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RESEARCH ARTICLE

ASSESSMENT OF MILK CONDUCTIVITY AND PH AS EARLY INDICATORS OF MASTITIS IN LACTATING DAIRY COWS

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ABSTRACT

Mastitis, especially in its subclinical form, remains one of the most prevalent and economically detrimental diseases in dairy farming. It leads to a reduction in milk yield, alters milk composition, and generates considerable economic losses due to decreased quality and increased treatment costs. Early detection is therefore crucial to limit both health impacts on the animals and financial losses for producers. This study was conducted at the Jéthro center, a semi-intensive dairy farm located in Burkina Faso, with the objective of assessing the relevance of two key physicochemical parameters—electrical conductivity (EC) and pH—as potential early indicators of mastitis. Four cows at different stages of lactation were selected randomly from a herd of 15, and 56 residual milk samples were manually collected from individual udder quarters over four sampling campaigns. The electrical conductivity of milk samples was measured using a calibrated conductimeter, while pH values were obtained via a laboratory pH meter following standard calibration procedures. The findings show that 92.86% of the quarters presented EC values below 6 mS/cm, a level generally associated with healthy mammary quarters. However, one quarter (7.14%) displayed a conductivity between 6 and 7 mS/cm, suggesting potential subclinical mastitis. Across all samples, pH values remained relatively stable, within the normal range for bovine milk (6.6 to 6.8), with no strong anomalies observed. These results highlight milk electrical conductivity as a more sensitive and responsive indicator of udder health compared to pH. While pH remained largely unchanged even in potentially infected quarters, EC exhibited measurable variations correlated with udder condition. The study supports the integration of EC measurements into routine herd monitoring as a practical, cost-effective, and non-invasive tool for early detection of mastitis, particularly subclinical cases. Additionally, improvements in hygiene practices—such as teat disinfection, individual cleaning cloths, and regular milking equipment maintenance—are recommended to reduce infection risks. In conclusion, the evaluation of milk EC, supported by pH monitoring, can serve as a valuable diagnostic approach in dairy herd management. Further research involving a larger number of farms and incorporating microbiological analyses would strengthen these findings and contribute to better prevention strategies.

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INTRODUCTION

Bovine mastitis remains one of the most prevalent and economically significant diseases affecting dairy cattle worldwide. It leads to substantial financial losses through decreased milk production, deterioration of milk quality, increased veterinary expenses, and premature culling of affected animals (**1, 2**). Mastitis can present in two distinct forms: the clinical form, which is easily identified by visible signs such as swelling, pain, and changes in milk appearance; and the subclinical form, which lacks overt symptoms but can cause equally severe damage. Subclinical mastitis is particularly problematic due to its silent nature, allowing the infection to persist undetected and spread within the herd, thereby compounding both health and economic impacts. Early detection of subclinical mastitis is therefore critical to enable timely and effective intervention, limiting the disease's progression and its consequences on herd productivity. Conventional diagnostic tools such as somatic cell count (SCC) and bacteriological culture are widely accepted and accurate; however, they are often labor-intensive, expensive, and unsuitable for frequent or real-time monitoring in large-scale dairy operations (**3**). In this context, increasing attention is being paid to indirect and on-farm diagnostic indicators, particularly the physicochemical properties of milk. Among these, electrical conductivity and pH have emerged as valuable parameters. During mammary gland inflammation, changes in epithelial integrity lead to increased permeability of the alveolar cell membranes. This disruption allows for the leakage of blood-derived ions—particularly sodium (Na^+) and chloride (Cl^-)—into the milk, thereby elevating its electrical conductivity (**4–6**). Similarly, the milk pH, which typically ranges between 6.6 and 6.8 under normal conditions, tends to rise during infection as a result of ionic imbalances and altered biochemical composition (**7, 8**). This study aims to evaluate the combined diagnostic potential of electrical conductivity and milk pH as practical, rapid, and cost-effective tools for the early detection of subclinical mastitis in dairy cows. The research contributes to a broader framework of mastitis prevention and control, essential for improving milk quality, enhancing herd health management, and promoting long-term sustainability and animal welfare in the dairy industry.

