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Experimental milking tests on Murgese mares for the design of *ad hoc* milking plants

F. Bellomo, B. Bianchi & F.P. D'Emilio

Summary

The results about a scientific research regarding milking of mares of Murgese breed are related in the present work. The developed pregramme had the aim to compare hand and mechanical milking with two pulsation rates (120 and 140 cycles/min) and to define dimensional standards, mechanical and operative solutions, to design and/or to conform machine milking of mares with special reference to Murgese breed. The study was carried out on 4 multiparous mares, after a suitable adaptation period. The trial lasted 45 days, and during this period the animals were milked twice a day. The research showed a considerable advantage, both from a productive and a technical-operative point of view, to milk this species with mechanical plants, instead of by hand. Moreover, mechanical milking at 140 cycles/min, was the better conditions than those examined, because it's possible to obtain the best productions of milk, the smallest specific power consumptions, and moreover the greatest working capacities and labour productivity. The standard of adaptation of the observed animals to the mechanical milking and their obtained productions, can be considered adequate; yet, with the present study, some mechanical and operative solutions are defined to project plants and to fit in secirity those existing

Keywords

Mares - Milking - Milking plants.

Introduction

Previous trials on mechanical and hand milking of mares have shown that mares weighing 500-600 kg, and milked 6 times per day, produce 8-18 kg/24h of milk per day (4); lactation usually lasts 5 to 7 months, but cases where it extends over 10 to 11 months are reported (5). From the mechanical point of view, in the experimental trials carried out so far, the following plant engineering parameters have been adopted:

- vacuum levels ranging from 37 (9) to 53 kPa (2);
- pulsation ratios of about 50% (10);
- pulsation rate variable from 60 to (10) 180 cycles/min (3);
- brass-plated teat cups (14), silicone liners (10), internal diameters of the order of 19.0 mm (10).

However, the studies carried out so far on mares have basically considered animal husbandry and veterinary aspects (6, 8, 13, 14) and no exhaustive scientific results on the comparison between the said mechanical milking parameters have been published. Some authors refer to pulsation rate as one of the main factors that affect milk yield in mechanically milked mares, specifying that with 120 cycles/min a more complete extraction of alveolar milk and higher yields than at lower pulsation rates are obtained (10); but, such results refer to old trials carried out on horse breeds not present in our country (10).

This paper reports the results of hand and mechanical milking trials on Murgese mares in order to define some mechanical and plant engineering parameters, as well as technical-operational solutions that allow full extraction of

PROGESA Dept., University of Bari - Italy

milk, the adaptation of milking plants designed for other animals to the anatomical-physiological characteristics of the udder, the design of ad hoc plants, and milking procedure on the farm under safety conditions.

Materials and methods

The scientific research was carried out on 4 clinically healthy Murgese mares, weighing from 500 to 600 kg, between the third and the tenth week of lactation; the year before, the same mares, hand milked over the same period of time, had produced 8.0-10.0 kg/24h of milk. Mares and their fouls were allowed to pasture the whole day freely on uncultivated land feeding on wild flora and having free access to water trough.

The investigated milking methodologies were:

- hand milking,
- mechanical milking at 120 cycles/min,
- mechanical milking at 140 cycles/min.

The trial totally lasted 45 days, after a short adaptation period of about 20 days. During this period, for three days per week, the mares were milked every day using one of the three investigated methodologies, with 2 milkings per day every 3 hours (at 10.00 a.m. and at 1.00 p.m.). The latter value was fixed on the basis of the results from previous research works (9).

Two hours before sampling, mares and their foals were taken from pasture, then parted and led to a stable consisting of two parallel rows of cubicles separated by a 3 m large feed alley (Figure 1). Foals stayed in the feed alley, whereas individual mares were placed in the cubicles.

The mares routinely received about 300 g of concentrate (10).

The milking unit included (Figure 1): a tubular box (0,9 m x 3,0 m) (Figure 2a), an electrical control and regulation board (Figure 2b), the teat cup cluster, a milking pail and a milk technical scale (± 0.001 g). The vacuum pump and the other components of the plant were located in the next room to prevent any acoustic shock to animals while waiting and upon milking (Figure 1).

