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Article

Amiata donkey body conformation, udder characteristics, and their relationship with milk yield and quality

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Abstract

To date, no selective actions have been taken to improve milk traits in dairy donkeys, and the characteristics of the udder are not well defined in relation to the productive characteristics. This study aimed at increasing knowledge on Amiata dairy donkey body conformation, udder traits, and their relationship with milk yield and quality. Morphological, udder, and teat measurements and milk evaluations of 45 pluriparous jennies were carried out. The average wither height of the jennies was 126 cm and the chest girth was 148 cm; a large standard deviation of some body measurements was found. Forty-nine percent of the animals showed a moderately developed udder, while most of the jennies had symmetrical half-udders (96%) and the intermammary cleft was clearly visible in 53% of subjects. Correlation analysis indicated that bigger animals tend to have bigger udders, higher teat diameter, and greater distance between teat tips. A positive correlation between the teat length and the milk fat was found ($p < 0.01$), which suggests that jennies with longer teats have a better ability to release milk fat. The results of this paper may be useful to define the characteristics of the milking device and address selective choices of the animals.

Key words: dairy donkey, body conformation, udder morphology, milk quality

1. Introduction

The donkey species consists of about 50 million individuals (Norris et al. 2021), which vary greatly in body size: from miniature (about 180 kg and 92 cm in wither height) to the largest donkey type (about 430 kg and 143 cm in wither height) (Huggins 2002). The morphological diversity is probably related to changes that have taken place in order for donkeys to survive better in the local conditions where they are reared.

In Europe, there are more than 50 breeds or varieties of donkeys, and there are eight main breeds in Italy (DAD-IS 2021) including the Amiata donkey, which is an endangered Tuscan breed (Martini et al. 2018*a*). Since the 13th century, the native Italian population has been characterised by a Mediterranean grey-cruciate phenotype, currently typical of the Amiata donkey genetic type, while in the 16th century, large Hispanic and French donkeys were introduced, which were dark or darkish coloured (Matassino et al. 2014). The movement of animals across national borders and within the country led to admixtures and contributed for cross-breeding different donkey breeds through mating (Gichure et al. 2020).

Animal body conformation is related to function and may help in better understanding the relation with functional characteristics and directing the selective choices in donkeys. For example, in the case of pack donkeys, the body size determines the load they can carry (Gichure et al. 2020).

Today, the farming management of donkeys has changed from traditional to more organised systems (Bibbiani et al. 2017); for example, mechanical milking is widespread on dairy donkey farms in Italy (Dai et al. 2017). In fact, donkey milk has been rediscovered as a human food, especially in Europe and Asia (Martini et al. 2021).

Machine milking reduces the milking time and creates better working conditions for the farmers (Gelasakis et al. 2012). The conformation of the udders and teats of dairy animals is an important indicator of the aptitude for mechanical milking (Vrdoljak et al. 2020). It affects the efficiency of the milking and milkability, and thus the aptitude of an animal to give a regular, complete, and rapid milk secretion in response to an appropriate milking technique.

Udder morphology is therefore related to milk production traits in dairy species and has received particular attention in ruminants (Akdag et al. 2017; Vrdoljak et al. 2020; Tuliozi et al. 2021), lesser for donkeys (D'alessandro et al. 2015).

In donkeys, each of the mammary complexes consists of a glandular body and a nipple placed on both sides of the ventral part of the trunk, parallel to the midline, in the inguinal area.

Donkeys have a low udder capacity, and the average daily milk collected from mechanical milking is about 1–1.5 L/day (Martini et al. 2018*b*). In equids, 70%–85% of secreted milk is alveolar and can be drawn only if milk ejection occurs (Castillo et al. 2008). The size of the cistern thus affects the storage of milk between milkings and its yield at the time of milking, together with milk removal (Stelwagen 2001). Ultrasound evaluations of the donkey udder have shown that it is composed of several cavities, formed by many ducts that directly empty into the nipples (D'Alessandro et al. 2015).

In dairy dromedaries, as well as in donkeys, the udder has small cisterns (containing about 19.3% of the total milk in the udder) (Ayadi et al. 2009). On the other hand, in ruminants, the ducts flow into a cisternal cavity that contains approximately 20%–40% of the total milk volume in cattle, and 50%–75% in dairy sheep and goat breeds (Caja et al. 1999; Salama et al. 2004).

The distribution of milk in the udder also affects the milk composition. In dairy ruminants, correlations have been found between udder size and the content of some milk constituents (Akdag et al. 2017; Vrdoljak et al. 2020).

The optimal operational conditions for milking should aim to harvest the maximum amount of milk secreted and stored in the udder, with the highest content of total solids in the milk, causing no injury to the udder of the animals and requiring the minimum time taken by the milker (Pourlis 2020).