MATERIALS AND METHODS

Materials

Study Area: The samples were collected from the Jéthro Association farm, an agricultural and livestock training center situated in the village of Benda-Toeega, approximately 15 kilometers north of Ouagadougou, Burkina Faso. The farm is geographically positioned at 12°27'52.6''N latitude and 1°37'50.1''W longitude. It lies within the Sudanian-Sahelian zone, which is characterized by a short rainy season from June to September and high ambient temperatures frequently exceeding 30°C during the prolonged dry season. These climatic conditions create considerable thermal stress for livestock. The farm operates under an intensive livestock production system (Picture 1), driven by the scarcity of natural resources, particularly grazing land, which is increasingly affected by limited and erratic water availability. These environmental constraints necessitate strict herd management practices to safeguard animal health and maintain acceptable zootechnical performance. Within this context, the Jéthro center serves as an ideal setting for applied research. As both a training and experimental platform, it offers a controlled and practical environment for testing innovative animal health monitoring tools. This includes the assessment of milk physicochemical parameters—such as electrical conductivity and pH—as potential indicators for the early detection of subclinical mastitis in dairy cattle.

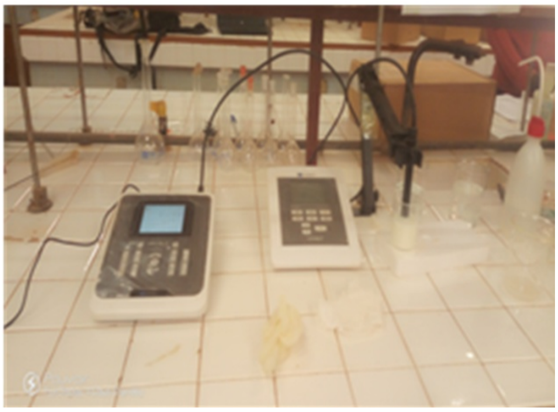
Picture 1. Feeding the cows

The experimental herd: The experimental herd was randomly selected from a group of fifteen (15) dairy cows housed within the same enclosure, in order to ensure that the sample accurately reflected the farm's general management and environmental conditions. The cows were fed a balanced diet consisting of hay, maize silage, and sorghum, supplemented with a concentrated ration composed of cottonseed meal and industrial maize bran. The concentrate was evenly distributed to all animals after milking and before forage distribution to optimize nutrient absorption and intake efficiency. Milking was performed mechanically twice per day, with individual milk yields reaching up to 20 liters per day during early lactation, then gradually declining as lactation progressed toward the dry period. The morning milking session began at 5:30 a.m., preceded by routine cleaning of the enclosure and rinsing of the teats with water. However, essential hygiene measures—such as post-milking teat disinfection or the use of individual drying towels—were seldom or never applied, potentially compromising udder health and milk quality. Over a one-week period, four sampling campaigns were carried out involving a subset of four dairy cows at different lactation stages. Among these, three cows exhibited no visible signs of mastitis, while the fourth had two non-functional quarters. Milk samples were collected manually at the start of each milking session, following proper cleaning of the teats and discarding of the first streams of milk, in line with hygienic sampling protocols. In total, 56 residual milk samples were obtained—one per quarter during each campaign—using sterile 30 mL tubes, each labeled with the corresponding cow and quarter identification. Samples were immediately stored in an ice-filled cooler for transport to the laboratory (Picture 2). For analyses that were delayed, the milk was kept at 4°C to ensure sample stability and support repeatability checks. The study focused on measuring the electrical conductivity (EC) of milk from each quarter. This parameter, which is inversely proportional to resistivity, is widely recognized as a potential marker for detecting subclinical mastitis.

Picture 2. Sample, sampling and packaging materials

Physicochemical Measurements

Electrical Conductivity: Measuring electrical conductivity makes it possible to evaluate the mineral content of a sample and serves as a sensitive indicator of changes related to chemical contamination (9, 10). Due to their ability to deliver fast results without the need for complex laboratory procedures, conductivity sensors are widely used in environmental monitoring (11). In laboratory settings, this parameter is typically measured using a conductivity meter, an instrument designed to precisely determine the electrical conductivity of milk. Milk electrical conductivity was measured using aMU6100 L multimeter set to conductivity mode (Picture 3) fitted with a CO11 graphite probe connected via cable. Prior to each measurement series, the device was calibrated with a standard conductivity solution, following the manufacturer's instructions. Measurements were carried out at ambient temperature (around 25°C), without applying temperature correction. To prevent cross-contamination, the probe was rinsed with distilled water after each use. Samples were analyzed on the day of collection or, at the latest, the following day. For improved result reliability, a second measurement was performed on a subsample stored at 4°C for 24 hours. The minimum immersion depth of the probe was maintained during all readings. Results are reported in millisiemens per centimeter (mS/cm).



