Evaluation of Cow Milk Electrical Conductivity Measurements

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Abstract
The efficiency of subclinical mastitis diagnosis using an electrical conductivity (EC) meter was evaluated in the dairy farm of Agricultural Research and Development Station (ARDS) Simnic Craiova. The results were compared with those obtained by using the California Mastitis Test (CMT) and the Somatic Cell Count (SCC).The milk quarter samples (1176) from Holstein Friesian cows were analysed between September and December 2015. The EC evaluation with the EC meter, showed a high proportion of results differing from SCC and CMT results. The CMT still shows to be the most accessible and efficient test in comparison to the EC meter tested.

Keywords: California Mastitis Test, electrical conductivity, somatic cell count.

1. Introduction

Sodium (Na), Chloride (Cl), lactose and potassium (K) are the solutes in milk which, largely determine the osmolarity of milk. The milk osmolarity is in a continuous equilibrium with the blood plasma osmolarity and which is kept virtually constant by the homeostatic mechanism of dairy cow. Therefore, the milk osmolarity is unchangeable, whether it is normal or abnormal milk as the mastitic milk [1]. If an increase of Na, which is always associated with an increase of Cl, occurs in an abnormal milk, the decrease of other milk constituent counterbalance it in order to keep the constancy of milk osmolarity.
Interrelation ships between the increases and the decreases in various milk constituents in the abnormal quarter milk were studied and simple correlations expressible by linear regression equations were found [1].
For several years many attempts had been made on application of the electrical conductivity test of milk for detection of subclinical mastitis. The electrical conductivity (EC) of milk is determined largely because of change in the concentration Na, K and Cl ions. Measurement of conductivity can therefore assist in the early identification of mastitis.
If the cow is affected by mastitis, the sodium and chloride concentrations increase determining an increment of EC value too, especially from the infected udder quarter.
Subclinical mastitis is considered the mast economically important type of mastitis because of long term effects on total milk yields. Diagnostic tests include individual cow Somatic Cell Count (SCC) values, the California Mastitis test (CMT), milk Electrical Conductivity (EC) and milk microbiology. Other tests, such as antimicrobial susceptibility tests are used to guide treatment decisions.
Bacterial culture from the milk has been considered as standard method for confirming subclinical udder infections in dairy cows (TDF, 1991), but it is not feasible as a routine test to detect mastitis. Tests as indicators of inflammation are therefore necessary.
Milk Somatic Cell Count (SCC) has been used extensively as an indicator of intra mammary

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infection (IMI) since the nineteen-six-ties. The threshold of 500000 cells/ml for a quarter has not been relevant. Using a lower threshold of SCC, 200000 cells/ml, for IMI has been evaluated in several studies [2].

The reported sensitivities range from 73.to 89 % and specificity from 75 to 85 %. Also, an SCC limit of 100000 cells/ml was suggested for a healthy quarter [1].

A healthy udder quarter with no bacterial growth contains less than 100000 cells/ml. Use of consecutive SCC records for individual cows makes the evaluation of the udder health status of the cow more reliable [3].

The use of EC measurement as a form of diagnosis of subclinical mastitis can be a valuable tool for the producers.

The present work evaluated diagnostic efficiency of subclinical mastitis using an EC meter, and comparing the results obtained with those obtained by CMT and SCC.

2. Materials and methods

Data were collected from 21 Holstein Friesian cows in the herd of Agricultural Research and Development Station (ARDS) Simnic-Craiova, for a period of 14 weeks between September and December 2015. Cows were milked through a 2x5 DeLaval herringbone milking system. The sampling was realized weekly (week 1, 3, 5, 7, 9, 11, 13 for morning milking, and week 2, 4, 6, 8, 10, 12, 14 for evening milking). All samples were collected to give weekly means resulting in a total of 1176 "quarter-weeks" of data for individual udder quarter values.

After all udder quarters were cleaned up by removing any possible dirt and washed with tap water, the teat and was dried and swabbed with cotton soaked in 70 % ethyl alcohol.

Approximately 50 ml was then collected aseptically from each quarter into sterile bottles, after discarding the first 3 milking streams. Samples from each quarter were transported to the laboratory of ARDS Simnic-Craiova and analyzed immediately.

The California Mastitis test was done according to the method, by mixing an equal volume of milk with 3 % sodium lauryl sulphate and bromocresol (DeLaval, Romania). Each udder quarter milk sample was placed in 1 clean well of a plastic test paddle, divided into 4 separate wells. As the plate was rotated gently, any color changes or formation of a viscous gel were interpreted. Scores were given within the range 0-3, with: score 0 for no reaction, score 1 for slight thickening of the mixture (reaction seems to disappear with continued rotation of the paddle; if all four quarters read 1 there is no infection, and if one or two quarters read 1, infection are possible), score 2 for distinct thickening of the mixture, but no tendency to form a gel (if the paddle is rotated more than 20 seconds, thickening may disappear, and score 3 for immediate thickening of the mixture, with gel formation. The CMT paddle was rinsed after each test.

Somatic cell counts were performed within 24 h of sample collection using a Soma Scope MK 2 Automatic analyzer (Delta Instruments, The Netherlands). The hart of the instrument is a fluorescence flow-cytometer specially developed for cell counting on a cell-by-cell basis rapidly and with a very high accuracy.

Electrical conductivity of each udder quarter milk was performed with the Cond 3310 meter (WTW, Germany) and Tetra Con 325 (WTW, Germany as measuring cell.

The General Linear Model procedure was used to analyze the data.

3. Results and discussion

The number (n) and relative frequency (%) of quarter herd test records classified for EC and quarter difference of EC are presented in table 1.