To date, in dairy donkeys, no selective actions have been taken to improve milk traits (Salari et al. 2019). Moreover, the characteristics of the udder are not well defined in relation to milk yield and quality.

To the best of our knowledge, in the literature, there are only two studies on the morphological examination of the donkey udder (D'Alessandro et al. 2015; Hassan et al. 2016), which concern the Martina Franca and Baladi Egyptian breeds. In the light of the increased use of donkey milk for human consumption and the importance of the udder morphology for milk production, this study aims to increase the knowledge of body conformation and udder traits in Amiata dairy donkeys and on their relationship with milk yield and quality.

2. Materials and methods

2.1. Animals and morphological measurements

The research was conducted according to Animals in Research: Reporting In Vivo Experiments (ARRIVE) guidelines and approved by the Ethics Committee of University of Pisa, Italy (protocol code 33949/2018 and 31 May 2018).

This study examined 45 Amiata lactating pluriparous jennies (Fig. 1). The weight of the jennies was registered using scales before the morning milking. The following measurements were taken of each jenny using a Lydtin stick or a flexible meter.

Body measurements:

(1) Wither height (from the ground to the top of the withers)
(2) Chest girth (immediately behind the shoulder blade)
(3) Trunk length (from the tip of the shoulder to the hip)
(4) Front rump width (distance between the hook tips)
(5) Rear rump width (distance between the rear udder and the pin bones)

Udder measurements and traits:

(1) Udder height measured from the base of the abdomen to the teat attachment
(2) Udder length (at the base) distance between the most cranial and caudal points of udder attachment at the intermammary groove
(3) Udder width (at the base) distance between the widest lateral points of the udder
(4) Circumference at the site of attachment

Teat measurements and traits:

(1) Teat length: distance between the tip of the teat and where it attaches to the udder
(2) Teat diameter at the base
(3) Distance between the teat tips: distances between the right and left teats (at the apex)
(4) Teat position (i.e., teat angle from the vertical line)
(5) The udder volume (cm^3) was calculated as the volume of two cones, one for each half-udder. On the basis of the distribution of the calculated volumes, the udders were classified as poorly developed (volume <350 cm^3), moderately developed (volume between 350 and 650 cm^3), and highly developed (volume >835 cm^3)

The milk yield was measured and recorded by milk meters connected to the milking machine. Milk samples were analysed for chemical composition within 24 h of collection: fat, non-fat dry matter (NFDM), protein, casein, lactose, urea, freezing point, and pH were determined by an infrared automatic milk analyser (MilkoScan™ 7 RM; Italian Foss Electric, Padua, Italy). Somatic cell counts (SCCs) were analysed by flow cytometry (Fossomatic™ device) (Accreditation Certificate POS CIP 018 INT rev 14 2022).

2.2. Statistical analysis

Descriptive statistics were calculated for body weight, body, udder and teat measurements, and udder traits. To test for any associations between the morphological characteristics of the animals, udder measurements, and milk quality, pairwise correlation coefficients were computed (JMP 2002).

3. Results and discussion

The animal, udder, and teat measurements are shown in Table 1.

The average wither height of the jennies was in the lower range limit for the breed standard for Amiata donkeys (119–142 cm in females) and similar to the findings for the same breed (Casini et al. 2007). The large standard deviation of some donkey body measurements including wither height was in agreement with Sargentini et al. (2018). The variability

Fig. 1. Amiata jennies.