The tubular box (Figure 1) was designed: to limit the movements of the mares, to allow easy handling of the milking cluster and encourage the foal to approach, though without reaching the udder (Figure 2a).

In mechanical milking, a plant for sheep and goats as well as adequately designed teat cup clusters were used (Tables I and II, Figures 2c and 2d). A working vacuum of 42 kPa and a pulsation ratio of 50% were established (Table I).

Milking was performed with no drug administration. The following parameters were measured:

- waiting time for the first let-down of milk (s);
- amount of milk at the end of milking (g);
- milking time (s);
- amount of residual milk (g);
- stripping time (s);
- labour productivity (h-worker/kgmilk);
- working capacity (mare/h);
- teat cup falling-off frequency (no. falling-off/h);
- power consumption (Wh).

Power consumption was determined by measuring the effectively used electrical power, through a watt-hour meter exclusively connected to the

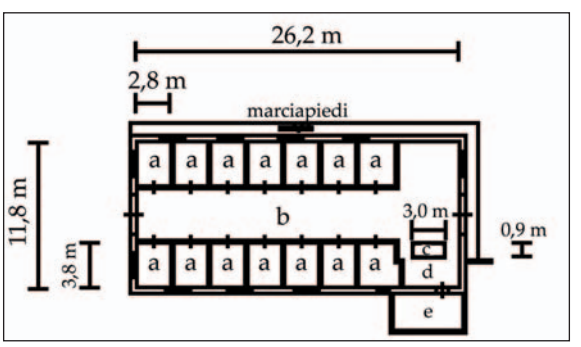


Figure 1
Schematic plan of the breedig modulus: a) cubicles, b) feed alley, c) tubular box, d) milking unit, e) room of accomodation of the plant

Table I
Main characteristics of milking plant object of the experimental trials

Type of plant	Fixed milking buckett
Working vacuum	42.0 kPa
Pulsation ratio	50%
Vacuum pump	Q = 1,150.0 dm^3/min n = 1,370.0 giri/min Motor: P = 1.5 kW Displacement: 350.0 dm^3
Vacuum tube	Material: zinc steel Inside diameter= 25.4 mm
Pulsators	Model: LP 20 electronic
Liners	Material: rubber food
Short milk tubes	Material: rubber food Inside diametee = 8.0 mm; Length = 300.0 mm
Long milk tubes	Material: rubber food Inside diameter = 16.0 mm Length = 1400.0 mm
Vacuum regulator	Type: servohelped

plant.

The operators who performed milking after washing and massaging the udder were always the same: 1 operator to position the mare, 1 milker. Prior to each extraction, on each milked mare, the following was performed: massage of the udder, cleaning of the teats and of the sphincter with a cloth impregnated with chlorexidine.

Results

The analysis of the let-down time shows that when using hand milking methodology (Table III), the waiting time until the flow lets down in the udder upon the first milking is by at least 5% higher than upon the second milking. In the two other investigated methodologies, the let-down time for the first milking was always smaller than at the following milking; for instance, in the mare no. 4, upon the second milking, the average value of this parameter was by 27-29% greater than the first milking for both the investigated pulsation rates (Tables IV and V). As compared with the average total time to complete the operation (Figure 3), the average let-down time (Tables III, IV and V) corresponds to 2.8-26.7%, depending on the considered mare, and lower values not exceeding 10.0 s correspond to milking at 140 cycles/min.

Moving to the following milking, the average mechanical milking time at 120 cycles/min varies from 51.5-77.5 s to 60.8-94.8 s, with an increase of at least 9.3 s in each mare (Table IV); when milking at 140 cycles/min, the same average values are quite similar to each other and increase from 39.3-46.3 s, at 10.00 a.m., to 49.0-56.8 s, at 1.00 p.m. with a rise of at least 6.0 s for each mare (Table V). With hand milking, the milking time for each mare follows a decreasing pattern as compared with the previous releases (Table III) and the increase in the average total milking time is negligible (Figure 3).

