**Effect of vacuum level on milk flow traits in Mediterranean Italian buffalo**

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**Abstract**

The aim of this study was to determine the effects of six different working vacuum levels (range 37-52 kPa) on the milk production, milk flow rate and milking times of Mediterranean Italian buffalo. A total of 801 milk flow curves of 450 animals of different parity and at different stages of lactation were recorded at random by electronic milk flow meters (Lactocorder®) over a period of 12 weeks. The vacuum level did not significantly affect the individual milk production per milking (average 4.02±0.06 kg). Lower vacuum level resulted in a decrease in average and peak flow rate (P<0.001), and an increase in effective milking time between attaching the teat cup and reaching the value of 0.20 kg/min at the end of milking (P<0.001). Vacuum levels of 37 and 40 kPa provided good milkability conditions, in which the plateau phase was longer than the decline phase while lag time was not affected by vacuum level.

**Introduction**

Milkability is an important factor which affects milking time, labour efficiency and udder health. The milk let down is influenced by anatomical, physiological, sanitary and environmental factors. Many studies carried out in different countries have shown that buffalo are difficult to milk because there is a delay in milk ejection. The udder anatomy and the internal arrangement of the mammary tissue, cisternal fraction of milk and teat canal length are quite different in buffaloes compared to dairy cattle (Thomas et al., 2004). Although each animal has its own anatomical and physiological characteristics, the setting factors characterizing the milking machine and the variations in vacuum level may improve milk flow and milking machine times. The buffalo is often exposed to a long period of vacuum without any ejection of milk (Caria et al., 2011). A vacuum of up to 45 kPa in buffalo is generally ineffective unless alveolar milk ejection has occurred (Ambord et al., 2009). Teat stimulation before milking is important to start milking ejection and to reduce lag time (Thomas et al., 2005). The use of high-working vacuums combined with the absence of milk can cause irritation in the delicate mammary tissues and, thus, discomfort to the animals (Bruckmaier and Blum, 1996). A positive relationship between increasing working vacuum and the milk somatic cell counts (SCC) has been found in buffalo (Badran, 1992; Pazzona and Murgia, 1992). High SCC reduce buffalo milk production and quality because of the negative effect on milk and lactose (Cerón-Muñoz et al., 2002), as already described in cows (Galton and Mahle, 1980; Langlois et al., 1980; Osteras and Lund, 1988) where increasing vacuum levels negatively affected the teat condition and increased the incidence of mastitis. By contrast, a longer milking time and a higher number of teat cups falling off are the principal negative factors caused by lowering the milking vacuum level (Spencer and Rogers, 1991). As for the milking vacuum, higher values of pulsation rate and ratio increases both milk flow rate and somatic cell counts (Dogra et al., 2000; Badran, 1992). Efficiency of milking is influenced by the characteristics of the milking cluster (weight, mouthpiece liner diameter) (Pazzona, 1989). Although many studies have dealt with changes in milking vacuum level for cows, sheep and goats, there is little literature concerning buffalo. Thomas (2004) reported studies conducted in different parts of the world in which the vacuum level varies in the range of 43-68 kPa for buffalo. In Italy, the most used vacuum levels are 44-46 kPa (range 40-53 kPa) (Caria et al., 2011). In order to define the optimal milking vacuum level, it is important to record and measure the milk flow profile to study the response of the animals to the milking conditions. An understanding of this can help improve the work efficiency.

The aim of this study was to determine the influence of different vacuum levels (range 37-52 kPa) on the milking of buffalo through the evaluation of milk flow curve (milk flow rate and time of milking), and to evaluate the suitability of a low vacuum level to milk the Mediterranean Italian buffalo.

**Materials and methods**

The study was carried out in a buffalo dairy farm located in Pontinia (Lazio, Italy) over a period of 12 weeks. A total of 450 Mediterranean Italian buffalo of different parity and at different stages of lactation were milked in a 2±28parallel milking parlor with a low level milking system (DeLaval, Tumba, Sweden). The milking unit (Harmony Plus, DeLaval) weighed 1.80 kg, the conic rubber liners had a diameter of mouthpiece lip of 20 mm, the claw had a volume of 450 mL, the diameter of the short milk tube was 12.5 mm and that of the long milk tube 16 mm. The unit was set at a 60 cycles/min pulsator rate and 65% pulsator ratio. During the experiment, six milking vacuum levels (37, 40, 43, 46, 49 and 52 kPa) were tested, each for a period of two weeks. Milk flow curves were recorded at random from all of the animals in lactation during the evening milking session using 3 electronic mobile milk flow meters (LactoCorder®), WMB, Balgach, Switzerland as used in previous studies (Bava et al., 2007; Bava and Zucalli, 2007; Borghese et al., 2007; Ambord et al., 2009; Caria et al., 2011). Before milking, teats were cleaned with tap water and subsequently dried with towels; the milking cluster was then applied after approximately 60 sec. During milking sessions the animals were not fed with any concentrates.
Variables measured per each milking were: 
MY (kg) total milk yield per head from the beginning to the end of the milking; LT (min) lag time from the beginning of measurement until a 0.50 kg/min threshold in the milk flow was reached; MET (min) milk ejection time from the beginning of milking until a 0.20 kg/min at the end of milking; 2MY (kg) milk yield from the beginning of measurement to completion of 2 min measuring time; 3MY (kg) milk yield from the beginning of measurement to completion of 3 min measuring time; MMY (kg) main milk yield emptied in the milk ejection time (MET); PFR (kg/min) peak flow rate in the main milking process within a time interval of 8 measuring points (22.4 sec); IPT (min) time of incline phase from the start of milking from >0.50 kg/min of flow to the start of plateau phase; PPT (min) the time of plateau phase from the start of plateau phase to the vertex of the incline phase to the vertex of the decline phase; DPT (min) time of decline phase, a period of milk flow from end of plateau phase to flow rate <0.20 kg/min at the end of milking.

