Influence of vacuum level, pulsation rate and pulsator ratio on machine milking efficiency in local Greek goats

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Abstract

Effects of vacuum level, pulsation rate and pulsator ratio on machine milking efficiency in local Greek goats were studied in three separate experiments lasting 12, 10 and 11 weeks in three different years. After weaning (49 days) all goats were milked for 14 days at a vacuum level 44 kPa, a 90-pulsations/min and a 50:50 pulsator ratio (this 2-week interval was considered the familiarization period). In the first experiment, three groups (treatments) of goats were subjected to 70, 90 and 120 pulsations/min at milking. For the second experiment another three groups were milked with a vacuum level of 36, 44 and 52 kPa. For the third and final experiment, three pulsator ratios; 65:35, 50:50, 35:65 were compared in three groups. Results suggest that a faster rate (120 pulsations/min) and a higher vacuum level (52 kPa) decreased the percentages of machine milk (MM; from 60.6 to 55.1% for the rate and from 77.3 to 67.9% for the vacuum) and total machine milk (TMM) while increasing the percentage of machine stripped milk (MSM) and hand stripped milk (HSM; from 17.1 to 20.3% for the rate and from 5.7 to 10.0% for the vacuum). Milking time decreased as vacuum levels increased from 36 to 52 kPa and as pulsator ratios increased from 35:65 to 50:50 and 65:35. The pulsator ratio did not modify the percentage of the above milk fractions (MM, MSM, HSM and TMM) but did increase the average milking rate. Optimum conditions for machine milking of local Greek goats appears to be a vacuum level of 36–44 kPa, a pulsation rate of 70–90 and a pulsator ratio of 65:35.

Keywords: Goats; Machine milking efficiency; Machine parameters; Milk fractions

1. Introduction

Milkability is the degree to which animals can be machine milked and is an important factor in the application of machine milking in sheep and goats. Milk fractions (machine milk, MM; machine stripped milk, MSM; hand stripped milk, HSM), residual milk (i.e., obtained by injection of oxytocin after milking), types of milk flow curves in ewes (with or without ejection reflex) and milk flow rate in goats during machine milking are commonly used in small ruminants to evaluate this milkability (Labussière, 1988; Le Du, 1989). It is generally accepted that goats are easy to milk (Le Du, 1989), but some of them (those with a higher proportion of machine stripped milk) are generally harder to milk (Bouillon
and Ricordeau, 1970). Sinapis et al. (1993) found that, in local Greek goats, the percentage of machine milk was relatively lower than for other breeds, whereas the percentage of stripped milk (by machine and by hand) was higher, suggesting poor milkability for these goats. In goats with a low milk yield (local Greek goats), the best milking performances have to be achieved mainly through maximizing the machine milk fraction and milking rate while minimizing the hand stripped milk fraction. The reduction or eradication of laborious hand stripping is a prerequisite for the global efficiency of a dairy breed.

Different operations can be applied during machine milking of small ruminants in order to simplify the milking procedure and to extract the milk present in the udder completely and rapidly (Labussière, 1969; Ricordeau, 1974; Le Mens et al., 1979). It is well known that the volume of machine milk and hand stripped milk can be affected by mechanical factors (i.e., vacuum level, pulsation rate and pulsator ratio) and by the diameter of the liners (Le Du, 1989; Thomas et al., 1991). Additionally, milking rate in goats (a highly inheritable trait, Ricordeau et al., 1989) can be increased by higher vacuum levels (Lu et al., 1991), by higher pulsator ratios (Ricordeau and Labussière, 1970; Le Du, 1989; Lu et al., 1991) and to a lesser extent by faster pulsation rates (Lu et al., 1991). Before improvement of milkability, can be achieved through genetic selection, we have to identify the best procedures involved in machine milking in order to realise the full potential of our local Greek goats.

The aim of this study was to determine the optimum vacuum level, pulsation rate and pulsator ratio by measuring various milk fractions and quantifying milk emission characteristics in local Greek goats.

