Effects of Infection by Caprine Arthritis-Encephalitis Virus on Milk Production of Goats

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ABSTRACT

The effects of caprine arthritis-encephalitis virus on lactational performance of goats were examined. The results of an ELISA for antibodies against caprine arthritis-encephalitis virus were compared with milk production records. Mean production of milk, protein, fat, and lactose and somatic cell counts were compared for seropositive and seronegative goats of similar ages. The results from 1799 lactating goats from 66 herds suggested that milk production was similar for 1-yr-old goats that tested seropositive and those that tested seronegative. For 900 of those goats for which data permitted comparison, milk fat and protein were also similar. A comparison of 331 goats showed that lactose contents did not differ between 1- and 2-yr-old goats, but somatic cell counts were higher in 2-yr-old seropositive goats.

(Key words: goats, caprine arthritis-encephalitis virus, milk production, somatic cell count)

Abbreviation key: CAEV = caprine arthritis-encephalitis virus, GMR = Goat Milk Recording Scheme.

INTRODUCTION

Caprine arthritis-encephalitis virus (CAEV), like other lentivirus, causes a persistent lifelong infection. The CAEV induces a subclinical infection in most goats. Signs of disease include progressive inflammation in one or more organ or tissue system, such as joints, bursae, brain, spinal cord, lungs, and udder (2, 4). Most females that are infected with CAEV are likely to have a viral infection of the mammary gland, which is a target organ for the virus (9, 11). Lesions in the udder may arise even before puberty. Diffuse or nodular indurative changes tend initially to develop deep in the udder tissue and later become gradually more extensive (4). Milk produced by infected goats appears normal, and mastitis may not be suspected as the cause of a gradual decline in milk production. However, some studies (10, 15, 24) suggest that indurative mastitis may prove to be the most economically significant component of CAEV because of the effect of this type of mastitis on milk production, fat production, and SCC. To our knowledge, only two studies (8, 13) have revealed statistically significant differences in milk production between goats that were seropositive and those that were seronegative for CAEV. In one study (13), seropositive goats were compared with seronegative goats from different herds. In the other study (8), differences were found only when supplementary feed was reduced to a minimum.

Goats that are free from bacterial mastitis may produce milk with high SCC; SCC of about 800,000/ml is a normal mean (16). High SCC have been attributed to the presence of cytoplasmic particles that originate from apocrine secretions (5), and SCC estimated by particle counters may be elevated falsely by the presence of these cytoplasmic masses. However, SCC measured by automated DNA detection methods are not affected (17). Even with the use of more accurate cell counters, Post et al. (16) and Ryan et al. (21) found high SCC in milk from goats that were free of bacterial infection in the udder. Those researchers (16, 21) suggested that CAEV infection might be the cause of the high SCC. The purpose of this study was to compare milk parameters between goats infected with CAEV and uninfected goats.

MATERIALS AND METHODS

Goats

About 540 herds representing 47% of the total dairy goat population in Norway participate in the Goat Milk Recording Scheme (GMR); all 66 herds included in this study participated in the GMR. The
lactation period usually begins in January or February and ends in September or October. Most of the goats were machine-milked. Goats that were culled during the lactation period prior to blood sampling or that lacked essential data for the study were excluded.

During the period from August 1993 through January 1994, blood samples were taken from 26 goats that were >1 yr of age in each of the 34 herds in the 11 counties in Norway that have the highest number of goat herds (K. Nord, 1996, unpublished data). Goats were randomly selected according to the total age distribution in each herd based on groups of 1 to 2 yr olds, 3 to 4 yr olds, and ≥5 yr. In two other herds, all of the goats that were >1 yr of age were sampled. A total of 1025 goats were tested, and their milk production was compared during the lactation period of 1993. For 569 of the goats, recorded data were sufficient for statistical analyses of the contents of milk fat and protein.

From August 1994 through January 1995, blood from 774 goats in 30 other herds was sampled at the request of the herd owners, and milk production of those goats in 1994 was compared. For the goats from these other herds sufficient recorded data concerning milk fat, protein, lactose, and SCC were available only for 331 of the 1- and 2-yr-old goats in 28 herds.

**Serological Examination**

The sera were stored at −20°C until examination for antibodies against CAEV by an ELISA as described previously (19). Briefly, microtiter plates were coated with 100 ng per well of purified recombinant capsid (p28) and matrix (p17) CAEV proteins; test sera were diluted 1:100 (vol/vol), and antibodies were detected by the method using the streptavidin-biotin-peroxidase complex.

The sera that were collected during the period from August 1993 through January 1994, hereafter referred to as 1993, were tested for antibodies against capsid CAEV proteins only. The sera that were sampled during the period from August 1994 through January 1995, hereafter referred to as 1994, were tested against both capsid and matrix CAEV proteins.