A total of 801 individual milk flow curves were recorded. All data are presented as arithmetic mean values and standard error of the mean (SEM). Parameters measured were compared by ANOVA using SPSS software (ver. 13.0, SPSS, Inc., Chicago, IL, USA).

Differences in means were localized by Bonferroni’s t-test in order to classify the effect of the different vacuum levels. P<0.05 was considered significant.

### Results and discussion

The effects of different vacuum levels on the milk flow curve parameters are shown in Tables 1 and 2. The average milk yield (MY) of 801 milk curves obtained during our tests (4.02±0.06 kg/milking) agree with data recorded in previous studies (Bava and Zucali, 2007; Borghese et al., 2007; Caria et al., 2011) (Table 1). There was no significant variation in milk yield during the experiment, confirming that all vacuum levels allowed udders to be completely emptied. An increase in vacuum level produced a significant increase in milk yield at the beginning of milking, i.e. at 2 and 3 min (2MY; 3MY). In fact, 2MY represented 37.3% of the total milk extracted at 37 kPa. This rose to 51.1% at 46 kPa and 60.9% at 52 kPa. Similar considerations can be made for 3MY which showed a constant increase from 53.7 to 81.0% of MY when the vacuum level rose from 37 kPa to 52 kPa. In contrast, main milk yield (MMY), representing milk yield during milk ejection time (MET), was not significantly influenced by the vacuum level, being an average 87.6% of MY.

The vacuum level affected both average (AFR) and peak (PFR) flow rate (P<0.001). The comparison between 37 and 52 kPa showed an increase in AFR of 24.0% (0.75 vs 0.93 kg/min) and an increase in PFR of 24.8% (1.13 vs 1.41 kg/min). AFR and PFR values obtained at a vacuum level of 45 kPa reported by Borghese et al. (2007) (0.77 kg/min and 1.22 kg/min, respectively) and Boselli et al. (2010) (0.79 kg/min and 1.13 kg/min, respectively) are consistent with the values obtained in this study at vacuum levels of 37 and 40 kPa (AFR 0.75-0.82 kg/min and PFR 1.13-1.22 kg/min, respectively).

Variation in milking times at different vacuum levels is shown in Table 2. The effective milking time (EMT) decreased by 26.4% when passing from 37 kPa to 52 kPa (7.76 vs 5.71 min; P<0.001). This confirms that, as reported for dairy cows (Reinemann et al., 2001), the milking time increases as the working vacuum is reduced. The greatest variations in EMT were recorded from 37 to 40 kPa (-36.6 s), while smaller variations were recorded from 49 to 52 kPa (-7.4 sec). By separating lag time (LT) and milk ejection time (MET) from the EMT, we can identify which of the two phases was most influenced by the vacuum level. While MET increased as the working vacuum

### Table 1. Milk production and milk flow rate per buffalo (mean±SEM) at different vacuum levels.

| Parameter | 37 | 40 | 43 | 46 | 49 | 52 | Total |
|-----------|----|----|----|----|----|----|-------|
| MY, kg    | 4.21±0.16 | 4.30±0.16 | 4.10±0.16 | 3.95±0.15 | 3.80±0.13 | 3.72±0.11 | 4.02±0.06 | 0.106 |
| 2MY, kg   | 1.57±0.44 | 1.79±0.44 | 1.57±0.44 | 2.02±0.44 | 2.12±0.44 | 2.27±0.44 | 2.04±0.36 | 0.001 |
| 3MY, kg   | 2.26±0.06 | 2.56±0.06 | 2.58±0.06 | 2.71±0.06 | 2.81±0.06 | 3.02±0.06 | 2.65±0.04 | 0.001 |
| MMY, kg   | 3.72±0.17 | 3.75±0.17 | 3.56±0.17 | 3.45±0.17 | 3.28±0.17 | 3.33±0.17 | 3.52±0.06 | 0.135 |
| AFR, kg/min | 0.75±0.02 | 0.82±0.02 | 0.84±0.02 | 0.88±0.02 | 0.91±0.02 | 0.93±0.02 | 0.85±0.01 | <0.001 |
| PFR, kg/min | 1.13±0.04 | 1.22±0.04 | 1.31±0.04 | 1.40±0.04 | 1.41±0.04 | 1.41±0.04 | 1.31±0.02 | <0.001 |