In hand milking the stripping time is always equal to zero (Table III), the same as the milk yield at this phase. In mechanical milking of some mares (no. 3 and no. 4 in Tables IV and V), the stripping time is different from zero and varies from 4.2 s to 8.8 s; it tends to decrease with increasing milking frequency; in the latter cases, the milk yield at the stripping phase is not very high: not exceeding 1% of total milk for the mare no. 4 and no more than 2.5% for the mare no. 3 (Tables IV and V).

At the second milking, the production of each investigated mare tends to increase: by 20 - 103% with hand milking (Table III), by 23 – 29 % with mechanical milking at 120 cycles/min (Table IV), by 14 - 22 % with mechanical milking at 140 cycles/min (Table V).

The time to accomplish the whole operation reduces by more than 65% when moving from hand milking to mechanical milking at higher frequency. In fact, we move from a total average value of about 183.0 s, that characterizes hand milking at both hours without remarkable variations, to an average value for milking at 140 cycles/min that is about 50.8 s

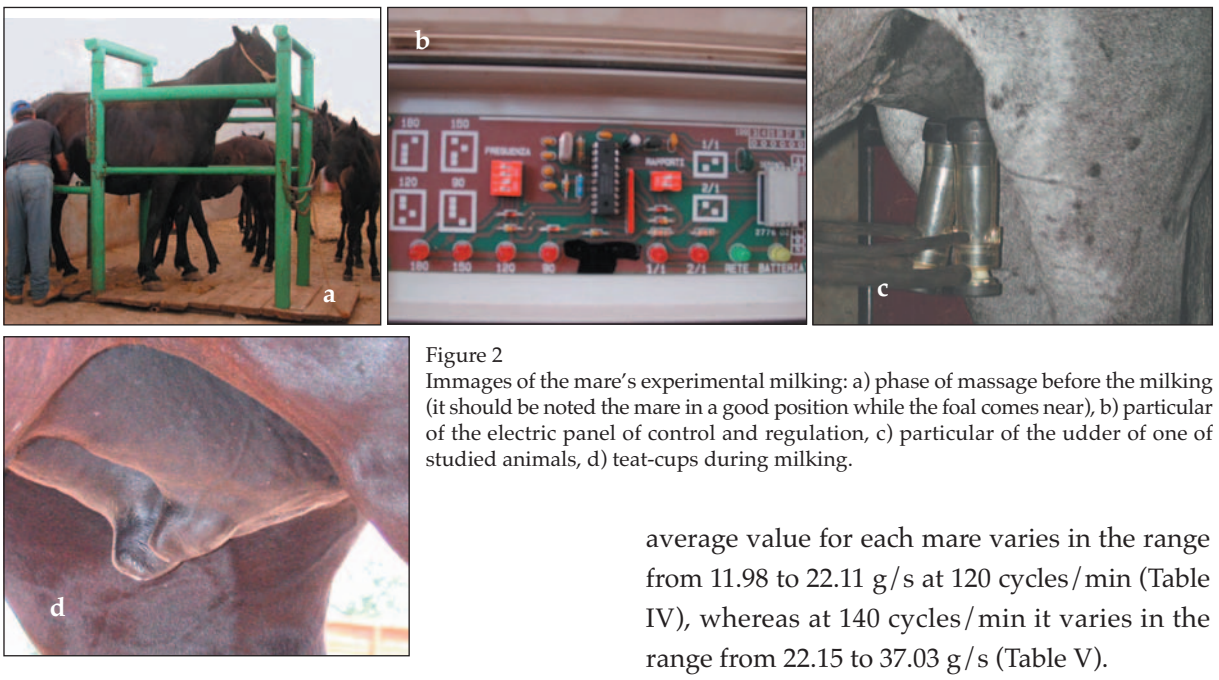


Figure 2
Immages of the mare's experimental milking: a) phase of massage before the milking (it should be noted the mare in a good position while the foal comes near), b) particular of the electric panel of control and regulation, c) particular of the udder of one of studied animals, d) teat-cups during milking.

at 10.00 a.m., and 61.0 s. at 1.00 p.m. (Figure 3). Milking at 120 cycles/min is always much shorter than hand milking but, as compared with milking at 140 cycles/min, its average duration is by 50-53 % longer, both for the measurements at 10.00 a.m. and for those at 1.00 p.m. (Figure 3).

