Portable milkmeters for the rapid in-field collection of milkability phenotypes in dairy goats

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***Abstract*— The present study aimed to investigate the phenotypic factors affecting the variability of the milkability traits measured in Italian dairy goats through a portable milkmeter in commercial herds. Milkability descriptors combine either milk production, milking time, or milk flow and are important to consider for reasons related to udder health, e.g. they can be exploited for large or small scale monitoring of mechanical milking stress. The milkability traits recorded in this study were analysed through a linear model. Almost all the traits were influenced by lactation stage, but only part of them were affected by parity and season of sampling. With exception of blind phase (overmilking indicator), estimates decreased along the lactation, suggesting that fresh animals –especially pluriparous - are those with the greatest productivity, milk emission flow, and milking time. As regards the effect of parity, for the majority of traits the estimates of primiparous were lower compared to those of pluriparous. Since the milk somatic cell count is reported to be scarcely correlated with mastitis in goats, milkability traits collected on a large scale may be useful for genetic purpose. In addition, monitoring milking ability of goats through milkmeters in the field can be a strategy to evaluate milking procedures of farmers and could thereby boost the implementation and effectiveness of udder health improvement schemes with positive implications on milk quality and farm profitability.**

Keywords—goats, udder health, novel phenotypes, milk yield

I. INTRODUCTION

Milkability traits are used in dairy species to evaluate the response to new milking technologies or protocols [1]. The milking ability of lactating animals can be described by traits combining milk production, milking time, and milk flow. Characteristics related to milk flow can be recorded with portable devices like the Lactocorder® (WMB, Balgach, Switzerland), a milkmeter that measures the flow rate during milking and distinguish different milking phases [2]. For example, Lactocorder® can provide information about individual milk yield and the length (min) of specific phases automatically detected [3]. In particular, the maximum flow rate (MFR, kg/min), recorded at the beginning of milking, where most of milk is obtained, is the flow rate at the peak of production. The average flow rate (AFR, kg/min), instead, is calculated as the mean of milk flow rate measurements. The lag time (LT, min) starts with attachment of milking devices and stops when milk flow is 0.25 kg/min. Milk emission time (MET), expressed in min, starts to be recorded when milk flow rate is greater than 0.25 kg/min and ends when the rate goes down to 0.20 kg/min. The plateau phase (PPT, min) is the duration of the phase where milk flow is constant, i.e. with no disturbances in the milk emission. The decline phase (DPT, min) starts immediately after the PPT and closes at a milk flow rate < 0.20 kg/min. In case of overmilking after the end of DPT, the blind phase (BT, min) can be observed. Usually, in this phase the milk flow is very low, i.e. < 0.10 kg/min, or absent [3]. In all dairy species, milk emission is influenced by anatomical, physiological, sanitary and environmental factors. In lactating goats, for example, 2 milk fractions are present: the cisternal and the alveolar milk. The first is the fraction accumulated in the mammary cisterns and in the large galactophore ducts during the interval time comprised between two consecutive milking events. While this is readily available at milking, the alveolar fraction, accumulated in the alveolar structures, is only available after the oxytocin action after pre-milking stimulation. Compared to cows and buffaloes, small ruminants present larger cisterns, resulting milk from cisternal fraction to be greater compared to the alveolar one [4]. For these anatomical reasons, prestimulation before milking with the goal of oxytocin release is not as important as in other species (e.g. cow) [5].

In goats, the milk emission profile, associated with individual milk yield and milk quality parameters, can provide important practical information on milking operations and can be useful to identify mechanical milking stress. Differently from cows, milk somatic cell count, in fact, is reported to be scarcely correlated with mastitis in small ruminants. In the present study we investigated the phenotypic factors affecting the variability of the milkability traits measured in Italian dairy goats and their association with the amount of milk yielded during the milking.

II. MATERIALS AND METHODS

A. Data collection

Milkability traits and individual information of 1775 goats were available for this study. Animals belonged to different breeds (759 Alpina, 713 Saanen and 303 Maltese goat breeds) and parities (1 to 6) and were reared in three farms of Latium region, in Italy. In all the enrolled farms goats were milked twice a day. Milking machine was under standard dynamic conditions during data collection, with pulsation rate of 90 cycle/min and with vacuum showing variation from a minimum of 40 kPa to a maximum of 44 kPa across the farms. In all herds the pre-milking routine included only teats cleaning and attachment of milking cluster. The manual detachment of milking cluster was performed in all herds.

