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Use of Electrical Coductivity Sensors to monitor Health Status and Quality of Milk in Dairy Goats

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Article

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Introduction

Intramammary infection (IMI) can adversely affect, in dairy goats, milk quality and milk yield leading to high economical losses. Although somatic cell count (SCC) and microbiological tests could be valid approaches to detect IMI, other methods of IMI early detection may be useful to detect infected animals and to improve milk quality. In this respect, the evaluation of electrical conductivity (EC) of milk, by on-line sensors, represents an interesting approach. The concentrations of Na^+ and Cl^- in milk increase during an IMI due to a change of the permeability of the udder tissue, influencing the EC of milk (Tangorra *et al.* 2010). This effect has been largely studied in dairy cows and the use of EC has been adopted with successful results in terms of detection accuracy (De Mol *et al.* 2001). On the contrary, in dairy goats, this has not been the case mainly because less research studies have been conducted.

However, our research group has shown that a specificity of 65% and a sensitivity of 81% could be reached by a univariate model based on evaluations of time series of gland milk EC (Zaninelli *et al.* 2015). These results are in accordance with other authors (Diaz *et al.* 2011; Romero *et al.* 2012) that suggest: to consider the intrinsic variation of animals (as in cows), to avoid the use of simple thresholds, and to use other significant factors in the model such as the EC values of milk in different milking fractions (Romero *et al.* 2012). In agree with these latter suggestions, in another study our research group has tested a multivariate model, developed with the fuzzy logic technology, based on the EC of gland milk and the evaluation of the goats milk yield (Zaninelli *et al.* 2014). The results obtained have shown an improvement in the detection accuracy of the model evaluated (specificity of 69% and a sensitivity of 81%). Nevertheless, the reached values are not still enough high if compared with results obtained in dairy cows (De Mol *et al.* 2001). Further studies, on multivariate models that use more informative parameters derived from the EC of milk, are necessary.

The aim of this study was to test a new multivariate model developed with the fuzzy logic technology and based on the milk EC - acquired on-line for each gland by dedicated sensors - and on new qualitative and quantitative indexes derived from the spectrum of the recorded signals.

Material and Methods

The experiment was carried out for two weeks. Ten healthy Saanen goats at second lactation were randomly selected from a herd of 400 dairy goats. The animals were milked twice a day (7:00 a.m. and 5:00 p.m.). Milking parlor had: a low-line design, self-locking gates and 2 platforms with 16 milking units and milking posts per platform. Milking parameters were: a pulsation rate of 90 cycles/min, a vacuum level of 40 kPa and a pulsation ratio of 60%.

Two individual milk samples were collected from each mammary gland, during the morning milking, and frozen. According to microbiological tests and SCC performed on collected samples results were classified as: Case 1 (C1) if SCC<1,000,000 cells/mL and no pathogenic microorganisms were found; Case 2 (C2) if milk samples had bacteriological tests positive for IMI; and Case 3 (C3) if SCC>1,000,000 cells/mL in 2 or more consecutive sampling

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days for non-physiological causes and without pathogenic microorganisms. Subsequently, samples classified in C1 were associated with healthy glands, while those in C2 and C3 with non-healthy mammary glands.

Five experimental milking clusters were used to measure on-line the EC (mS/cm) of gland milk (Zaninelli et al. 2015b). Estimated EC values were then calculated through a *moving-average* model (using the ten previous values of EC observations) and the relative deviations of EC between measured and estimated values were calculated.

From acquired electrical signals - and through a customised Matlab routine (The Mathworks, USA) - the Fourier frequency spectrum of each signal was calculated and other qualitative and quantitative indexes were determined: the bandwidth length and the three highest frequency peaks of each spectrum (Zaninelli *et al.* 2015b, 2015c).

All the EC data were evaluated by a multivariate model developed using the fuzzy logic technology. Input variables were: the EC deviations, the bandwidth length and the three highest frequency peaks of each frequency spectrum. After "defuzzification", a couple of sensitivity and specificity of the model was calculated for different cut-off levels. Finally, the cut-off level that allowed to reach a sensitivity of at least 80% was identified and the resulting pair of sensitivity and specificity was considered as the level of accuracy reached by the multivariate model.

