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Analysis of the relationship between milk production, milk composition and morphological udder measurements in Wallachian sheep

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Abstract: The aim of this study was to evaluate the potential of udder measurements for prediction of milk yield, milk components and somatic cell count in non-dairy Wallachian sheep. The study was performed on 38 ewes in the Beskids Mountains kept under extensive management on pasture. Milk production (MILK) as well as samples for milk component and somatic cell count determination were collected during two separate control days (42nd day and 100th day of lactation on average). Rear udder depth (RUD, cm), udder width (UW, cm), and teat length (TL, mm) were measured at each control day as well. Linear regressions of udder measurement characteristics showed a predictive character ability for MILK only. An increasing of 70 g MILK corresponded with a 1 cm increase of RUD (P < 0.01) or 1 cm increase of UW (P < 0.001). These positive linear relationships were supported by the positive partial correlation analysis between MILK and RUD (r = 0.503; P < 0.001) or MILK and UW (r = 0.627; P < 0.001). An increase of 1 mm TL was associated with a 10 g (P < 0.01) increase of MILK; however, correlations between these traits were not significant. Results of this study demonstrate an alternative way of MILK ability in non-dairy Wallachian sheep population in general. Correlation and regression analysis further estimated this expected potential in detail using udder measurement characteristics. Measurement of RUD and UW could serve as a tool for breeding and flock management in order to maintain and improve milk production; however, there was no obvious evidence for the prediction of milk composition characteristics and somatic cell count.

Keywords: ewe; milk yield; rear udder depth; udder width; teat length

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Wallachian sheep are not currently milked in the Czech Republic, although their milk production represented a substantial part of their multiple utilization under the traditional Carpathian production system in the past (Jandurova et al. 2005; Ptacek et al. 2019a). An alternative way for the prediction of milk yield and composition is within the scope of interest for non-dairy Wallachian sheep in order to maintain their historical predispositions for this purpose. Besides genetic (Manuelian et al. 2019; Citek et al. 2020; Macuhova et al. 2020), physiological (Gelasakis et al. 2012; Sezenler et al. 2016; Ptacek et al. 2018; Macuhova et al. 2020) or environmental (Addis et al. 2005; Gomez-Cortes et al. 2008; Marnet and Komara 2008; Dzidic et al. 2019) factors, milk production is influenced by morphological formation of udder (Legarra and Ugarte 2005; Casu et al. 2006; Margetin et al. 2012; Merkhan 2014). Kominakis et al. (2009) and McKusick et al. (1999) predicted milk production from udder measurement characteristics. Moreover, in milk production, Iniguez et al. (2009) reported the positive relations between udder measurements and protein or fat percentages. Additionally, Kominakis et al. (2009) and McKusick et al. (1999) evaluated the effect of udder measurements on somatic cell count; however, they reached ambiguous results on this important trait of milk quality. More publications concerning evaluation of the effect of udder measurements on milk production or milk quality traits were recently reviewed by Pourlis (2020).

The aims of the present study are: 1) to predict milk production based on udder morphological formation of original Wallachian sheep, 2) to define and express potential relations between udder morphological formation and milk components or somatic cell count for these sheep during a defined period.

MATERIAL AND METHODS

Animals and flock management

The study was performed on non-dairy purebred Wallachian sheep kept in one flock, located in the Beskids Mountains. This research was a part of a complex study bringing information about Wallachian sheep and showing their potential in current farming systems. Therefore, location, flock management, feeding regime and information about the base of the research design were described in detail in previous studies (Ptacek et al. 2018; 2019a; 2019b). The milk samples were collected from a group of 38 ewes selected from the basic flock on two control days (in early and late lactation): 1st control day of milk collection (27th April, the average 42nd day of lactation; n = 38), 2nd control day of milk collection (23rd June, the average 100th day of lactation; n = 35, as three ewes did not persist in their lactation until the end of our observation). Before starting the control milking the udder dimension characteristics of ewes were routinely monitored within udder linear score description for dairy sheep flocks in the Czech Republic: rear udder depth (RUD, cm), udder width (UW, cm), and teat length (TL, mm) were measured according to Milerski et al. (2006). Milk collection procedure, milk production (MILK), and analysis of milk components (fat percentage, FAT; protein percentage, PROT; casein percentage, CAS; lactose percentage, LACT; dry matter percentage, DM; non-fat solids percentage, NFS) – similarly like information concerning the flock and flock management – were methodically described in Ptacek et al. (2018; 2019a; 2019b). Milk sample (30 ml) for somatic cell count (SCC) estimation was collected in accordance with the standard protocol (ICAR 2012) during the control days. SCC was determined using a Somacount 150 instrument (Bentley Instruments, Inc., Chaska, MN, USA). Totally 73 sets of measurements were recorded. Additionally, information about the age of ewe, and litter size were also noticed for further analyses.