Quarter difference of EC (QdEC) for each quarter was calculated as the difference between EC value for that quarter and de EC value of the quarter with the lowest value within an individual cow.

Of the 1176 records 84.4 % were below 5.50 mS/cm (table 1), and 7.6 % of the quarters had values above 6.01 mS/cm. For QdEC, 88.7% of quarters had values below 0,3 mS/cm, and 3.7% had values above 0.5 mS/cm (Table 1).

Mean SCC for each class of EC as summarized in Table 2.

An udder quarter with EC greater than 5.76 mS/cm had a mean SCC in excess of 400.000 cell/ml (maximum admitted in raw milk). Each quarter was categorized as uninfected, with a SCC ≤ 200.000 cells/ml, or infected, with a SCC > 200.000 cell/ml and then this was related to the percentage of quarter which had an EC rose within 10% calculated from EC value of 5.0 mS/cm (normal value) and over 10 % EC rose (Table 3).

Table 1. Number (n) and relative frequency (%) of quarter herd test records classified for electrical Conductivity (EC) and quarter difference of EC (QdEC)

Class	EC mS/cm	N	%	QdEC mS/cm	N	%
1	5.00-5.25	160	13.6	0.0-0.1	102	8.7
2	5.26-5.50	804	68.4	0.1-0.2	941	80.0
3	5.51-5.75	87	7.4	0.3-0.4	42	3.6
4	5.76-6.00	36	3.0	0.4-0.5	47	4.0
5	6.01-6.25	57	4.8	0.5-0.7	24	2.0
6	6.25-6.50	32	2.8	0.7-0.9	20	1.7
Total	-	1176	-	-	1176	-

Table 2. Mean somatic cell Count (SCC) related to quarter Electrical Conductivity

	Quarter Electrical Conductivity (mS/cm)						**Total number or %**
	5.0-5.25	**5.26-5.50**	**5.51-5.75**	**5.76-6.00**	**6.01-6.25**	**6.26-6.50**	
Quarter SCC (x 1000)	70.5	110.8	198.7	600.4	649.0	680.8	-
Number (n)	160	804	87	36	57	32	1176
Relative frequency %	13.6	68.4	7.4	3.0	4.8	2.8	100

Table 3. Estimation of false positive and false negative EC values

Electrical conductivity	Quarter SCC ≤ 200.000 cells/ml (%	Quarter SCC > 200.000 cells/ml (%)	Total numbers
0-10	873 (74.2)	91 (7.7)	964 (82)
> 10 %	118 (10.0)	94 (8.0)	212 (18)
Total numbers	991 (84.2)	185 (15.7)	1176 n(100)

Below 10 percent, EC rose, 91 udder quarters had a SCC of more than 200.000 cells/ml and were described as false negative. Over 10 percent, EC rose, 118 udder quarters had a SCC of less than 200.000 cells/ml and were described as false positive. From this data the sensitivity was calculated and was 50.8 % and the specificity 88 %. The positive predictive value was 44.3 % and the negative predictive value was 90.5 %.

To use the conductivity change in the detection of mastitis high level of sensitivity and specificity is desirable to avoid "missing' infected cows or treating uninfected cow on necessarily.

Using a threshold of 200.000 cells/ml as recommended by International Dairy Federation, the data indicated a specificity of 88 % but a sensitivity of only 50.8 %, suggesting that a small percentage (12 %) of un infected cows would be wrongly identified and treated un necessarily but an unacceptable percentage (50.8 %) of infected cows (SCC > 200.000) would be missed.

When the quarters were diagnosed as positive for subclinical mastitis by EC (Table 4) 130 (11 %) had score of 0 an CMT and could be classified as false positive, while 227 (19.3 %) of the quarters were considered normal by EC and had scores 1:2 and 3 on CMT, being classified as false negative (Table 4).

Using the electrical conductivity meter 644 (54.8) of the quarters were evaluated correctly as quarters with normal milk.

A similar frequency of false positives (16.5) and higher of false negatives (47.7 %) were observed [4] and [5].

Electrical conductivity measuring can be converted into a computer readable signal and this method is easily applicable to on line automatic monitoring of udder health and can be installed in milking machine [3, 6].

Table 4. Diagnoses of subclinical mastitis by electrical conductivity and California Mastitis Test of 1176 individual quarter milk samples

Diagnosis by EC	California mastitis test				Total numbers (%)
	0	1	2	3	
Quarters with subclinical mastitis	130 (11.0)	64 (5.5)	60 (5.1)	51 (4.3)	305 (25.9
Quarters with normal milk	644 (54.8)	80 (6.8)	77(6.5)	70 (6.0)	871 (74.1)
Total numbers	774 (65.8)	144 (12.3)	137 (11.6)	121 (10.3)	1176 (100)

Mastitis is not the only factor affecting the ionic content of milk, and non-mastitis related variation in EC is a major drawback to the diagnostic value of EC [7].

4. Conclusions

● Over a 3 months period 18 % of quarter-weeks had an increase in quarter conductivity of 10 % on more compared to quarter conductivity of 5 mS/cm (normal quarter).
● Mean SCC was higher in quarter with a 10 % plus increase in conductivity, compared to quarters with a conductivity change less than 10 %.
● The EC evaluation through the EC meter tested showed a high proportion of results differing from SCC and CMT results.
● Estimated with SCC specificity of EC system was estimated to be 88 %, the sensitivity only 50.8 %.
Estimated with CMT, specificity of EC system was lower (83.2 %) and the sensitivity also lower (43.5 %) than estimated with SCC data. The CMT still shows to be the most accessible and efficient test as cow-side test.

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