Picture 3. Milk conductivity measurement

pH of milk: Milk pH was measured using a PHENOMENAL 1000L laboratory pH meter. Prior to measurement, the device underwent a three-point calibration using buffer solutions with pH values of 4.00, 7.00, and 10.00. The probe was successively immersed in each buffer to verify the instrument's stability and calibration slope, ensuring measurement accuracy. Analyses were conducted at room temperature, and the probe was rinsed with distilled water before each use. pH readings were recorded immediately once the display stabilized. Picture 4 shows an example of measuring the pH of milk.

Picture 4. pH measurement

Interpretation Criteria: The interpretation of the pH and electrical conductivity (EC) results for milk was based on references from the scientific literature.

Electrical conductivity (EC) (1, 12, 13):

Electrical conductivity values are classified into three ranges as follows:

- EC < 6.0 mS/cm: quarter considered healthy.
- 6.0 ≤ EC < 7.0 mS/cm: suspected subclinical mastitis.
- EC ≥ 7.0 mS/cm: quarter considered infected (probable subclinical mastitis).
- Milk pH: (**4, 7, 8**),

The normal pH range of milk from a healthy cow is between 6.6 and 6.8. A pH value below 6.6 may reflect acidification caused by fermentation processes, possibly indicating early acute mastitis or bacterial contamination. Conversely, a pH above 6.8 may suggest alkalinization, often associated with elevated levels of sodium (Na^+) and chloride (Cl^-) ions, as observed in certain cases of subclinical mastitis. These thresholds help identify at-risk quarters, in addition to other screening methods (cell tests, bacteriological examinations). Combining the two parameters (pH and EC) increases the reliability of early mastitis detection.

Statistical Data Analysis: Data on milk pH and electrical conductivity (EC) were recorded and analyzed using Microsoft Excel (Office 2010). The statistical analysis focused on calculating the means and standard deviations for each parameter, categorized by udder quarters and individual cows. Results were summarized in tables to allow clear visual interpretation. This approach helped identify significant variations potentially indicative of subclinical mastitis.

RESULTS AND DISCUSSION

Results

Table 1 below presents the values of electrical conductivity (EC) and potential of hydrogen (pH) for the different samples. Table 2 provides Mean and standard deviation of EC and pH by district, and Table 3 gives the EC values according to the interpretation ranges.

Table 1: conductivity (EC) and potential of hydrogen (pH) for the different samples The analysis of results highlighted several significant deviations from the reference thresholds defined in this study:

- **High conductivity:** quarter Q3 of cow 3 recorded a conductivity of 6.0 mS/cm, reaching the critical threshold and placing it in a high-risk category, suggesting possible subclinical mastitis.
- **Elevated pH:** The same quarter exhibited a pH of 6.70, slightly above the normal physiological range, which may indicate a disruption in the milk's ionic balance, commonly linked to inflammation.
- **Other quarters:** The remaining districts showed values within the healthy range, with conductivity between 4.45± 0.15 and 5.87± 0.39 mS/cm and pH between 6.6 and 6.8, consistent with normal udder health.

DISCUSSION

The results from conductivity and pH measurements revealed a clear correlation between these physicochemical parameters and the presence of clinical or subclinical signs of mastitis. - Electrical Conductivity (EC): quarters exhibiting EC values above 6 mS/cm were linked to visible abnormalities such as hardened teats, sensitivity during milking, or reduced milk yield. For instance, quarter Q3 of cow 4 showed an EC of 6.9±0.06 mS/cm, accompanied by decreased production and a slightly altered milk texture.

- **Milk pH:** Elevated pH levels above 6.8 frequently coincided with abnormal EC readings, indicating a disruption in the ionic balance of the mammary gland commonly caused by inflammation. Samples with pH values exceeding 6.87 consistently corresponded to increased EC.

These findings support the hypothesis that combining EC and pH measurements offers a reliable, rapid, and non-invasive approach for early detection of subclinical mastitis in dairy cows. Using established reference thresholds (conductivity > 6 mS/cm and pH > 6.8), udder quarters were classified as follows:

- **Healthy quarters:** 13 districts (92.9%) showed conductivity below 6 mS/cm and pH between 6.6 and 6.8, with no signs of clinical or subclinical mastitis.
- **Suspected case:** One quarter (7.1%), identified as quarter 3 of cow 4, exhibited conductivity of 6.9±0.06 mS/cm and pH of 6.87. This quarter had notably low milk production and slightly altered consistency, with no visible clinical symptoms, indicating subclinical mastitis.
- **Confirmed case:** No quarter showed simultaneously very high conductivity (>7 mS/cm), elevated pH (>6.8), and clear clinical symptoms (redness, pain, swelling), so no clinical mastitis cases were diagnosed.