### Table 2. Milking times per buffalo (mean±SEM) at different vacuum levels.

| Parameter | 37 | 40 | 43 | 46 | 49 | 52 | Total |
|-----------|----|----|----|----|----|----|-------|
| EMT, min  | 7.76±0.24 | 7.15±0.24 | 6.75±0.23 | 6.39±0.22 | 6.00±0.18 | 5.71±0.15 | 6.64±0.09 | <0.001 |
| LT, min   | 2.76±0.21 | 2.50±0.21 | 2.40±0.18 | 2.39±0.20 | 2.33±0.18 | 2.13±0.12 | 2.42±0.08 | 0.275 |
| MET, min  | 5.00±0.18 | 4.64±0.17 | 4.34±0.17 | 4.00±0.17 | 3.66±0.12 | 3.58±0.11 | 4.22±0.07 | <0.001 |
| IPT, min  | 0.23±0.03 | 0.30±0.03 | 0.38±0.05 | 0.33±0.03 | 0.37±0.04 | 0.31±0.04 | 0.32±0.02 | 0.079 |
| PPT, min  | 2.41±0.13 | 2.23±0.12 | 1.91±0.13 | 1.67±0.11 | 1.58±0.10 | 1.59±0.08 | 1.91±0.05 | <0.001 |
| DPT, min  | 2.35±0.17 | 2.11±0.15 | 2.04±0.13 | 2.00±0.14 | 1.71±0.10 | 1.67±0.08 | 1.99±0.05 | <0.001 |

N 801 for each parameter considered. M, total milk yield; 2MY, milk yield in the first two measuring minutes; 3MY, milk yield in the first three measuring minutes; MMY, main milk yield; AFR, average milk flow rate; PFR, peak flow rate. *Means within a row with different letters are significantly different (P<0.05).
was reduced, vacuum level did not influence LT. This could be explained by the anatomy of buffalo’s teat where the canal closure is quite tight and requires a tactile stimulation to be opened, rather than by the vacuum applied (Ambord et al., 2010). These results are in contrast to the findings of Caria et al. (2011) who reported that a difference in vacuum level between 36 and 42 kPa did not influence MET (P=0.138) while it did affect LT (P=0.049).

Analysis of the three main phases (incline, plateau and decline phase) provided by Lactocorder® to describe the highest part of the milk flow curve provides an additional tool in the evaluation of individual milk emission profiles. Average incline phase (IPT) was 0.32±0.02 min and no difference was seen between all the vacuum levels tested (P=0.079). The duration of the plateau phase (PPT), that is generally influenced by the different distribution of milk among the quarters and the udder health status, can be shortened by an irregular milk ejection or vacuum instability. In this study PPT decreased linearly with an increase in vacuum level (P<0.001), similar to results reported for cow milking (Ambord and Bruckmaier, 2010), and also in proportion to a reduction in MET from 48.2% at 37 kPa to 44.4% at 52 kPa. The highest values obtained (2.41 and 2.23 min) were recorded at 37 and 40 kPa, respectively. When using lower vacuum levels, there was an increase in decline phase (DPT) (P<0.001), even if up till 46 kPa these differences were not significant. Differences in DPT remained without significance between 49 and 52 kPa. Long DPT can indicate that the milk flow is low or absent. This is associated with a higher risk of mastitis infection due to the possible passage of pathogens throughout the open teat canal. Borghese et al. (2007) obtained a DPT value of 2.29 min at 45 kPa, while Bava et al. (2007) reported that values increased as the stage of lactation increased (>180 days in milk, 1.62 min).

Conclusions

Results of the study into the effects of milking buffalo at different vacuum levels (37, 40, 43, 46, 49 and 52 kPa) on milk production, milk flow rate and milking times showed that:

- the Mediterranean Italian buffalo is suitable for mechanical milking at different working vacuum levels;
- milk yield (MY) was not influenced by the working vacuum level and was also satisfactory at lower levels. This showed that even though it is considered difficult to milk the buffalo, low vacuum levels can be adequate to completely empty the udder;
- average and peak milk flow rate (AFR and PFR) increased significantly along with an increase in working vacuum level. Consequently, the time between attaching the teatcup and reaching the value of 0.20 kg/min (EMT) was reduced with an increase in vacuum level;
- vacuum levels of 37 and 40 kPa provided good milkability conditions in which the plateau phase (PPT) was longer than the decline phase (DPT), while lag time (LT) was not affected by vacuum level.

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