Statistical evaluation

All statistical analyses were performed using SAS/STAT® v9.3 software (SAS Institute Inc., Cary, NC, USA). The UNIVARIATE procedure was used to calculate descriptive statistics. Pearson partial correlation coefficients were used to express relations between milk production, milk components, somatic cell count on the one hand and udder measurement traits (RUD, UW, TL) on the other hand. These relations were expressed after the data adjustment for control day of milk collection, ewe age category, and litter size.

The second used approach consisted of linear regressions of individual udder dimension character-

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istics included in the model equation for analysis of variance of milk traits and somatic cell count. These results were estimated by the GLM procedure of SAS® software using the following statistical model:

$$Y_{ijklm} = \mu + \text{DAY}_i + \text{AGE}_j + \text{LS}_k + \text{DIM}_l\,(\text{DAY}) + b(\text{RUD}_m) \text{ or } b(\text{UW}_m) \text{ or } b(\text{TL}_m) + e_{ijklm} \quad (1)$$

where:

Y_{ijklm} – evaluated trait (MILK, FAT, PROT, CAS, LACT, DM, NFS, SCC);

μ – mean value of the evaluated trait;

DAY_i – fixed effect of the control day of milk collection (i = 1st day of milk collection, n = 38; i = 2nd day of milk collection, n = 35);

AGE_j – fixed effect of ewe age category (j = 1-year-old ewes, n = 14; j = 2-years-old ewes, n = 20; j = 3-years-old ewes, n = 44; j = 4-years-old ewes, n = 35; j = 5-years and older ewes, n = 29);

LS_k – fixed effect of litter size (k = ewes with single lambs in litter, n = 30; k = ewes with twins in litter, n = 43);

DIM_l (DAY) – nested effect of days in milk within particular control days of milk collection;

$b(\text{RUD}_m)$ – linear regression for evaluated trait by rear udder depth (range = 7–16 cm);

$b(\text{UW}_m)$ – linear regression for evaluated trait by udder width (range = 9–16 cm);

$b(\text{TL}_m)$ – linear regression for evaluated trait by teat length (range = 17–53 mm);

e_{ijklm} – residual error.

Significance levels of $P < 0.05$, $P < 0.01$, and $P < 0.001$ were used for evaluation.

RESULTS AND DISCUSSION

Milk production and udder measurement characteristics

Arithmetic means with standard deviations for parameters of milk production, milk components, SCC and udder dimension traits during the whole trial are reported in Table 1. Milk production or milk components were in a similar or even in a higher amount in confrontation with phylogenetically related animals bred under extensive conditions (Mierlita et al. 2011; Pesinova et al. 2011; Tancin et al. 2011; Macuhova et al. 2017; Kusza et al. 2018). Other results obtained in intensive sheep breeds showed that Lacaune sheep reached higher milk production and fat percentage during a similar period of lactation, while their protein content was on a similar level (Konecna et al. 2019). However, previously published results of Konecna et al. (2013) obtained in Lacaune sheep, East Friesian sheep and their crossbreds showed very comparable results of milk production or milk components to our study. In this sense the genotype × environment interaction should be well considered in flock management to achieve required milk performance (Robles Jimenez et al. 2020). Similar results of udder dimension traits were demonstrated for Tsigai and Improved Wallachian sheep, while considerably higher RUD and UW were noticed for Lacaune sheep (Milerski et al. 2006). In general, higher udder dimensions were also detected for Improved Wallachian, Tsigai, Lacaune sheep, and their crossbreds (Margetin et al. 2012) or Istrian sheep (Prpic et al. 2013). In the context of previous studies performed on milked extensive breeds our results suggested the milk production potential of non-dairy Wallachian sheep.