At both rates, total average milk yields are greater than with hand milking (Figure 4). In particular, for each mare, milk yield varies from 333.5 g to 1,156.0 g for hand milking (Table III) and from 923.17 g to 1,778.67 g for mechanical milking (Tables IV and V); out of the latter, the highest values correspond to the milking performed at 140 cycles/min giving an average total yield by 35% greater in the trials at 10.00 a.m. and by 27 % in those at 1.00 p.m., as compared with the average yield of milking at 120 cycles/min (Figure 4).

At higher pulsation rate milking, milk yield from all the milked mares tends to take values increasingly greater than 1,000.0 g/milking, contrary to the other investigated methodologies by which such values are not always obtained.

When the milking pulsation rate increases, an increase in the milk flow is also recorded, and its average value for each mare varies in the range from 11.98 to 22.11 g/s at 120 cycles/min (Table IV), whereas at 140 cycles/min it varies in the range from 22.15 to 37.03 g/s (Table V).

The working capacity increases from an average value of 0.9 mares/h with hand milking, to 2.0 mares/h with milking at 120 cycles/min and 2.8 mares/h for the one at 140 cycles/min; similarly, with mechanical milking, labour productivity considerably increases and ranges from 0.056 h-worker/kgmilk, for hand milking, to 0.019 h-worker/kgmilk with lower pulsation rates milking and to 0.010 h-worker/kg milk with milking at higher pulsation rate (Table VI).

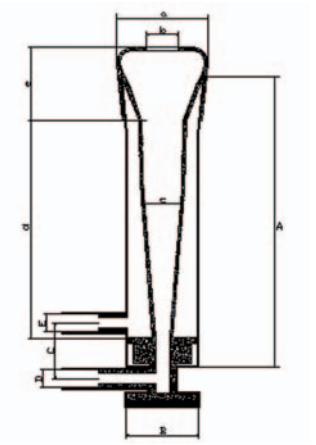
When the plant works at 140 cycles/min, an average power use of 9,7 Wh is recorded and it further reduces depending on the amount of milk released: 6,8 Wh/kgmilk. Whereas, at the rate of 120 cycles/min, power consumption per mare is greater, the power used to obtain 1 kg of milk is even greater because at 120 cycles/min less milk is released: 14,3 Wh and 13,0 Wh/kgmilk (Table 4).

Finally, in all the measurements performed, no falling-off of the teat cup cluster occurred during mechanical milking (Tables IV and V).

Discussion

The increase in yield at the second milking could

Table II
Main sizes of the teats of the milked animals and schematic description of the prototipe of designed shell and liner ad hoc designed for mare's milking

Teats characteristics*		Shells characteristics	Liners characteristics
Length = 40.0 mm		A = 140.0 mm	a = 49.0 mm
Diameter (connection with the udder) = 31.8 mm		B = 36.0 mm	b = 18.0 mm
Circumference (connection with the udder) = 100.0 mm		C = 34.0 mm	c = 20.0 mm
Gap from trampling plane = 800.0 mm		D = 8.0 mm	d = 110.0 mm
		E = 5.0 mm	e = 30.0 mm
		Total mass = 362.5 g	

** Middle values of no. 10 measures carried out on 15 animals of Murgese breed during lactation*

be due to different physiological reasons, the evaluation of which goes beyond the scope of the present research and would require an ad hoc study. However, operationally speaking, in agreement with what is reported in the literature (7, 15), it is observed that also for the mares of the investigated breed (Murgese), a milking schedule with at least two daily releases could give maximum yield. Such schedule has also to envisage the absence of the foal in the time period between milkings, as well as its approaching to the mare only during the milk release phase.

The results of the experimental trials highlight that mechanical milking with the investigated mares is highly profitable; as compared with hand milking, it allows shortening all the phases considerably, thus improving total yield and the operational capacity (Tables III, IV, V and VI, Figures 3 and 4).