2. Materials and methods

The effects of vacuum level, pulsation rate and pulsator ratio on machine milking efficiency in local Greek goats were investigated in three separate experiments at the Thessaloniki University Farm, in three different years (i.e., one experiment per year), over a 12-, 10- and 11-week period, following the weaning at 49±4 days after kidding. Goats of different parity, 1,2,3+ lactation (2,3,4+ years old), were randomized in each experiment. Thus, there were not the same animals during the 3 years. Animals were milked twice daily (08:30 and 17:30 h) in a 1 × 24 side by side milking parlor, with 12 milking units, and a low milk line and air pipeline.

During a control period (14 days) of familiarization and equilibration of the lots on the basis of milk production, age and parity, the goats were milked at a 44-kPa vacuum level, at 90 pulsations/min and using a 50:50 pulsator ratio. After this control period, the following treatments were applied:

- in experiment 1, pulsation rates of 70, 90 and 120 pulsations/min in 12, 11 and 12 goats, respectively, were used;
- in experiment 2, vacuum levels of 36, 44 and 52 kPa, in 15, 16 and 15 goats, respectively, were used;
- in experiment 3, pulsator ratios of 65:35, 50:50 and 35:65, in 19, 18 and 19 goats, respectively, were used.

Simultaneously, for each experiment the other two machine milking parameters did not differ from those of the control period.

During the first experiment the teatcup used consisted of a transparent plastic shell and a silicon liner especially designed for goats (20-mm mouthpiece bore and 21.5 mm i.d. 75 mm down from the mouthpiece, Fullwood, no. 20236). For the other two years, because of the high percentage of HSM observed, liners, especially designed for sheep, with the same reduced diameter of 19.5 mm from the mouthpiece to 75 mm down in the barrel (Fullwood, no. 20119) were used.

In each experiment every Wednesday, milk fractions at morning and afternoon milking were recorded as follows (Labussière, 1969):

(a) machine milk (MM);
(b) machine stripped milk (MSM);
(c) hand stripped milk (HSM); in this way, it was possible to calculate for each goat;
(d) total machine milk (TMM = MM + MSM); and
(e) milk yield (MY = TMM + HSM).
Each fraction was expressed as a percentage of milk yield.

In the second and third experiment, the milk flow curve of each goat was drawn by using a paper tape attached to the milk recording jars. The milk yield level was recorded every 4 s. The milk emission kinetics were measured during three successive morning milkings of the second, fifth and eighth weeks of the experimental periods. The average milking rate (ml/s) was calculated as: machine milk yield/milking time.

Data were analyzed separately for each experiment. All the parameters measured were compared by ANOVA using the SAS General Linear Model procedure (SAS, 1994). The weeks were treated as different block. Multiple mean comparisons were made using Duncan’s multiple range test, to classify the effect of the different treatments (pulsation rate, vacuum level and pulsator ratio).

3. Results and discussion

In the first experiment, the increase of pulsation rate from 90 to 120 pulsations/min decreased the percentage of machine milk ($P < 0.01$) and increased ($P < 0.05$) the percentage of machine stripped and hand stripped milk (Table 1). Although the percentage of machine stripped milk increased significantly with 120 pulsations/min, the total machine milk (TMM%) remains significantly lower than with 90 or 70 pulsations/min (79.7, 82.1 and 82.9%, respectively). It should be noted, however, that the average daily milk yield was similar in all groups.

Bouillon et al. (1984) observed that an increase from 90 to 120 pulsations/min increased milk production by only 2% in French Alpine and Saanen goats. Lu et al. (1991) also reported that, in Alpine goats, the optimal pulsation rate appeared to be 90 pulsations/min. A range of pulsation rates from 70 to 100 pulsations/min has been proposed by Le Du (1989).

In Norwegian goat herds Rønningen and Lunder (1999) reported that the optimum pulsation rate ranged from 60 to 90 pulsations/min.

Considering all this data and our results, where the MM% was lower with 120 pulsations/min, we can conclude that the optimal pulsation rate for all breeds of goat, especially the local Greek breed, ranges from 70 to 90 pulsations/min.