**Examination of Milk Parameters**

Data on the production of milk, fat, protein, and lactose and on SCC were provided by the GMR. Milk production was based on 5 or 6 test d for each goat (monthly for the first 3 mo of lactation, then every 2nd mo, and about 30 d prior to drying off). A test day included the evening and morning milk during a 24-h period. Milk quantity was recorded with approved milk meters. Samples for further milk analyses were normally taken twice when goats were kept indoors and at least once when goats were fed summer pasture. The contents of fat, protein, and lactose in milk were analyzed (Milkoscan 605-B; Foss Electric, Hillerød, Denmark), and the SCC were estimated using the automated DNA particle counter (Fossomatic 360; Foss Electric). In 1993, the statistical analysis was based on annual production as calculated by the GMR. In 1994, the analysis was based on the records of milk parameters for each test day, hereafter referred to as daily production.

**Statistical Analyses**

The milks of goats with positive, indeterminate, and negative results from the ELISA were compared. Age was recorded to the closest year. A requirement for this study was that first kidding take place at 1 yr of age and that second kidding take place at 2 yr of age. In 1994, only records between the 5th and 365th d of lactation were included.

Analyses of variance were performed on the records from 1993, comparing annual milk production and mean percentages of fat and protein using the model annual milk production = age + herd + CAEV + (CAEV × age) + residual error.

The 1994 records for daily milk production (kilograms); percentages of fat, protein, and lactose; and log SCC were analyzed using the statistical model daily production = D + (D × D) + log(D) + [log(D) × log(D)] + age + CAEV + (CAEV × AGE) + herd + control date(herd) + goat(CAEV herd) + residual error, where CAEV = one result of an ELISA for antibodies against CAEV per goat [classified as negative, positive, or indeterminate (fixed class variable)]; age = age in years, either divided into two classes (1 or 2 yr) or including 1, 2, 3, 4, 5, and ≥6 yr (fixed class variable AGE); CAEV × AGE = interaction of CAEV and AGE (fixed class variable); and D = day of lactation/365 d. The four functions of days fit a common lactation curve for all goats. This method of fitting the lactation curve is described by Ptak and Schaeffer (18) and Schaeffer and Sullivan (23).

In 1993, herd was regarded as a fixed effect. In 1994, herd and control date within herd were analyzed as random effects. In the latter model, goat(CAEV herd) = goat within CAEV test result and herd, and the repeated observations of daily production for goats were regarded as first-order autoregressive. The GLM and MIXED procedures of SAS (22) were used for statistical analyses.
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Figure 1. A) Least squares means of annual milk production of 428 seropositive (●) and 480 seronegative (○) goats in 36 herds examined by ELISA for antibodies against caprine arthritis-encephalitis virus (CAEV). Data presented are from 1993. B) Least squares means of daily milk production of 313 seropositive (●) and 355 seronegative (○) goats in 30 herds examined by ELISA for antibodies against CAEV. Data presented are from 1994.

RESULTS

Serological Findings

Serological findings are presented in Table 1. About 40% of the goats tested were seropositive.

Milk Production

In 1993, mean annual milk production was 551.5 kg for seronegative goats and 597.6 kg for seropositive goats. However, after adjustment for the effects of age and farm using least squares means, the production was 579.7 kg for seronegative goats and 597.7 kg for seropositive goats. The difference in mean annual milk production between seropositive and seronegative goats was not significant in the analysis of variance (P = 0.09). Least squares means of annual milk production (in kilograms) for different age groups of seropositive and seronegative goats are plotted in Figure 1. Seropositive goats seemed to have a slightly higher mean annual milk production than did seronegative goats in most age groups; the largest production difference was found at 5 yr of age. Although no statistically significant main effect of the CAEV antibody test results was found, the interaction of CAEV and age was significant. At 5 yr of age, seropositive goats produced more milk than did seronegative goats or goats that had an indeterminate response to the ELISA (P = 0.03 and 0.001, respectively), and seronegative goats produced more milk than did goats that had indeterminate test results for the CAEV antibody test (P = 0.02).

In 1994, the least squares means of daily milk production were 2.31 kg for seronegative goats, 2.34

Figure 2. A) Least squares means of the milk fat percentages of 272 seronegative (○) and 233 seropositive (●) goats examined by ELISA for antibodies against caprine arthritis-encephalitis virus (CAEV). B) Least squares means of the percentages of protein in the milk from 272 seronegative (○) and 233 seropositive (●) goats examined by ELISA for antibodies against CAEV. All data presented are from 1993.