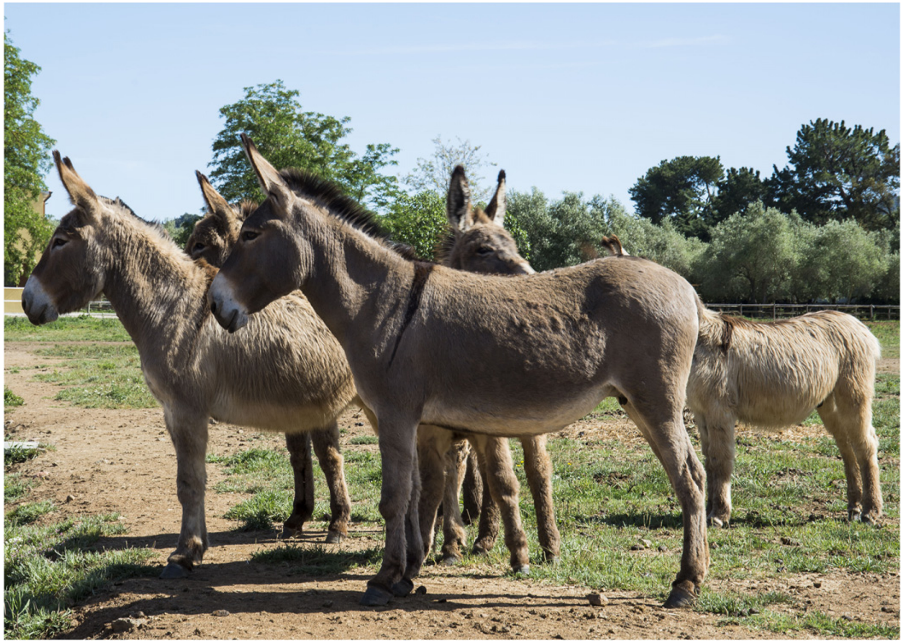

Table 1. Body, udder, and teat measurements of the jennies.

	Mean	SD
Weight (kg)	309.68	49.174
Wither height (cm)	125.85	8.977
Trunk length (cm)	134.42	7.307
Chest girth (cm)	148.34	9.247
Front rump width (cm)	39.93	3.515
Rear rump width (cm)	27.24	3.397
Udder height (cm)	8.55	2.135
Udder circumference at the site of attachment (cm)	63.84	11.721
Udder width (at the basis) (cm)	14.83	2.941
Udder length (at the basis) (cm)	25.59	5.015
Teat length (cm)	4.22	0.749
Teat diameter (cm)	2.56	0.682
Distance between the teat tips (cm)	6.23	1.335

in the morphology of the Amiata population could be useful when selecting breeds.

The average wither height of the Amiata jennies was similar to those reported for the Sicilian Gray, Calabrese, and Pantesco donkeys (Liotta et al. 2005, 2014), which is larger than adult females from Ethiopian (Kefena et al. 2011) and Czech donkey populations (Kosťuková et al. 2015) but smaller than other breeds frequently used for milk production such as Martina Franca, Ragusana, Romagnola, and the Dezhou (AIA 2013; Sun et al. 2016). The smaller size of Amiata donkeys compared to breeds frequently used for milk production is probably linked to their selection in the past for work in mines (Sargentini et al. 2018).

The chest girth was in the range described for the breed (between 133 and 163 cm); the mean value of chest girth was higher than the average values reported for the Ragusana and the Calabrese donkey (142 and 143 cm, respectively) (AIA 2013; Liotta et al. 2014) but similar to Dezhou jennies (Zhang et al. 2021).

With regard to the morphological characteristics of the udder (Fig. 2), the Amiata jennies showed longer and wider udders than those reported for the Martina Franca breed (average length and width of 25.59 and 14.83 cm versus 16.7 and 11.8 cm, respectively) in the only paper in the literature evaluating donkey mammary morphology (D'Alessandro et al. 2015). On the other hand, the characteristics of the teats (length, diameter, and distance between the tips of the teats) were similar between the two breeds.

Most of the jennies (49%) had a moderately developed udder (calculated volume between 350 and 650 cm^3), while the 27% had a highly developed one and 24% showed poor udder development.

Symmetrical half-udders were found in most of the animals (96%), while the intermammary cleft was clearly visible in 53% of subjects.

The teats were cylindrical in 54% of the jennies, and the rest were conical. Teats were vertically positioned with respect to the ground in 80% of the jennies. Almost all the jennies (98%) had teats positioned in the middle of the half-udders.

The lack of variability in the udder characteristics are important to standardise the groups more easily for machine milking, as also reported in dairy species (Pourlis 2020). The vertical teats positioned in the middle of the half-udder in most of the jennies facilitate the adaptation to milking cups; in fact, teat placement and angle influence the adaptation to the milking cup and the aptitude for mechanical milking.

Fig. 2. Udder and teats of lactating jennet.