The first constraint of hand milking is longer duration, which is due to very high excess time; this basically derives from the difficulties of the staff in managing the mare and the foal upon milking. In fact, as compared with the use of the teat cups, both mares and fouls perceive the milk extraction phase more promptly. This causes anxiety to both the foal and the mare.

As from the above, the average time relative to the first and the second hand milking is comparable (Figure 3), independently of the yield obtained that tends to increase at the subsequent extraction (Figure 4). On the contrary, in mechanical milking, the yields relative to the two daily-investigated extractions are more uniform, especially at 140 cycles/min; moreover, the duration tends to increase if the amount of extracted milk increases too. Consequently, the working capacity considerably increases and it is the highest at the higher pulsation rate (Table VI).

With milking at 140 cycles/min, milk release time values for each mare (Table V) are the shortest and, yield being equal, they are also comparable to each other and this indicate that, if pulsation rate increases, excess time reduces and the experimentally obtained values can be considered to be representative of the actual duration of the

operation (Figure 3).
Through processing these results, we can define the plant engineering and sizing criteria for the design of mechanical milking plants for mares with special reference to the Murgese breed.
To perform the whole operation employing two workers, we should consider not exceeding around 90.0 s, the major portion of which, not greater than 78.0 s, for the extraction phase. The time for the flow to be established decreases with the pulsation rate and doesn't exceed 16.0 s. Finally, the study of yields and stripping time values highlights that for this breed, milking could be stopped as the milk flows stops, without further waiting; we may prolong again for 10.0 seconds to recover a portion of milk but in our trials this residual milk was, on average, rather small.

In addition to the said milking time, one should add the time for lodging the mare and allow it to get out of the box. It is of the order of 120.0 s and amounts to a total time of 120.0 s per animal.
The 140 cycles/min rate results to be an optimal operational condition among those studied, considering that it gives the highest yields, the least power consumption as well as the highest operational capacity and labour productivity. This data is quite in agreement with the results of similar research works carried out by other authors on mares of other breeds that show better plant performance at high pulsation rates (10).
The obtained values of the working capacity and labour productivity are rather low (Table VI), since they are negatively affected by causes related to inadequate training of the staff especially mre

Tabella III
Results of the trials of hand milking, regarding each studied animal (middle values of no. 7 measures for mare and time each)

Measured parameters	Animal	Milking hour 10,00 a.m.	_	Milking hour 13,00 a.m.	_
Waiting time for the first let-down of milk (s)	1	16.2	1.47	12.7	1.21
	2	49.0	4.69	41.8	3.71
	3	6.3	0.52	5.3	0.52
	4	6.5	0.55	6.2	0.41
Amount of milk (g)	1	559.00	23.00	1,136.33	112.90
	2	333.50	31.85	444.00	31.81
	3	828.17	81.39	993.00	87.54
	4	833.33	51.86	1,156.00	85.43
Milking time (s)	1	191.7	18.62	185.8	18.28
	2	247.5	23.61	240.8	23.54
	3	96.7	9.29	119.7	11.52
	4	118.3	8.16	120.8	10.68
Amount of residual milking (g)	1	0.0	0.0	0.0	0.0
	2	0.0	0.0	0.0	0.0
	3	0.0	0.0	0.0	0.0
	4	0.0	0.0	0.0	0.0
Dripping time (s)	1	0.0	0.0	0.0	0.0
	2	0.0	0.0	0.0	0.0
	3	0.0	0.0	0.0	0.0
	4	0.0	0.0	0.0	0.0
Average flow of milk (g/s)	1	2.94	0.29	6.13	0.47
	2	1.35	0.09	1.85	0.18
	3	8.59	0.69	8.33	0.66
	4	7.07	0.70	9.61	0.89

milking, as well as inevitable plant engineering and construction constraints. Through ad hoc design, adequate training of the staff and training of mares, milking and handling operations could be performed by a single worker thus considerably improving the said parameters that in our study refer to two workers.