TABLE 1. Results of an ELISA for antibodies against caprine arthritis-encephalitis virus (CAEV).

<table>
<thead>
<tr>
<th>Year</th>
<th>Herds</th>
<th>Goats</th>
<th>Goats</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Examined (no.)</td>
<td>Positive (no.)</td>
<td>Positive (%)</td>
</tr>
<tr>
<td>1993</td>
<td>36</td>
<td>32</td>
<td>1025</td>
</tr>
<tr>
<td>1994</td>
<td>30</td>
<td>30</td>
<td>773</td>
</tr>
</tbody>
</table>

\(^1\)Positive indicates that goats tested seropositive for CAEV; negative indicates that goats tested seronegative for CAEV.

Figure 3. Least squares means of the percentages of lactose in the milk from 125 seropositive goats (solid bar), 163 seronegative goats (light bar), and 43 goats with indeterminate results (patterned bar) from an ELISA used to test for antibodies against caprine arthritis-encephalitis virus. Data presented are from 1994. Bars represent standard errors.

Figure 4. Logarithm of least squares means of milk SCC for 125 seropositive goats (solid bar), 163 seronegative goats (light bar), and 43 goats with indeterminate results (patterned bar) from an ELISA used to test for antibodies against caprine arthritis-encephalitis virus. Data presented are from 1994. Bars represent standard errors.
kg for seropositive goats, and 2.33 kg for goats with indeterminate test results. This milk production is plotted for different age groups in Figure 1. Analyses of variance revealed no significant differences between seropositive and seronegative goats and no differences for the interaction of CAEV and age.

**Percentages of Fat, Protein, and Lactose and SCC**

In 1993, the least squares means of the annual percentage of milk fat were 3.47% for 272 seronegative goats, 3.37% for 233 seropositive goats, and 3.16% for 64 goats that had an indeterminate response to the ELISA. Percentages of milk fat for different age groups are presented in Figure 2. The difference between percentages of milk fat of seronegative and seropositive goats was not significant (P = 0.19). However, the percentage of fat in the milk of goats with indeterminate antibody results was significantly lower than the percentage of fat in the milk of the seronegative goats (P = 0.007).

Least squares means of the annual percentage of protein in milk were 2.77% for seronegative goats, 2.70% for seropositive goats, and 2.77% for goats that had an indeterminate response to the ELISA. Least squares means of the percentage of protein for different age groups are plotted in Figure 2. The analyses of variance revealed no significant differences.

The 1994 records for 125 seropositive goats, 163 seronegative goats, and 43 goats with indeterminate test results were compared. Analyses of variance revealed no significant differences in concentrations of fat, protein, or lactose in milk between seropositive and seronegative 1- and 2-yr-old goats (Figure 3).

An overall statistically significant interaction between CAEV infection and age was found for SCC (P = 0.03; Figure 4). The SCC for seropositive goats increased from first to second lactation (P = 0.06), but, for seronegative goats, SCC decreased from first to second lactation (P = 0.06). During first lactation, the difference was not statistically significant (P > 0.05) between goats that were positive or negative for CAEV antibodies. However, during the second lactation, seropositive goats had slightly higher SCC than did seronegative goats (P = 0.05).

Table 2 presents the estimated variance components for herd, sampling date, and goat and the correlation of repeated records within goat for the 1994 data. Sampling date, goat, and autocorrelation were always significantly different from 0; no difference among herds was found for protein, lactose, or SCC.

**DISCUSSION**

The lack of differences in milk production and percentages of fat, protein, and lactose in milk between seropositive and seronegative herdmates indicated that CAEV infection in otherwise healthy goats did not influence lactation performance to any great extent. The distribution of the CAEV infection in the examined herds (approximately 40% seropositive and 46% seronegative goats) was well suited for comparison. The size of the study (66 herds with data for 1799 goats collected over two different lactation periods) and similarity of results even when using two different analytical methods for the two lactation periods strengthened the conclusions.

No differences were found in percentages of milk fat and protein because of CAEV infection. For goats >2 yr of age, data on fat and protein were only available for 1993. However, the 144 goats that were >2 yr of age for which sufficient data were available were evenly distributed among age categories and herds, allowing satisfactory statistical analysis.