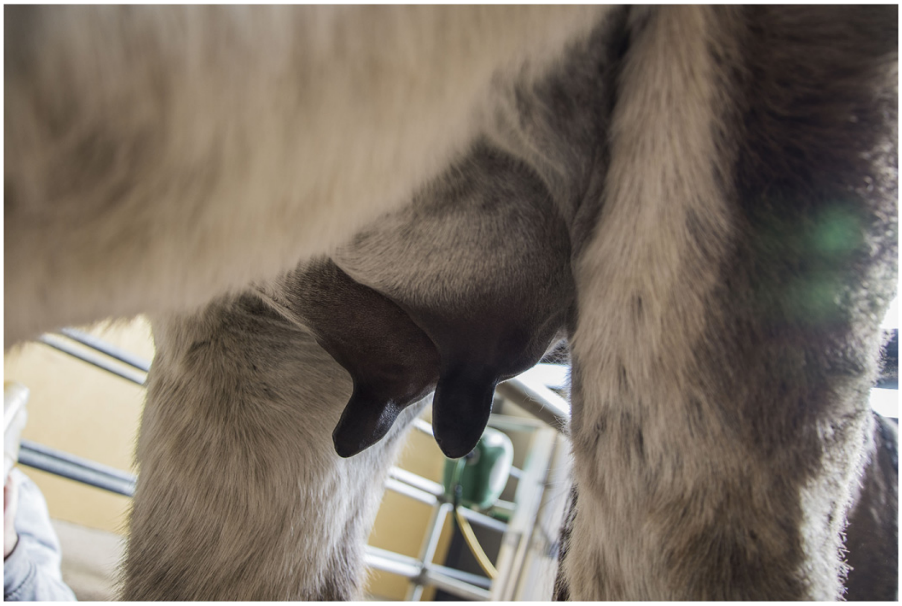

Table 2. Pairwise correlations between body animal measurements and udder measurements.

	Weight	Wither height	Trunk lenght	Front rump width	Rear rump width	Chest girth
Udder length (at the basis)	0.520**	—	0.376**	0.286*	—	0.518**
Udder width (at the basis)	0.340*	—	—	—	—	0.393**
Teat diameter	0.533**	0.454**	0.329*	0.286*	—	0.555**
Distance between the teat tips	0.295*	0.389**	0.324*	—	0.388*	—

Note: Only significant correlations are shown: $^{*}p < 0.05$; $^{**}p < 0.01$.

Table 3. Pairwise correlations among udder measurements and milk yield and quality.

	Milk yield	Fat	Protein	Casein	Lactose	NFDM	SCC	pH
Teat length	—	0.412**	—	—	—	—	—	—
Teat diameter	—	−0.387**	—	−0.347*	−0.531**	—	—	—

Note: NFDM, non-fat dry matter; SCC, somatic cell count. Only significant correlations are shown: $^{*}p < 0.05$; $^{**}p < 0.01$.

The udder cleft was detected in just over half of the subjects, which indicated the strength of the suspensory ligament. In sheep, clearly divided udder glands have shown a higher percentage of machine-produced milk compared to udders with no differentiation between the two halves (Sagi and Morag 1974). Also in cows, the fore udder attachment and central ligament can be used as positive selection criteria in improving milk production (Nemcova et al. 2007).

Table 2 shows the results of the correlations between the body and udder measurements.

Udder length correlated positively with body weight, trunk length, chest girth ($p < 0.01$), and front rump width ($p < 0.05$). Udder width also correlated positively with body weight ($p < 0.05$) and chest girth ($p < 0.01$).

The diameter of the teats was positively correlated with almost all measurements, in terms of weight, wither height, chest girth ($p < 0.01$), trunk length, and front rump width ($p < 0.05$). Similarly, the distance between the teats showed positive correlations with all body measurements except for the front rump width and chest girth.

Regarding the Amiata breed, larger animals showed larger udders in terms of length, width, teats diameter, and distance between the teats.

Neither the somatic measurements nor the weight correlated significantly with the quantity of milk produced. Although some authors (De Palo et al. 2016; Salimei et al. 2011) have speculated that milk production in jennies is proportional to body weight, our results do not confirm this hypothesis.

Studies on the relation between measurements and milk quality parameters regard ruminants and mostly goats (Vrdoljak et al. 2020) and have shown that the udder size is correlated with some milk components.

In our study (Table 3), negative and significant correlations were observed between teat diameter and fat, lactose, and casein ($p < 0.01$).

Similarly in goat milk, an increased teat size has been associated with a marked decrease in the percentage of fat (Cedden et al. 2008).

We also found a positive correlation between the teat length and milk fat ($p < 0.01$). It would therefore seem that jennies with longer teats have a better aptitude to release milk fat, which is perhaps easier to collect with mechanical extraction. In fact, better milkability may favour the release of the residual milk in the udder, which is known to be richer in fat compared with the cisternal milk.

4. Conclusions

We believe that this is the first study to provide information on udder and teat measurements in Amiata jennies reared for milk production and on the relationship between udder morphology and productive traits. Our results suggest that larger animals tend to have larger udders, a higher teat diameter, and a greater distance between teat tips. However, our results do not confirm that milk production in jennies is related to body weight since neither the weight nor the somatic measurements were directly correlated with the milk quantity. Although the relationship between udder measurements and milk quality needs to be clarified further, longer teats seem to be linked to better milk fat extraction. The results of this paper may be useful to help define the specific characteristics of the milking device and address selective choices of the animals.

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Data availability

The datasets generated during and (or) analysed during the current study are available from the corresponding author on reasonable request.

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Methodology: FS, CB
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Writing – original draft: FS, IA, CB, MM
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