improvement of local dairy ewes.

CONCLUSION

The experimental results suggest that crossbreeding of local dairy breeds with Lacaune breed may be a good strategy for improvement of milkability of Improved Valachian and Tsigai ewes. Selection based on such traits as machine milk yield or stripping percentage seem to be crucial for improving adaptation to machine milking and for increasing milk production. Both traits should be considered in a breeding programme since these traits require no additional costs when they are recorded routinely within milk performance testing.

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