Table 1. Basic data structure of milk production, milk components, and somatic cell count during control days of monitoring

	AM ± SD (n = 73)
MILK (kg)	0.88 ± 0.32
FAT (%)	6.58 ± 1.34
PROTEIN (%)	5.06 ± 0.55
CASEIN (%)	3.80 ± 0.52
LACTOSE (%)	5.11 ± 0.28
DM (%)	17.05 ± 1.44
SCC (cells/ml)	395.65 ± 1 224.00
RUD (cm)	10.18 ± 1.69
UW (cm)	12.55 ± 1.54
TL (mm)	27.18 ± 6.89

AM = arithmetic mean; CASEIN = casein percentage in milk; DM = dry matter in milk; FAT = fat percentage in milk; LACTOSE = lactose percentage; MILK = milk production; NFS = non-fat solids in milk; PROTEIN = protein percentage in milk; RUD = rear udder depth; SCC = somatic cell count in milk; SD = standard deviation; TL = teat length; UW = udder width

https://doi.org/10.17221/196/2020-CJAS

Table 2. Regression and correlation analysis of rear udder depth and milk production, milk components or somatic cell count in Wallachian sheep

Linear regression	R^2 MODEL	MODEL	DAY	AGE	LS	DIM (DAY)	Pearson partial correlations (r)
MILK = –0.27 + 0.07 × RUD**	0.94	***	***	***	*	***	0.503***
FAT = 9.51 – 0.17 × RUD^{ns}	0.79	*	***	ns	ns	ns	–0.245*
PROTEIN = 5.78 – 0.01 × RUD^{ns}	0.90	***	***	ns	ns	ns	0.199^{ns}
CASEIN = 4.27 – 0.01 × RUD^{ns}	0.85	***	***	ns	ns	ns	0.174^{ns}
LACTOSE = 4.93 + 0.00 × RUD^{ns}	0.80	**	***	ns	ns	ns	–0.092^{ns}
DM = 20.47 – 0.18 × RUD^{ns}	0.85	***	***	ns	ns	*	–0.199^{ns}
SCC = 156.17 + 8.31 × RUD^{ns}	0.96	***	***	ns	ns	***	0.078^{ns}

AGE = ewe age category; CASEIN = casein percentage in milk; DAY = day of milk collection; DIM (DAY) = nested effect of days in milk within control days; DM = dry matter in milk; FAT = fat percentage in milk; LACTOSE = lactose percentage; LS = litter size; MILK = milk production; ns = not significant; PROTEIN = protein percentage in milk; RUD = rear udder depth; SCC = somatic cell count in milk (cells/ml)
*P < 0.05; **P < 0.01; ***P < 0.001

Correlation and linear regression analyses

Information about linear regression and correlation analysis is reported in Tables 2, 3 and 4. This evaluation should demonstrate specific prediction of milking ability using an alternative way of udder dimension measurement for non-dairy Wallachian sheep. The models for the estimation of linear regressions used to explain the variation in milk production, milk composition, and SCC were significant. Their R^2 values ranged from minimal 0.78 to 0.95 in maximum. Day of milk collection was a major driving factor influencing all the evaluated variables. Fixed effects of AGE and LS were significant only for MILK. A significant effect on MILK concerned also linear regression by RUD, WL, and TL.

Tables 2, 3 and 4 show in detail linear relationships between Wallachian sheep udder dimension characteristics and milk production, milk composition, and SCC, after correction for the defined factors in the model. As indicated by the model description, a significantly predictive character ability of udder dimensions was detected only for milk yield. Namely, an increase of 70 g milk yield corresponded with a 1 cm increase of RUD (P < 0.01) or 1 cm increase of UW (P < 0.001). These positive linear relationships were supported by the positive partial correlation analysis between MILK and RUD (r = 0.503; P < 0.001) or MILK and UW (r = 0.627;

Table 3. Regression and correlation analysis of udder width and milk production, milk components or somatic cell count in Wallachian sheep

