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Relationship of mammary gland health status and other noninfectious factors with electrical conductivity of milk in Manchega ewes

G. Romero, A. Roca, M. Alejandro, R. Muelas, and J. R. Díaz[1]
Dpto. Tecnología Agroalimentaria, Universidad Miguel Hernández (UMH), Ctra. de Beniel km 3.2, 03312 Orihuela, Spain

ABSTRACT

Measuring the electrical conductivity (EC) of milk during milking has been extensively studied in cattle as a low-cost mastitis detection method that can be easily automated. The aim of this work was to study the effect of the health status of the glands and several noninfectious factors (lactation stage, milking session, and lactation number) that affect the use of EC measurement of milk to detect mastitis in dairy sheep livestock. Likewise, we studied the relation between EC and milk composition (macrocomposition and mineral content) and between EC and somatic cell count (SCC). Finally, we evaluated the use of EC thresholds as a mastitis detection method. To this end, we monitored the glandular milk EC throughout 2 consecutive lactations, during which 42 and 40 ewes were controlled, respectively. We carried out 7 biweekly checks, analyzing the EC, SCC, composition, and mineral content of glandular milk at morning and evening milkings. Before the morning milking, samples were aseptically collected for bacteriological analysis, and the results along with the SCC were used to classify the glands according to their sanitary status (healthy, latently infected, or infected). Lactation stage, parity, milking (morning or evening), health status, and the interactions of parity with health status, lactation stage with health status, and parity with lactation stage all had a significant effect on SCC and EC of the milk. The correlation between EC and SCC was only significant when all the data were analyzed jointly ($r = 0.33$) and for SCC $\geq$ 600.000 cells/mL ($r = 0.25$). The changes in milk composition, mainly in fat content, largely explained the variation in EC ($R^2 = 0.69$). For the same EC threshold, the specificity and sensitivity varied depending on the parity or the milking, with the negative predictive value obtained being higher than the positive predictive value at all times. We concluded that developing methods of detecting mastitis in sheep by milk EC readings would require consideration of noninfectious factors that also affect the gauging of EC. One option to consider would be individualized daily monitoring of the glands, as demonstrated in other species such as cattle and goat.
Key words: mastitis detection, electrical conductivity, dairy sheep, sensitivity, specificity

INTRODUCTION

Mastitis in dairy sheep, both clinical and subclinical, causes economic losses because of decreased milk production and cheese yield (Leitner et al. 2008). These problems are compounded by the expenses arising from treatment costs and losses from milk withdrawal periods following the treatments. In some cases, mastitis may even lead to animal death or the total loss of one or both mammary glands.

In sheep, production losses due to subclinical mastitis can reach 12.2% in herds with 75% of glands infected, whereas the losses in goat livestock are only 2.3% with the same percentage of infected glands (Leitner et al. 2008). The alteration of milk composition and the consequent decline in cheese yield is also more acute in sheep than in cattle or goats (Leitner et al. 2011). For this reason, the development of techniques that allow early and effective detection of mastitis cases in sheep and help minimize the associated economic losses is of prime importance.

Electrical conductivity (**EC**) of milk during milking has been widely studied in cattle as a mastitis detection method. The method can be automated, and in some cases it reaches 92% sensitivity and 93% specificity (Cavero et al., 2006).

In small ruminants, only a few reports have been published on the effect of mastitis on EC of milk, and some of the results are contradictory. In recent studies carried out in Murciano-Granadina goats, Díaz et al. (2011) observed that in addition to the glandular health status, milk EC is also affected by animals' lactation stage and parity number and the farm from which the animals are sourced. In the same study, the authors set out a series of absolute thresholds for EC (5, 5.10, 5.20, 5.30, 5.40, 5.50, 5.60, 5.70, 5.80, 5.90, and 6.00 mS/cm)