**TABLE 2. Variance components and significance for 1- and 2-yr-old goats that were tested for antibodies against caprine arthritis-encephalitis virus (CAEV).**

<table>
<thead>
<tr>
<th>Effect</th>
<th>Farm</th>
<th>Sampling date within farm</th>
<th>Goat</th>
<th>Correlation within goat</th>
<th>Contrasts</th>
<th>CAEV</th>
<th>CAEV × AGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Milk</td>
<td>0.113**</td>
<td>0.042***</td>
<td>0.148***</td>
<td>0.58***</td>
<td>***</td>
<td>NS²</td>
<td>NS</td>
</tr>
<tr>
<td>Fat</td>
<td>0.178**</td>
<td>0.094***</td>
<td>0.571***</td>
<td>0.36***</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
</tr>
<tr>
<td>Protein</td>
<td>0.0034</td>
<td>0.0354***</td>
<td>0.057***</td>
<td>0.65***</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
</tr>
<tr>
<td>Lactose</td>
<td>0.0043</td>
<td>0.0047***</td>
<td>0.039***</td>
<td>0.63***</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
</tr>
<tr>
<td>SCC</td>
<td>145,000</td>
<td>463,000***</td>
<td>130,000***</td>
<td>0.33***</td>
<td>NS</td>
<td>NS</td>
<td>*</td>
</tr>
</tbody>
</table>

*¹Age = Age in years, either divided into two classes (1 or 2 yr) or including 1, 2, 3, 4, 5, and ≥6 yr (fixed class variable AGE); CAEV × AGE = interaction of CAEV and AGE.

*²P > 0.05.
*³P < 0.05.
*⁴P < 0.01.
*⁵P < 0.001.
For lactose and SCC, comparisons were restricted to 1 and 2 yr olds for the 1994 lactation; few other recordings were available. Because the host may be infected with CAEV for several years before developing clinical and pathological signs of disease (2, 4), differences in lactational performance may increase with age, and, therefore, potential differences may remain undetected if only 1- and 2-yr-old goats are compared. However, SCC was increased for seropositive 2 yr olds, indicating an effect of CAEV on milk quality and possible pathological changes caused by the CAEV even in the udders of young goats. The increase in SCC for the milk of goats that were infected with CAEV was similar to that found in bacterially infected mammary glands of goats (5). However, a correlation between CAEV infection and bacterial mastitis as has been previously suggested (21, 24), was not found in this study (K. Nord, 1996, unpublished data). Because SCC was not distributed normally, arithmetic means were not well suited for comparisons (14); therefore, a logarithmic transformation of SCC was employed.

Indeterminate serological results could have either been due to low concentrations of antibodies against the CAEV antigens that were employed in the test, to unspecific reactions, or to crossreactions caused by antibodies against other antigens. Thus, the lower milk production and changes in constituents in milk of goats that had an indeterminate response to the ELISA might have been due to diseases other than CAEV. After goats with indeterminate ELISA results were retested, about 50% were seropositive, and most of the others were seronegative (data not shown).

The occurrence of antibodies against CAEV is considered to be diagnostic for infection (3). The slightly larger mean value for milk production of the seropositive goats was inconsistent with any large reductions in milk production caused by CAEV. However, a small reduction in milk production that is caused by the virus may be disguised if seropositive goats have an overall greater potential capacity to produce milk than do the seronegative goats with which they are compared. Delayed seroconversion is common (1, 6, 7, 12, 20). The virus infection may be latent, and antigen production may be limited. Limited antigen expression does not induce a marked immune response, and such goats are found to be seronegative despite being seropositive for the virus. High milk production may be an important stress factor that induces the expression of antigen and, therefore, the immune response of infected goats. The possibly larger mean milk production of the seropositive goats might indicate an increased immune response by high producing goats that are infected with CAEV. High producing goats may also be more susceptible to infection from CAEV. To breed high producing goats, males are often purchased or exchanged among herds, increasing the risk that infected goats will enter the herd. For the herds in this study, high milk production seemed to be correlated with a high prevalence of CAEV antibodies (data not shown). The confounding effects may be difficult to correct completely. However, the inclusion of herd as a model term amounts to a comparison of herdmates with different infection status and keeps differences in management conditions and inheritance to a minimum.

Blood sampling was performed toward the end of lactation or after the lactation periods during which milk parameters were compared. Culling because of mastitis, infection by Streptococcus agalactiae, low milk production, arthritis, or other reasons during the lactation period prior to blood sampling might have excluded the goats that had larger reductions in milking performance caused by CAEV. Only 6 seronegative goats and 2 goats with indeterminate test results were excluded from the GMR data for calculation of annual production in autumn 1993 because those goats were culled before 211 d of lactation but after blood sampling. Further examination of the causes of culling and time at which culling takes place is needed before firm conclusions can be drawn regarding the total effects of CAEV infection on lactational performance. However, even though increased SCC was associated with CAEV infection of the mammary gland, changes in milk production caused by CAEV were definately much smaller than previously suggested (10, 24).

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EFFECTS OF CAPRINE ARTHRITIS-ENCEPHALITIS VIRUS ON MILK PRODUCTION