Linear regression	R^2 MODEL	MODEL	DAY	AGE	LS	DIM (DAY)	Pearson partial correlations (r)
MILK = –0.35 + 0.07 × UW***	0.95	***	***	***	*	***	0.627***
FAT = 9.67 – 0.16 × UW^{ns}	0.79	*	***	ns	ns	ns	–0.286*
PROTEIN = 5.78 – 0.01 × UW^{ns}	0.90	***	***	ns	ns	ns	0.144^{ns}
CASEIN = 4.27 – 0.01 × UW^{ns}	0.85	***	***	ns	ns	ns	0.085^{ns}
LACTOSE = 4.93 + 0.00 × UW^{ns}	0.80	**	***	ns	ns	ns	–0.059^{ns}
DM = 20.47 – 0.18 × UW^{ns}	0.85	***	***	ns	ns	*	–0.248*
SCC = 156.17 + 8.31 × UW^{ns}	0.96	***	***	ns	ns	***	0.001^{ns}

AGE = ewe age category; CASEIN = casein percentage in milk; DAY = day of milk collection; DIM (DAY) = nested effect of days in milk within control days; DM = dry matter in milk; FAT = fat percentage in milk; LACTOSE = lactose percentage; LS = litter size; MILK = milk production; ns = not significant; PROTEIN = protein percentage in milk; SCC = somatic cell count in milk; UW = udder width
*P < 0.05; **P < 0.01; ***P < 0.001

https://doi.org/10.17221/196/2020-CJAS

Table 4. Regression and correlation analysis of teat length and milk production, milk components or somatic cell count in Wallachian sheep

Linear regression	R^2 MODEL	MODEL	DAY	AGE	LS	DIM (DAY)	Pearson partial correlations (r)
MILK = –0.09 + 0.01 × TL**	0.94	***	***	***	ns	***	0.190ns
FAT = 8.42 – 0.02 × TLns	0.78	*	***	ns	ns	ns	–0.196ns
PROTEIN = 5.81 – 0.01 × TLns	0.90	***	***	ns	ns	ns	0.044ns
CASEIN = 4.40 – 0.01 × TLns	0.85	***	***	ns	ns	ns	0.013ns
LACTOSE = 5.09 – 0.00 × TLns	0.81	**	***	ns	ns	ns	0.043ns
DM = 19.56 – 0.03 × TLns	0.84	***	***	ns	ns	ns	–0.175ns
SCC = 62.04 + 5.02 × TLns	0.96	***	***	ns	ns	***	0.002ns

AGE = ewe age category; CASEIN = casein percentage in milk; DAY = day of milk collection; DIM (DAY) = nested effect of days in milk within control days; DM = dry matter in milk; FAT = fat percentage in milk; LACTOSE = lactose percentage; LS = litter size; MILK = milk production; ns = not significant; PROTEIN = protein percentage in milk; SCC = somatic cell count in milk; TL = teat length

*P < 0.05; **P < 0.01; ***P < 0.001

P < 0.001). An increase of 1 mm TL was associated with a 10 g (P < 0.01) increase of milk production; however, correlations between these traits were not significant. A significantly positive predictive character for milk production was previously demonstrated by Kominakis et al. (2009) in Frizarta dairy sheep. This documented a significantly positive regression when an increase of 1 cm of udder height corresponded with 64–74 g increase of milk yield. Interestingly, these results are very close to ours. The positive linear regression function for milk yield by udder height was demonstrated by McKusick et al. (1999). No evidence of a significant positive linear relation was detected for milk composition or SCC in our study. Moreover, significantly negative Pearson partial correlation coefficients were detected between FAT and RUD (r = –0.245, P < 0.05) or FAT and UW (r = –0.286, P < 0.05). Also, these results virtually corresponded with those previously published on Frizarta sheep by Kominakis et al. (2009). Additionally, neutral regression – correlation relations concerning SCC in our study were in accordance with Kominakis et al. (2009) as well. Conversely, significantly negative linear regression for SCC by UW (–0.06, P < 0.05) or RUD (0.10, P < 0.01) was found by McKusic et al. (1999).

CONCLUSION

Milk production and milk composition of non-dairy original Wallachian sheep were on a similar or higher level than documented by the results detected in extensive sheep breeds kept under extensive breeding conditions. The results indicated the potential of Wallachian sheep for milk production under a traditional management system. The udder depth and udder width measurements could both serve as a tool for breeding and flock management to predict milk production of such breed. Additionally, results of this study were expressed by equations for these predictions. Udder measurements seem not to be reliable for the prediction of milk composition characteristics and somatic cell count.

Conflict of interest

The authors declare no conflict of interest.

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