The percentage of machine milk for the local Greek goats used in this experiment remain lower than that of other goats breeds milked at 60 to 90 pulsations/min. This percentage was: 87.4% in Saanen (Bouillon and Ricordeau, 1970), 89.5% in Alpine Chamoisée and Poitevine (Ricordeau and Labussiere, 1970), 86.9% in Alpine Chamoisée (Le Mens et al., 1979), 88.1% in Alpine Chamoisée and Saanen (Le Mens and Disset, 1984), 91.2–96.3% in Swiss Saanen (Bruckmaier et al., 1994) and 81.5% in Murciano Granadina (Peris et al., 1996). This suggests either a poor reactivity to stimulation by the pulsation rate (less oxytocin discharge or less sensibility of mammary gland?) or a morphological negative parameter (teat characteristics, udder shape or percentage of cisternal volume?) that need to be eradicated by genetic selection in local Greek goats.

In the second experiment the increase of the vacuum level from 36 to 52 kPa increased ($P < 0.01$)

### Table 1

<table>
<thead>
<tr>
<th>Pulsation rate (mean±S.D.)</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Milk yield (ml/day)</td>
<td></td>
</tr>
<tr>
<td>70</td>
<td>803.7±374.8</td>
</tr>
<tr>
<td>90</td>
<td>758.9±338.2</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Milk fractions* (day):</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Machine milk (MM)</td>
<td>60.6±34.1</td>
</tr>
<tr>
<td>Machine stripped milk (MSM)</td>
<td>22.3±12.1</td>
</tr>
<tr>
<td>Hand stripped milk (HSM)</td>
<td>17.1±12.4</td>
</tr>
<tr>
<td>Total machine milk (TMM)</td>
<td>82.9±12.4</td>
</tr>
</tbody>
</table>

* Means in a row with different superscripts (a,b) differ significantly ($*P < 0.05$; $**P < 0.01$).

* Percent of milk yield.
Table 2
Effect of vacuum level on machine milking efficiency in local Greek goats

<table>
<thead>
<tr>
<th>Vacuum level (kPa)</th>
<th>Mean±s.d.</th>
<th>Mean±s.d.</th>
<th>Mean±s.d.</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>36</td>
<td>776.8±392.2</td>
<td>760.3±413.9</td>
<td>787.4±474.4</td>
<td>NS</td>
</tr>
<tr>
<td>44</td>
<td>74.5±12.7</td>
<td>22.1±13.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>52</td>
<td>67.9±16.8</td>
<td>10.0±7.8</td>
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<td></td>
</tr>
</tbody>
</table>

Milk fractions (day):

<table>
<thead>
<tr>
<th>Milk fractions</th>
<th>Mean±s.d.</th>
<th>Mean±s.d.</th>
<th>Mean±s.d.</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Machine milk (MM)</td>
<td>77.3±16.8</td>
<td>74.5±12.7</td>
<td>67.9±16.8</td>
<td>**</td>
</tr>
<tr>
<td>Hand stripped milk (HSM)</td>
<td>5.7±5.7</td>
<td>6.3±5.7</td>
<td>10.0±7.8</td>
<td>**</td>
</tr>
<tr>
<td>Total machine milk (TMM)</td>
<td>94.3±7.9</td>
<td>94.0±5.7</td>
<td>90.0±7.8</td>
<td>**</td>
</tr>
</tbody>
</table>

Milk emission:

<table>
<thead>
<tr>
<th>Milk emission</th>
<th>Mean±s.d.</th>
<th>Mean±s.d.</th>
<th>Mean±s.d.</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Machine milk (ml)</td>
<td>396.5±160.1</td>
<td>362.4±140.5</td>
<td>334.1±139.7</td>
<td>NS</td>
</tr>
<tr>
<td>Average milking rate (ml/s)</td>
<td>7.2±1.8</td>
<td>7.7±2.4</td>
<td>8.1±2.2</td>
<td>NS</td>
</tr>
<tr>
<td>Milking time (s)</td>
<td>53.4±25.2</td>
<td>43.6±21.3</td>
<td>38.1±12.8</td>
<td>*</td>
</tr>
</tbody>
</table>

**abc** Means in a row with different superscripts differ significantly (*P < 0.05; **P < 0.01).  
*Percent of milk yield.  
**Recorded only at morning milking (see Section 2).  