The sizing of the milk circuit has to be made by referring to a maximum flow of 40.0 g/s downstream from the teat cups. The yield of each investigated animal was rather limited, although basically in agreement with the data reported in the literature (10); the maximum amounts of milk didn't exceed 1,800.0 g/milking, under the best operational conditions.

On the other hand, one should consider that lactating mares have to be milked several times on the space of one day and that subsequent milkings can be quite closely spaced; therefore, the sizing of the milk cooling tanks has to be made in relation to the maximum number of extractions planned in the farm milking schedule. To calculate the electrical power requirements we may consider a prudential value of 0.5 kW/mare, to be adequately integrated with the share of power for sizing the milk cooling tanks (1, 11).

Table IV
Results of the trials of mechanical milking at 120 cycles/min, regarding each studied animal (middle values of no. 7 measures for mare and time each)

Measured parameters	Animal	Milking hour 10,00 a.m.	_	Milking hour 13,00 a.m.	_
Waiting time for the first let-down of milk (s)	1	6.3	0.52	7.7	0.52
	2	6.3	0.52	7.7	0.52
	3	11.5	1.05	13.8	1.17
	4	12.8	1.17	16.5	1.38
Amount of milk (g)	1	1,089.50	92.31	1,337.50	97.64
	2	923.17	41.34	1,141.50	109.45
	3	1,013.83	71.41	1,285.83	121.26
	4	830.50	76.83	1,068.33	89.69
Milking time (s)	1	51.5	4.42	60.8	5.56
	2	77.5	7.58	94.8	7.96
	3	68.0	6.32	85.2	7.33
	4	59.2	4.79	71.8	6.11
Amount of residual milking (g)	1	0.00	0.00	0.00	0.00
	2	0.00	0.00	0.00	0.00
	3	25.17	2.32	29.67	2.94
	4	6.33	0.52	7.00	0.63
Dripping time (s)	1	0.0	0.00	0.0	0.00
	2	0.0	0.00	0.0	0.00
	3	7.0	0.63	8.8	0.75
	4	6.2	0.41	6.5	0.55
Average flow of milk (g/s)	1	21.24	1.98	22.11	2.20
	2	11.98	0.91	12.06	1.03
	3	15.35	1.18	15.45	0.52
	4	14.19	1.30	15.03	1.44
Teatcup falling-off frequency (no. falling-off/milking)	1	0.00	0.00	0.00	0.00
	2	0.00	0.00	0.00	0.00
	3	0.00	0.00	0.00	0.00
	4	0.00	0.00	0.00	0.00

The sizing criteria defined for manufacturing the liners and the shells used in the experimentation (Table II), were adequate to obtain a good adaptation of the teat cup cluster to the morphology of the udder, since no falling-off occurred, not even during the operational phases and on mares with reduced milk flow. Referring to the Murgese breed in particular, the following can be defined:

- a total length of the liner of 140.0 mm, 30.0 mm of which for the mouthpiece;
- an internal diameter at the mouthpiece of 18.0 mm;
- an internal diameter of 20.0 mm of the barrel of the liner, measured at 75.0 mm from the mouthpiece;
- a total mass of the teat cup cluster of 725.0 g.

The box for milking the mare can be in metal pipes but at the connection points adequate solutions should be envisaged to allow the animal to go in and out without shocks that would compromise subsequent milkings. As for the Murgese breed, the transversal side should not exceed 0.9 m and the longitudinal side 3.0 m; the vertical components can reach a height of 2.5 m, along which two longitudinal braces should be inserted but such not to hamper the teat cup cluster handling, considering that the teats of the mare are at about 0.8 m above the mare standing level (Table II).