Results and Discussion

The prevalence of bacteriological positive samples was 45.4% (n = 127). After the count of somatic cells in the milk samples, the resulting prevalence of glands with SCC > 1,000,000 and without pathogenic microorganisms was 2.9% (n = 8). No cases of SCC > 1,000,000 due to physiological causes were observed. The overall prevalence of samples from not healthy glands was 61.1% (n = 171) and no cases of clinical mastitis were observed.

As expected, not healthy glands showed higher mean value of SCC and of milk EC (Diaz *et al.* 2011, Romero *et al.* 2012, Zaninelli *et al.* 2014, 2015a, 2015b, 2015c). The cut-off level for a sensitivity of at least 80% was equal to 0.7. With this cut-off level, the resulting specificity and sensitivity of the model were respectively: 73% and 81%. These results were better than those obtained by other multivariate and univariate models that use the EC of milk to detect healthy status of dairy goats. Nevertheless, these results cannot be considered enough if compared with those obtained in dairy cows (De Mol *et al.* 2001).

However, "fuzzification" and "fuzzy inference" are the most important steps in the fuzzy logic technique since they affect the final accuracy of the model. In order to maximise the model accuracy, they need to use a big experimental data set. Therefore, with the collection of further experimental data the accuracy of the multivariate model, evaluated in this preliminary investigation, should be improved.

Conclusions

This preliminary evaluation demonstrated that the fuzzy logic model tested, based on the milk EC and on new qualitative and quantitative indexes derived from the spectrum of the recorded signals, could show better results than those already reached in dairy goat research. Nevertheless, further experiment and more field data could be useful to reach the best possible accuracy that this multivariate approach could show.

References

De Mol R. M. & Ouweltjes W. (2001). Detection model for mastitis in cows milked in an automatic milking system. PREVENTIVE VETERINARY MEDICINE, 49(1-2), 71–82.

Diaz J. R., Romero G., Muelas R., Sendra E., Pantoja J. C.F., Paredes C. (2011). Analysis of the influence of variation factors on electrical conductivity of milk in Murciano-Granadina goats. J. DAIRY SCI., 94, 3885–3894.

Romero G., Pantoja J.C.F., Sendra E., Peris C., Díaz J.R. (2012). Analysis of the electrical conductivity in milking fractions as a mean for detecting and characterizing mastitis in goats. SMALL RUMIN. RES., 107, 157–163.

Tangorra F.M., Zaninelli M., Costa A., Agazzi A., Savoini G. (2010). Milk electrical conductivity and mastitis status in dairy goats: Results from a pilot study. SMALL RUMIN. RES., 90, 109-113.

Zaninelli M., Rossi L., Tangorra F.M., Costa A., Agazzi A., Savoini G. (2014). On-line monitoring of milk electrical conductivity by fuzzy logic technology to characterise health status in dairy goats. ITAL. J. ANIM. SCI., 13, 340–347.

Zaninelli M., Rossi L., Costa A., Tangorra F.M., Agazzi A., Savoini G. (2015a) Monitoraggio dello stato di salute delle capre attraverso l'analisi on-line della conducibilità elettrica del latte. LARGE ANIM. REV., 21, 81–86.

Zaninelli M., Agazzi A., Costa A., Tangorra F.M., Rossi L., Savoini G. (2015b). Evaluation of the fourier frequency spectrum peaks of milk electrical conductivity signals as indexes to monitor the dairy goats' health status by on-line sensors. SENSORS, vol. 15, 20698-20716

Zaninelli M., Rossi L., Costa A., Tangorra F.M., Agazzi A., Savoini G. (*2015c*). Signal Spectral Analysis To Characterize Gland Milk Electrical Conductivity In Dairy Goats. ITALIAN JOURNAL OF ANIMAL SCIENCE, vol. 14, 362-367