The percentages of machine stripped and hand stripped milk (MSM and HSM; Table 2) while daily milk yield was not affected during the same period. Results from Table 2 also show that the percentage of MM and the TMM decreased and the MSM and HSM increased as the vacuum level reached 52 kPa. It appears that the milking time (Table 2) decreased markedly (15.3 s or 28.7%) at 52 kPa compared to 36 kPa. However, the milk flow rate (ml/s) of local Greek goats was not affected by the vacuum level because as the milking time decreased the volume of machine milk also decreased with vacuum level increased.

Bouillon and Ricordeau (1981) reported similar findings in that milk flow rate increased in French goats (Chamoises, Saanen and croises) as vacuum level increased from 38 to 51 kPa. Lu et al. (1991) also found that the milking time decreased significantly and average and maximum milking flow rate increased significantly as vacuum level increased from 38 to 52 kPa. These results confirm that a high vacuum level is needed to open the teat sphincter in goats. This point has been previously studied by Le Du and Benmederbel (1984) in French Saanen goats, in which a minimum vacuum of 34.6 kPa, without pulsation, was required at the beginning of lactation, while 44–50 kPa was often needed for 10–15% of the goats. It is generally admitted that an increase in vacuum level causes a decrease in milking time, but may increase the risk of mastitis (Le Du, 1989). In the same local breed of goats, Sinapis and Vlachos (1999) found that increasing the vacuum level from 36 to 44 and 52 kPa significantly increased (P < 0.001) the somatic cell counts (SCC) in the fraction of total machine milk (TMM) without the appearance of clinical mastitis.

Lu et al. (1991) preferred to milk Alpine goats at 52 kPa because of its positive effect on milking performance, but at the expense of increased SCC. For local Greek goats, the time spent milking is not the most important factor. The optimum range of vacuum level should be between 36 and 44 kPa to increase the fraction MM% and reduce HSM%, without significant modification of the milk flow rate. This result is in agreement with an average vacuum level of 46.5 kPa used in Norway (Rønningen and Lunder, 1999).

In the third experiment (Table 3) the decrease of pulsator ratio from 65:35 to 50:50 and 35:65 did not affect the TMM% (94.1, 93.8 and 94.8, respectively) nor the HSM% (6.0, 6.2 and 5.2, respectively), although Ricordeau and Labussière (1970) found that the modification of the pulsator ratio from 75:25 to 50:50 increases the volume of MSM at the morning (30%) and evening (24%) milking. The average milking time was higher (P < 0.05) in the group with pulsator ratio 35:65 and the average milking flow rate (ml/s) increased from 7.3 to 10.1
Table 3
Effect of pulsator ratio on machine milking efficiency in local Greek goats

<table>
<thead>
<tr>
<th>Pulsator ratio (mean±S.D.)</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>35:65</td>
<td>50:50</td>
</tr>
</tbody>
</table>

- **Milk yield (ml/day)**
  - 35:65: 819.2±325.9
  - 50:50: 830.5±387.3
  - 65:35: 884.1±307.3
  - NS

- **Milk fractions (day)**
  - **Machine milk (MM)**
    - 35:65: 75.0±13.7
    - 50:50: 72.0±15.1
    - 65:35: 75.1±13.1
    - *
  - **Machine stripped milk (MSM)**
    - 35:65: 19.2±11.2
    - 50:50: 21.8±12.1
    - 65:35: 19.0±11.4
    - NS
  - **Hand stripped milk (HSM)**
    - 35:65: 5.8±4.5
    - 50:50: 6.2±5.8
    - 65:35: 6.0±5.4
    - NS
  - **Total machine milk (TMM)**
    - 35:65: 94.2±4.5
    - 50:50: 93.8±5.8
    - 65:35: 94.1±5.4
    - NS