This screening effectively identified a suspected subclinical mastitis case, highlighting the value of combined pH and conductivity measurements as early, practical tools for monitoring udder health.
Under normal physiological conditions, milk pH typically ranges from 6.6 to 6.8, reflecting a stable acid-base equilibrium. An increase in pH may signal inflammation or infection, as the development of mastitis often leads to the production of alkaline substances and disrupts the ionic balance of the milk. In contrast, a decrease in pH, usually resulting from bacterial fermentation, is commonly associated with secondary microbial contamination. Milk electrical conductivity is largely influenced by the concentration of dissolved ions, particularly sodium (Na^+), chloride (Cl^-), potassium (K^+), and calcium (Ca^{2+}). During mastitis, damage to mammary epithelial cells increases membrane permeability, allowing more Na^+ and Cl^- to enter the milk,

Table 1. conductivity (EC) and potential of hydrogen (pH) for the different samples

Cow 1

Essay	Quarters							
	Q1		Q2		Q3		Q4	
	CE	pH	CE	pH	CE	pH	CE	pH
E1	4.96	6.67	6.31	6.68	4.53	6.67	4.47	6.69
E2	4.9	6.63	4.51	6.67	4.83	6.73	4.69	6.82
E3	4.82	6.67	4.81	6.69	4.82	6.67	4.70	6.67
E4	5.13	6.65	5.00	6.70	5.13	6.74	5.18	6.75
E5	5.02	6.64	4.88	6.74	5.10	6.66	5.14	6.67
Average	4.97	6.65	5.10	6.70	4.88	6.69	4.84	6.72
Standard deviation	0.09	0.01	0.48	0.02	0.19	0.03	0.26	0.05

Cow 2

Essay	Quarters							
	Q1		Q2		Q3		Q4	
	CE	pH	CE	pH	CE	pH	CE	pH
E1	4.96	6.62	4.75	6.58	4.12	6.63	5.13	6.64
E2	4.55	6.65	4.20	6.73	4.42	6.72	4.40	6.73
E3	4.70	6.68	4.72	6.67	4.46	6.63	4.99	6.63
E4	4.61	6.67	4.84	6.67	4.67	6.65	4.80	6.61
E5	4,62	6.61	4.78	6.64	4.6	6.60	4.67	6.59
Average	4.69	6.65	4.66	6.66	4.45	6.65	4.80	6.64
Standard Deviation	0.11	0.02	0.18	0.04	0.15	0.03	0.21	0.04

Cow 3

Essay	Quarters							
	Q1		Q2		Q3		Q4	
	CE	pH	CE	pH	CE	pH	CE	pH
E1	4.58	6.63	4.76	6.63	4.29	6.64	4.43	6.65
E2	4.81	6.57	4.82	6.61	5.10	6.61	4.43	6.62
E3	4.87	6.66	4.69	6.58	4.53	6.60	4.44	6.60
E4	4.82	6.64	4.62	6.65	4.50	6.59	4.75	6.63
E5	4.75	6.64	4.58	6.63	4.46	6.63	4.70	6.64
Average	4.77	6.63	4.69	6.62	4.58	6.61	4.55	6.63
Standard Deviation	0.08	0.02	0.08	0.02	0.21	0.02	0.14	0.01

Cow 4

Essay	Quarters			
	Q3		Q4	
	CE	pH	CE	pH
E1	6.83	6.92	4.89	6.67
E2	6.85	6.85	6.05	6.71
E3	6.92	6.84	5.87	6.72
E4	7.05	6.88	6.29	6.60
E5	6.87	6.87	6.26	6.79
Average	6.90	6.87	5.87	6.70
Standard Deviation	0.06	0.02	0.39	0.05

Table 2. Mean and standard deviation of EC and pH by district

Cow	Quarters															
	Q1				Q2				Q3				Q4			
	CE	SD	pH	SD	CE	SD	pH	SD	CE	SD	pH	SD	CE	SD	pH	SD
1	4.97	0.09	6.65	0.01	5.10	0.48	6.70	0.02	4.88	0.19	6.69	0.01	4.84	0.26	6.72	0.05
2	4.69	0.11	6.65	0.02	4.66	0.18	6.66	0.04	4.45	0.15	6.65	0.03	4.80	0.21	6.64	0.04
3	4.77	0.08	6.63	0.02	4.69	0.08	6.62	0.02	4.58	0.21	6.61	0.02	4.55	0.14	6.63	0.01
4									6.9	0.06	6.87	0.02	5.87	0.39	6.70	0.05