Parameters were recorded through a portable milkmeter (Lactocorder®, WMB, Balgach, Switzerland) following Boselli et al. (2020) [6] and included: the milk yield at milking (MY, kg), the milk yield in the first 60 s of milking (MY_1, kg), the maximum flow rate (MFR, kg/min), the AFR, the total milking time excluding forestripping (TMT, min), LT, PPT, DPT, and BT.

B. Statistycal analysis

To make sure all stages of lactation were represented in all parities, data were grouped based on parity and lactation stage. In particular, 4 parity classes were created: 1 (17% of data), 2 (28% of data), 3 (27% of data) and ≥ 4 (28% of data). Days in milk were grouped as: ≤ 50 (20% of data), 51-100 (56% of data), and ≥ 101 (24% of data). The model adopted for the analysis of variance of milkability traits included fixed effect of season of sampling (3 levels, i.e. spring, summer and autumn), herd, lactation stage, and parity class. Pearson correlations were calculated between sets of traits to evaluate presence of linear relationship. For data manipulation and analysis the R software was used [7].

III. Results

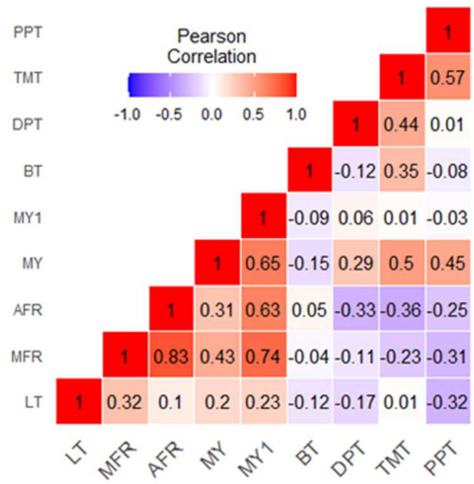
Descriptive statistics of traits calculated after editing are reported in Table I. In some cases, the goats produced less than 0.50 kg during the first 60 s of milking (n = 398), while some others produced more than 1.50 kg of milk. Overall, on average the MY was close to unity with an average TMT of 2.10 min. As regards flow rates, MFR ranged from 0.13 to 2.73 kg/min and AFR from 0.09 to 2.01 kg/min. Values equal to zero represented the 14, 7, 6 and 14% of the data for LT, PPT, DPT, and BT, respectively. Overmilking, occurring when BT is greater than 0, occurred in 86% of total records. Due to the nature of the trait, BT was the most variable phenotype (CV = 130%). Fig. 1 shows the Pearson correlations calculated between the traits. The correlations were significant (P<0.05), with the exceptions of AFR with MY and TMT, LT with PPT, and MY_1 with DPT. The strongest correlation was calculated between AFR and MFR, followed by the one between MY_1 and MFR.

TABLE I. Descriptive Statistics of milkability traits recorded

Trait[a]	Mean	CV[b], %	Min.	Max.
MY (kg)	1.05	45	0.18	3.15
MY_1 (kg)	0.66	41	0.25	1.75
MFR (kg/min)	0.99	38	0.13	2.73
AFR (kg/min)	0.69	38	0.09	2.01
TMT (min)	2.10	41	0.42	8.03
LT (min)	0.29	124	0.00	1.96
PPT (min)	0.55	118	0.00	4.39
DPT (min)	0.79	67	0.00	4.57
BT (min)	0.37	130	0.00	10.97

[a] MY=milk yield, MY_1 = milk yield in the first 60 s of milking; MFR=maximum milk flow rate; AFR=average milk flow rate; TMT=total milking time; LT=lag time; PPT=time of plateau phase; DPT=time of decline phase; BT=time of blind phase.
[b] Coefficient of variation (CV)

Fig. 1. Pearson correlations between milkability traits[a].



[a] MY=milk yield, MY_1 = milk yield in the first 60 s of milking; MFR=maximum milk flow rate; AFR=average milk flow rate; TMT=total milking time; LT=lag time; PPT=time of plateau phase; DPT=time of decline phase; BT=time of blind phase.

The outcome of the analyses of variance is summarized in Table II. While all traits were influenced by lactation stage, not all of them were affected by parity. For instance, TMT did not present significant variation due to parity. Season of sampling and herd, finally, significantly affected all the traits with very few exceptions (Table II).

The least squares means estimated for the fixed effect of parity and stage of lactation are presented with indication of the pairwise comparisons (Table III, Table IV, Fig. 2 and Fig. 3).