- **Milk emission**
  - **Machine milk yield (ml)**
    - 35:65: 414.7±192.6
    - 50:50: 417.9±270.5
    - 65:35: 469.3±185.0
    - *
  - **Average milking rate (ml/s)**
    - 35:65: 7.3±1.9
    - 50:50: 8.6±2.5
    - 65:35: 10.1±2.8
    - *
  - **Milking time (s)**
    - 35:65: 58.5±28.6
    - 50:50: 45.0±21.7
    - 65:35: 45.6±13.1
    - *

| **Means in a row with different superscripts differ significantly (*P < 0.05).** |
| **Percent of milk yield.** |
| **Recorded only at morning milking (see Section 2).** |

ml/s (an increase of 38.7%) as the pulsator ratio increased from 35:65 to 65:35 (P < 0.05). The same tendency has been reported by Ricordeau and Labussière (1970) in Alpine Chamoisés and Poitevine goats, by Bouillon and Ricordeau (1981) in French goats (Chamoisés, Saanen and croisés) and by Lu et al. (1991) in Alpine goats. In dairy cows Rosen et al. (1983) found that average milking rate increased and milking time decreased with wider pulsator ratios. Thus, in goats, just as in dairy ewes (Labussière et al., 1974) and in dairy cows (Labussière and Richard, 1965), the pulsator ratio is one of the main factors which determines the milk flow rate, with an increase of 23% as the pulsator ratio increased from 50:50 to 75:25 (Le Du, 1989).

The mean value of milk flow rate (10.1 ml/s) in group 65:35 was higher than that of 8.23 ml/s reported by Peris et al. (1996) in Murciano-Granadina dairy goats milked in the afternoon at 64:36 pulsator ratio, but it was lower than that of 16.1 ml/s in Alpine goats (Lu et al., 1991) and that of 14 ml/s, reported by Bruckmaier et al. (1994) in Swiss Saanen goats, milked at similar pulsator ratio of 60:40. The other two machine parameters were: for Murciano-Granadina 42 kPa and 90 pulsations/min and for Alpine and Swiss Saanen goats 90 pulsations/min and vacuum level of 52 and 48 kPa, respectively. Finally, the duration of suction phase under the teat sphincter seems to be more important than the vacuum level for the milking efficiency in goats. Perhaps this is because our local breed has a more resistant sphincter which requires more time to open.

In local Greek goats the desirable pulsator ratio appears to be between 65:35 and 50:50. This result agrees with those of 50:50–70:30 proposed by Le Du (1989) for the French Alpine and Saanen goats and with those of 60:40 found by Lu et al. (1991) for Alpine goats and with the recommendations of 60:40–65:35 for the Norwegian goats herds (Rønningen and Lunder, 1999).

To conclude, the results of our study showed that the optimum conditions for machine milking local Greek goats is a vacuum level of 36–44 kPa, a pulsator ratio of 65:35 and a pulsation rate of 70–90 pulsations/min. In spite of obvious differences in our goat breed, our results agree with the machine parameters classically used in 15 countries (vacuum level between 36 and 45 kPa, pulsator ratio between 50:50 and 60:40 and the pulsation rate between 70 and 90 pulsations/min) (Billon et al., 1999).

A final point must also be considered. When we examine the three experimental periods when the goats were milked with the same machine parameters (44 kPa, 90 pulsations/min and 50/50 ratio, i.e., the second column of data in Tables 1–3), it is obvious that the HSM% in experiment 1 was higher (17.9%) in comparison with the other two experiments, where the HSM% was lower (6.3 and 6.2%, respectively). This difference could be attributed to the different
type of liners used between the first year and the other 2 years since the age and parity of goats were the same among the 3 years (see Section 2). It could be assumed that the smaller diameter of liners is one of the essential factors which positively influenced (lower HSM%) the milking efficiency of local goats. It was observed that the teats penetrated too deeply inside the liners. That lead to bad efficiency of the massage because of the continuous existence of vacuum on the teat sphincter. Such a bad massage increases the teat end thickness (Hamann et al., 1993), reduces the milk flow and can increase the machine stripped milk yield and hand stripped milk yield. With better adapted liners, as used in experiments 2 and 3, the very low percentage of HSM suggests, it will be possible, in the near future, to apply simplified milking procedures to local Greek goats with a limited milk yield loss (6.3 and 6.2% of daily milk yield or 47.9 and 51.5 ml, respectively, in our study).

References


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