Tableau 3. Average EC values of the samples according to the interpretation domains

Total number	CEinterval	Number of quarter	%
14	< 6	13	92.86
	6 ≤ CE < 7	1	7.14
	≥ 7	0	0

which raises its conductivity. At the same time, concentrations of potassium and lactose decline, further contributing to these changes. Therefore, a marked rise in conductivity—especially when accompanied by a pH shift from the normal range—serves as an early indicator of subclinical mastitis. When analyzed together, these two parameters provide a more reliable means of detecting udder health issues than when assessed separately. The average electrical conductivity (EC) values observed in this study for healthy quarters, ranging from 4.45± 0.15 and 5.87± 0.39 mS/cm, are consistent with those reported by several authors, such as Hamann and Zecconi (1998) (14) and Jacquinet (2009) (15), who consider a maximum threshold of 6 mS/cm for an uninfected quarter. Similarly, The average pH measured, ranging from approximately 6.6 to 6.8, aligns with the standard physiological values observed in the milk of healthy cows. This range reflects a stable acid-base balance and indicates the absence of significant inflammatory or microbial disturbances in the mammary gland, as reported by Gwandu, S. H et *al*. 2018 (8)andBrodziak Aet *al*. 2021 (16).For quarters with conductivity values greater than 6 mS/cm, the observed elevation confirms the presence of a subclinical inflammatory state, in accordance with the results of Hillerthon and Walton (2000) that associate an increase in conductivity with a rupture of tight junctions in the mammary gland due to mastitis (17).Similarly, the slight exceedance of the normal pH in these quarters suggests an alteration of the acid-base balance, often linked to bacterial multiplication and the production of organic acids in the milk, which is consistent with studies conducted by other authors (18-20).

CONCLUSION

The study demonstrated that measuring the electrical conductivity and pH of milk is a valuable tool for the early detection of subclinical mastitis in dairy cows. The results show that the majority of quarters analyzed had conductivity and pH values within the standard thresholds defined in the literature for a healthy condition. However, some quarters exhibited significant deviations, indicating a risk or probable presence of subclinical mastitis, thus confirming the sensitivity of these parameters to udder abnormalities. Furthermore, the observed correlation between increased conductivity and decreased pH in the suspected quarters underscores the combined relevance of these two indicators for improving diagnostic reliability. Despite some limitations related to normal physiological variations and sampling conditions, these simple and rapid methods offer an effective and non-invasive means of herd health monitoring. Future prospects: Electrical conductivity and pH of milk are recognized as sensitive and early indicators of udder health abnormalities in dairy cows. Conductivity reflects ionic variations in milk, primarily due to the infiltration of sodium and chloride ions, which increase during inflammation caused by mastitis. An elevated conductivity above normal levels is therefore an early warning sign indicating a possible infection, often before the onset of clinical signs. Meanwhile, milk pH directly reflects the metabolic and biochemical changes associated with inflammation. In cases of mastitis, the pH tends to decrease due to increased lactose fermentation and acid production, indicating an acid-base imbalance in the udder. Measuring pH and conductivity together thus improves diagnostic specificity, as it allows for the simultaneous detection of different but complementary physiological changes. Combining these two parameters therefore offers a rapid, inexpensive, and non-invasive method for the early detection of mastitis, facilitating prompt intervention and the prevention of more serious complications. This relevance is largely confirmed by experimental and field studies, making them practical and effective tools for health monitoring in dairy farming. The results obtained in this study, while promising, remain limited by the small sample size and the specific characteristics of the farming environment. To strengthen the validity and generalizability of the conclusions, it would be beneficial to expand the study to a larger number of herds, distributed across different regions and farming conditions. This expansion would allow for the evaluation of the robustness of conductivity and pH parameters as early indicators of mastitis in various contexts, while taking into account environmental and nutritional factors that may influence the measurements. Furthermore, the integration of detailed microbiological analyses of infected milk samples is an essential step to validate and refine the relationship between physicochemical changes in milk and the specific presence of pathogens. These analyses would not only confirm suspected cases identified by variations in pH and conductivity, but also identify the bacterial strains involved and their susceptibility to treatments. By combining physicochemical data with microbiological results, it will be possible to develop more precise and targeted screening protocols, facilitating proactive mastitis management on farms. Finally, the use of portable devices for rapid field measurements could be evaluated within the framework of these expanded studies, in order to provide practical tools for farmers and veterinarians.

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Abbreviations

CE: Electrical Conductivity
pH: Potential of Hydrogen
SCC: Somatic Cell Count
SD: Standard Deviation
Q: quarter
E: Essay

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