Table V
Results of the trials of mechanical milking at 140 cycles/min, regarding each studied animal (middle values of no. 7 measures for mare and time each)

Measured parameters	Animal	Milking hour 10.00 a.m.	_	Milking hour 13.00 a.m.	_
Waiting time for the first let-down of milk (s)	1	6.5	0.55	8.2	0.75
	2	4.2	0.41	4.8	0.41
	3	4.8	0.41	5.7	0.52
	4	4.2	0.41	5.3	0.52
Amount of milk (g)	1	1,452.67	119.09	1,775.00	151.28
	2	1,023.17	69.76	1,178.67	93.51
	3	1,550.00	121.45	1,764.50	173.90
	4	1,218.00	118.30	1,439.83	128.22
Milking time (s)	1	39.3	3.20	51.3	4.55
	2	46.3	4.13	52.3	4.59
	3	45.8	4.17	56.8	3.13
	4	40.8	1.72	49.0	2.19
Amount of residual milking (g)	1	0.00	0.00	0.00	0.00
	2	0.00	0.00	0.00	0.00
	3	15.00	1.10	18.00	1.67
	4	6.33	0.52	8.67	0.82
Dripping time (s)	1	0.0	0.00	0.0	0.00
	2	0.0	0.00	0.0	0.00
	3	5.2	0.41	4.2	0.41
	4	6.2	0.41	6.5	0.55
Average flow of milk (g/s)	1	37.03	2.97	34.68	2.88
	2	22.15	1.36	22.60	1.94
	3	34.22	1.89	31.38	2.73
	4	30.01	2.86	29.60	2.85
Teat cup falling-off frequency (no. falling-off/milking)	1	0.00	0.00	0.00	0.00
	2	0.00	0.00	0.00	0.00
	3	0.00	0.00	0.00	0.00
	4	0.00	0.00	0.00	0.00

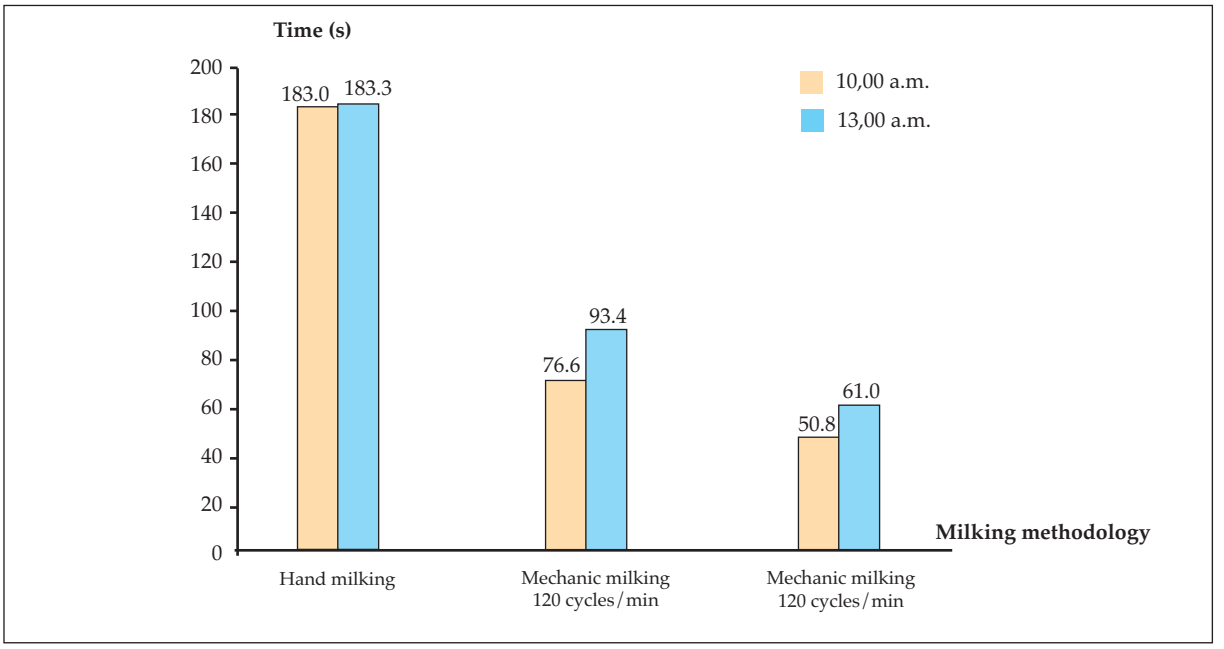


Figure 3
Total middle values (no. 28 measures for each time) of the time, including the first let down and stripping time