TABLE II. F-value and significance[a] of fixed effects

Trait[b]	Fixed effect			
	Stage of lactation	***Parity***	***Season***	***Herd***
MY (kg)	580.65***	28.21***	18.61***	76.97***
MY_1 (kg)	278.63***	15.13***	2.55 †	55.48***
MFR (kg/min)	88.43***	11.19***	4.96**	15.66***
AFR (kg/min)	23.00***	6.01***	6.95**	20.88***
TMT (min)	122.02***	ns	5.64**	24.65***
LT (min)	22.12***	2.44 †	ns	3.57*
PPT (min)	76.47***	ns	13.83***	25.34***
DPT (min)	44.01***	5.16**	2.35 †	ns
BT (min)	17.73***	2.17†	5.36**	8.39***

[a] ***P<0.001; **P<0.01; *P<0.05; †P<0.10; ns = not significant.
[b] MY=milk yield, MY_1 = milk yield in the first 60 s of milking; MFR=maximum milk flow rate; AFR=average milk flow rate; TMT=total milking time; LT=lag time; PPT=time of plateau phase; DPT=time of decline phase; BT=time of blind phase.

The TMT decreased by about 29.64% (from 2.26 to 1.59 min) from early to late lactation. The two main milking phases, PPT and DPT, presented decreasing estimates from early to late lactation, whereas BT showed an inverse pattern being the greatest in late and the lowest in early (Table III). The main milk ejection phases, PPT and DPT, represented in proportion most of the TMT regardless of the stage of lactation and parity. The BT contribution (in %) to TMT increased moving from early to mid (+12.39%) or late lactation (+23.90%). Both MY and MY_1, decreased along lactation and increased with parity (Fig. 2), following the same trends of MFR and AFR (Fig. 3).

TABLE III. LEAST SQUARES MEANS AND STANDARD ERROR OF THE MILKABILITY TRAITS[1] ESTIMATED FOR THE FIXED EFFECT OF LACTATION STAGE (DAYS IN MILK, DIM). VALUES WITH DIFFERENT SUPERSCRIPTS WITHIN ROW ARE SIGNIFICANTLY DIFFERENT (P≤0.05)

Trait[1]	Stage of lactation		
	<50 DIM	*50-100 DIM*	*>100 DIM*
TMT (min)	2.26(0.05) [a]	2.12(0.03) [a]	1.59(0.04) [b]
LT (min)	0.34(0.02) [a]	0.29(0.02) [a]	0.20(0.02) [b]
PPT (min)	0.62(0.04) [a]	0.57(0.03) [a]	0.26(0.03) [b]
DPT (min)	0.70(0.03) [a]	0.58(0.02) [b]	0.38(0.03) [c]
BT (min)	0.28(0.03) [b]	0.30(0.02) [ab]	0.38(0.02) [a]

[1] TMT=total milking time; LT=lag time; PPT=time of plateau phase; DPT=time of decline phase; BT=time of blind phase.

TABLE IV. LEAST SQUARES MEANS AND STANDARD ERROR OF THE MILKABILITY TRAITS[1] ESTIMATED FOR THE FIXED EFFECT OF PARITY. VALUES WITH DIFFERENT SUPERSCRIPTS WITHIN ROW ARE SIGNIFICANTLY DIFFERENT (P≤0.05)

Trait[1]	Parity			
	1	*2*	*3*	*≥4*
TMT (min)	1.92(0.05) [a]	1.98(0.04) [a]	2.05(0.04) [a]	2.01(0.04) [a]
LT (min)	0.27(0.02) [ab]	0.25(0.02) [b]	0.31(0.02) [a]	0.28(0.02) [ab]
PPT (min)	0.45(0.04) [a]	0.50(0.03) [a]	0.49(0.03) [a]	0.48(0.03) [a]
DPT (min)	0.46(0.03) [b]	0.56(0.03) [ab]	0.60(0.03) [a]	0.58(0.03) [a]
BT (min)	0.36(0.03) [a]	0.32(0.02) [a]	0.28(0.02) [a]	0.31(0.02) [a]

[1] TMT=total milking time; LT=lag time; PPT=time of plateau phase; DPT=time of decline phase; BT=time of blind phase.

IV. DISCUSSION

Romero et al. (2017) [8] found that MY is associated with milk flow and milking phases duration. This was confirmed in this study by the positive correlation calculated between MY and the other milkability traits (Fig. 1). On the contrary, there was an inverse relationship between BT and MY, indicating that overmilking, when present, is found in animal with low MY. However, with the data available for this study it was not possible to explore causality. For the majority of traits, values recorded in primiparous differed from those of pluriparous (Table II; Fig. 2; Fig. 3). The estimates reported for MY and MY_1 confirm findings reported for goats by other authors [4, 8, 9]. With exception of BT, which indicates overmilking, estimates suggest that fresh animals – especially pluriparous - are those with the greatest productivity, milk emission flow, and milking time. The difference in TMT between primiparous and pluriparous was low, probably due to the similar milking routine adopted for all animals [10]. Ideally, to limit overmilking and make the routine efficient goats should be divided in groups at milking based on the lactation stage and, if possible, on parity.