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[1]Corresponding author: jr.diaz@umh.es

for mastitis detection and found important variations in the sensitivity and specificity obtained for a threshold depending on the farm. Romero et al. (2014) proposed a series of algorithms for mastitis detection in goats based on the daily and individual measuring of the EC of glandular milk. The algorithms were able to classify all cases of clinical mastitis, although they obtained different values in subclinical cases. A higher sensitivity (58.3%) was obtained when cases were considered positive if the EC deviated over the moving average of the 4 previous days by at least 3 times the standard deviation. Specificity varied between 75 and 100%, according to the algorithm. In another goat study, Romero et al. (2012) obtained sensitivity of 70% and specificity of 50% with an EC threshold of 5.20 mS/cm, regardless of the milking fraction studied. Zaninelli et al. (2015) assessed the use of Fourier spectral analysis for online readings of glandular milk EC as a mastitis detection method. They concluded that the EC of milk from mastitic glands presented slower fluctuations and an irregular trend, and the frequency peaks obtained by the Fourier transformation could therefore be used as mastitis indicators and be included in the design of the algorithms for mastitis detection by means of online EC readings.

Very few studies are available in sheep. Peris et al. (1989) observed that mastitis caused an increase in milk EC and proposed 2 thresholds for mastitis detection. One threshold was 5 mS/cm for diagnosing glands with mastitis, which achieved 60.2% sensitivity and 91.4% specificity, with 87.9% of the samples classified correctly. The other threshold consisted of using a difference in milk EC between the 2 glands of the same animal of 0.3 mS/cm, which yielded better results (70% for sensitivity, 93% for specificity and 89.1% of samples properly classified). This latter threshold is similar to that obtained by Barth et al. (2008), who observed a difference in milk EC between glands of 0.1 mS/cm in healthy sheep and 0.4 mS/cm between glands of sheep with one infected gland. McDougall et al. (2002), despite finding no significant differences between the impedance (EC inverse property) of milk from healthy and infected glands, obtained a negative correlation between the impedance and SCC ($r = -0.27$), leading them to deduce that the increase in SCC must be related to an increase in EC. Caria et al. (2016) found a positive correlation ($r = 0.31$) between milk EC and SCC in Sarda sheep. In the same study, they achieved 73.08% sensitivity and 75.46% specificity, setting an EC threshold of 4.84 mS/cm, which was then applied in the evaluation of a prototype designed to detect subclinical mastitis by online gauging of the EC of the milk.

To determine the factors affecting the measuring of EC as a mastitis detection method, this investigation focused on the effect of different noninfectious (lactation status, milking type, and parity) and infectious factors on EC of glandular milk from sheep. Likewise, we also studied the relationship between EC and milk composition (macrocomposition and mineral content) and between EC and SCC.

MATERIALS AND METHODS

Location and Animals Used

The investigation was conducted at the Small Ruminants Teaching Farm of the Escuela Politécnica Superior de Orihuela, which belongs to the Miguel Hernández University (Spain).

We used Manchega ewes, a native Spanish breed with average milk production for every sheep in the breed of 1.156 L/d (Arias et al., 2012). The milk of this mixed-use breed is mainly used in Manchego cheese manufacturing. Manchego cheese and Manchego lamb are 2 products of great value, and they are traded under the European guarantee labels of Protected Designation of Origin and Protected Geographical Indication, respectively.

The farming system in practice was intensive, with permanent stabling. The reproductive rate was 1 annual litter, with lambs weaned at birth and reared by artificial feeding. Postpartum, the ewes were milked twice a day (0800 and 1600 h) in a Casse low-line milking parlor 1 × 12 × 12 (number of platforms × number of places/platform × number of milking units/platform) with the following milking parameters: 36 kPa vacuum level, 180 pulsations/min rate, and 50% pulsation ratio.

Diet, which consisted of 2.5 kg daily mix of Unifeed and straw ad libitum, was the same throughout lactation.

Experimental Design

During 2 lactations, we monitored 42 (22 primiparous and 20 multiparous) and 40 (3 primiparous and 37 multiparous) ewes, respectively. We performed 7 biweekly samplings, the first at 2 wk postpartum, and the sampling lasted 3.5 mo. Sheep were sampled at morning (0800 h) and evening (1600 h) milkings.

Two samples were taken from each gland at the morning milking (5 and 100 mL, respectively) and one of 100 mL at the afternoon milking. The first sample from the morning milking was used for bacteriological analysis and was obtained aseptically by milking in sterile tubes after cleaning the teats with 70% ethanol and eliminating the first streams. Next, the glands were machine milked separately, collecting the milk into volumetric meters. The production was measured with a 500-mL