Based on the above-said criteria, if adequately trained, the mare of the investigated breed can be easily positioned and milked, without making movements that may cause the teat cup cluster to fall off or any risk to the milkers. One should keep in mind that the training phase of the animals can be relatively long, depending on the breed and the mares to be milked; in view of that, one should not neglect the solution with a bucket or direct-to-can milking machines: for mares being milked at the stall. In the latter two cases, however, the mares to be milked can move more freely and this would not allow positioning them optimally: consequently, the operational capacity might be lower. The above said sizing criteria and plant solutions can be considered to be appropriate both for adaptation measures and for the design of ad hoc mare milking plants, with special reference to Murgese breed. The subsequent step of this study would be to check the results obtained in terms of plant engineering with respect to sanitary considerations.

Table VI
Operative performances and consumption of electrical power (calculated values or middle values of no. 56 measures)

Mechanical-operative valuations	Mechanical milking 120 cycles/min	_	Mechanical milking 140 ciycles/min	_	Hand milking
Working capacity (mare/h)	2.0	/	2.8	/	0.9
Labour productuvuty (h-worker/kg_{milk})	0.019	/	0.010	/	0.056
Power consumption (Wh)	14.3	0.21	9.7	0.13	/
Specific power consumption (Wh/kg_{milk})	13.0	/	6.8	/	/

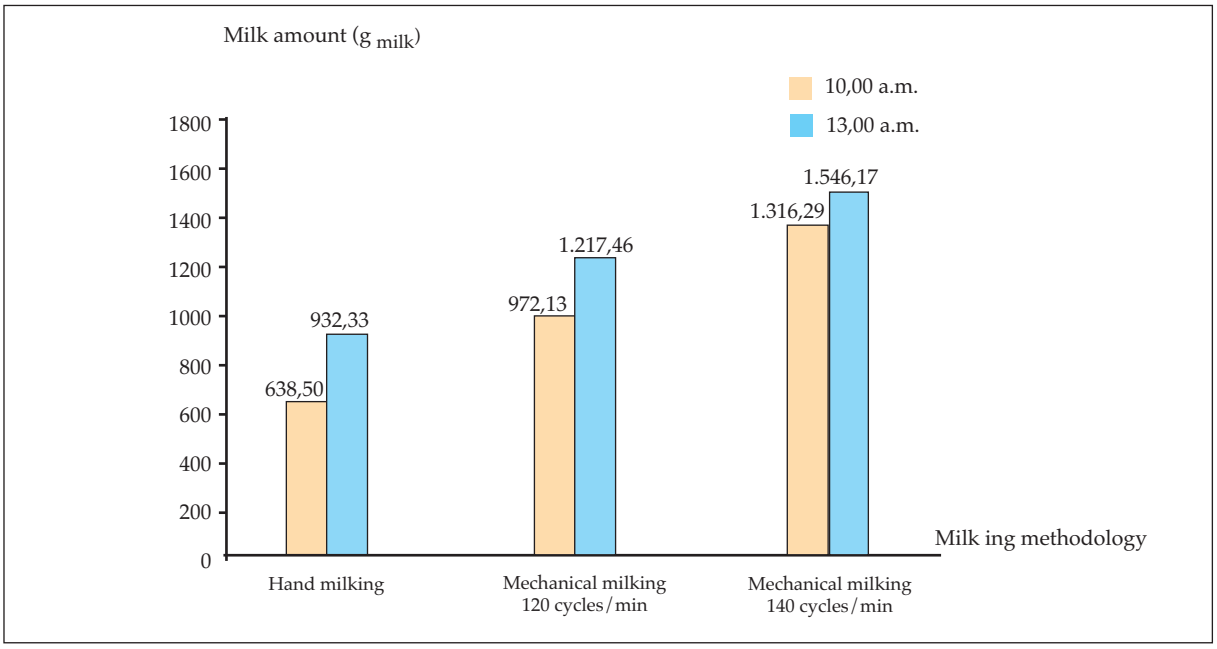


Figure 4
Total middle values (no. 28 measures for each time) of the milk amounts, including the portions of first let down and residual milk

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