Monitoring milk emission would be an optimal practice in order to adjust the TMT and avoid overmilking. With the results of this study it is recommended milking goats according to their stage of lactation in order to limit BT and LT. In fact, BT that is the indicator of overmilking recorded from end of declining phase to the moment where milk flow reached 0.10 kg/min, exposes the nipples and consequently the udder to an increased risk of inflammation.

Alejandro et al. (2014) [11] reported that an overmilking for 2 min in small ruminant increased the degree of congestion and/or oedema of the teats. In particular, overmilking in goats showed an increase in the values for teat wall area, teat end area and teat canal length, in addition to an increase of e teat wall thickness compared with normal milking [11]. In cows the increase in teat wall thickness affects the defence mechanisms of the teat, increasing the risk of new intramammary infections [12]. Moreover, Rasmussen et al. (2004) [13] reported that overmilking in cows may lead to a reverse pressure gradient, allowing bacteria to enter in teat canal and in cisternal teat, increasing the risk of contracting new infections.

For anatomical and physiological reasons, in goats oxytocin was usually released within 30 s after the start of prestimulation before milking [5]. Without prestimulation oxytocin concentrations increased only after the start of milking. However, Bruckmaier et al. (1994) [14] found that milking characteristics were scarcely different with or without prestimulation.

V. CONCLUSION

The present study showed how stage of lactation and parity affect the milkability traits of dairy goats. Results suggest that in general pluriparous animals in early lactation are those with the greatest productivity, milk emission flow, and milking time. Milkability traits, whose phenotypic variability is exploitable could be used as indicators of udder health for genetic purpose if collected on a large scale. In Italian dairy goat farms, in fact, udder health of goats is only monitored using milk somatic cell count which is, however, scarcely correlated with mastitis. Monitoring milking ability of goats through milkmeters in the field can be a good strategy to both i) evaluate milking procedures of milking personnel in the farm and ii) boost the implementation and effectiveness of udder health improvement schemes with positive implications on milk quality and farm profitability.

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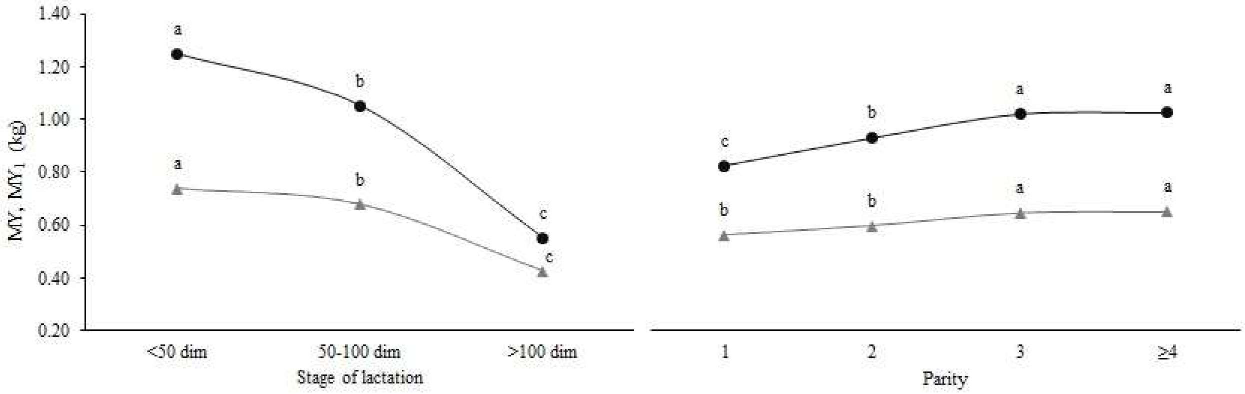
Fig. 2. Least squares means of milk production traits[a] estimated for the fixed effect of lactation stage (days in milk =dim) and parity. Values with different superscripts within row are significantly different (P≤0.05).



[a] MY=milk yield (black line), MY_1 = milk yield in the first 60 s of milking (grey line).

Fig. 3. Least squares means of the maximum (MFR, black line) and average milk flow rate (AFR, grey line) estimated for the fixed effect of lactation stage (days in milk =dim) and parity. Values with different superscripts within row are significantly different (P≤0.05).