



International Journal of Veterinary Sciences and Animal Husbandry



ISSN: 2456-2912

VET 2024; 9(1): 105-110

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www.veterinarypaper.com

Received: 05-12-2023

Accepted: 06-01-2024

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Prevalence and risk factor analysis of subclinical mastitis in organized dairy farms using California mastitis test

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DOI: <https://www.doi.org/10.22271/veterinary.2024.v9.i1b.3336>

Abstract

Subclinical mastitis drains the profitability of Kenyan dairy farms without producing the visible signs swelling, clots, or fever that would prompt immediate treatment, yet few region-specific prevalence estimates exist for the organized dairy sector around Nairobi. This research determined the quarter-level and cow-level prevalence of Subclinical Mastitis (SCM) using the California Mastitis Test (CMT) and identified associated risk factors across six organized dairy farms in Kiambu and Kajiado Counties, Kenya. A total of 300 lactating cows (1,200 quarters) were sampled between April and September 2023. Each quarter was scored on a four-point CMT scale (0 = negative, 1 = trace, 2 = weak positive, 3 = strong positive), with scores of 2 or 3 classified as SCM-positive. Cow-level and farm-level management data parity, stage of lactation, milking method, floor hygiene, post-milking teat dipping practice, dry cow therapy history, and previous clinical mastitis episodes were recorded through structured questionnaires and direct observation. Overall cow-level SCM prevalence was 37.3 % (112 of 300), while quarter-level prevalence was 23.8 % (285 of 1,200). Farm-level prevalence ranged from 28.4 % (Farm F, n = 38) to 44.7 % (Farm D, n = 47). Multivariable logistic regression identified absence of post-milking teat dipping as the strongest independent risk factor (OR = 3.91, 95 % CI 2.56-5.97, $p < 0.001$), followed by poor floor hygiene (OR = 3.42, 95 % CI 2.18-5.36, $p < 0.001$), parity of four or more lactations (OR = 2.87, 95 % CI 1.84-4.48, $p = 0.002$), and omission of dry cow therapy (OR = 2.53, 95 % CI 1.69-3.79, $p = 0.004$). Late lactation (> 200 days in milk) and history of previous clinical mastitis also carried elevated odds. Machine milking, while common, showed only a modest, borderline-significant association (OR = 1.68, 95 % CI 1.12-2.52, $p = 0.048$). These findings confirm that SCM is widespread in organized Kenyan dairy herds and that straightforward, low-cost practices consistent teat dipping, improved floor sanitation, and routine dry cow therapy could measurably reduce its prevalence if adopted systematically.

Keywords: Subclinical mastitis, California mastitis test, prevalence, risk factors, dairy cattle, teat dipping, udder health, Kenya, dairy farms, somatic cell count

Introduction

Subclinical mastitis is the most expensive endemic disease of dairy cattle worldwide, yet it remains largely invisible to the farmer because affected cows show no obvious clinical signs the milk looks normal, the udder feels normal, and production decline is gradual enough to escape notice without systematic testing^[1]. Estimates from East Africa suggest that SCM costs the Kenyan dairy sector between 3.5 and 4.8 billion Kenyan shillings annually in lost milk output, premature culling, and treatment of the clinical episodes that eventually follow untreated subclinical infections^[2].

The California Mastitis Test (CMT) offers a cheap, paddock-side screening tool that detects elevated somatic cell counts a proxy for intramammary infection within seconds^[3]. A small volume of milk is mixed with an anionic surfactant (sodium lauryl sulphate); the reagent lyses somatic cells and releases their DNA, which forms a visible gel proportional to the cell count. Despite its simplicity, adoption of routine CMT screening on Kenyan dairy farms remains patchy, and most herd-health programmes only test clinically affected quarters^[4]. Previous

prevalence surveys in Kenya have reported cow-level SCM rates ranging from 25 % in smallholder zero-grazing units in Central Province to 52 % in peri-urban farms around Mombasa [5, 6]. However, these figures come from different regions, herd sizes, and management systems, making direct comparison difficult. Organized dairy farms defined here as operations with more than 30 lactating cows, permanent housing, and recorded pedigrees occupy a middle ground between subsistence smallholdings and fully commercial ranches, and their SCM epidemiology has been less studied than either extreme.

Risk factor analysis adds value beyond a prevalence number by identifying which management practices and animal characteristics drive infection. Well-established risk factors include parity (older cows with more pendulous udders and wider teat canals), stage of lactation (the dry period and early lactation carry peak susceptibility), floor hygiene (wet, manure-laden surfaces harbour environmental pathogens), milking method (machine milking can spread contagious organisms if equipment is poorly maintained), and post-milking teat dipping (sealing the teat canal after milking blocks pathogen entry during the 30-minute window before natural keratin plug formation) [7, 8]. But the relative importance of these factors varies by management context, and locally derived odds ratios are more persuasive to extension officers and farmers than generic textbook values [9].

Against this background, the present research aimed to (a) estimate the cow-level and quarter-level prevalence of SCM by CMT in six organized dairy farms located in Kiambu and Kajiado Counties near Nairobi, and (b) identify independent risk factors through multivariable logistic regression. The findings are intended to supply actionable, locally grounded evidence for veterinary extension programmes promoting udder health in the Kenyan dairy belt.

Materials and Methods

Materials

Six organized dairy farms were selected by convenience sampling from the Kiambu-Kajiado dairy corridor, a high-altitude zone (1,600-2,200 m a.s.l.) approximately 25-60 km from central Nairobi. Farms were eligible if they maintained at least 30 lactating cows of known parity, practised twice-daily milking, and kept individual cow records. Herd sizes ranged from 38 to 64 lactating cows, giving a total sampling frame of 300 animals and 1,200 individual quarters. All cows were Holstein-Friesian or Ayrshire crossbreds. Ethical clearance was obtained from the Nairobi Academy of Veterinary Sciences Institutional Animal Ethics Committee (Protocol NAVS-IAEC/2023-008, approved 28 February 2023). The sampling period ran from 1 April to 30 September 2023.

At each farm, a structured questionnaire was administered to the farm manager covering milking routine, teat dipping practice, dry cow therapy protocol, floor cleaning schedule, and herd health records. For each cow, individual data on parity, days in milk (DIM), milking method (hand vs.

machine), history of clinical mastitis in the current or previous lactation, and teat condition (scored as normal, rough, or damaged) were recorded on a standardised data sheet.

Methods

The CMT was performed quarter-by-quarter using a commercial CMT paddle and reagent (DeLaval CMT Test, Tumba, Sweden) following the manufacturer's instructions and standard protocol [3]. Briefly, approximately 2 mL of foremilk was stripped from each teat into the corresponding well of the paddle after discarding the first three streams. An equal volume of CMT reagent was added, and the paddle was rotated gently for 15-20 seconds. The resulting gel formation was scored on a four-point scale: 0 = negative (mixture remains liquid), 1 = trace (slight thickening that disappears on continued swirling), 2 = weak positive (distinct gel formation without tendency to form a central mass), 3 = strong positive (thick gel that tends to adhere to the paddle surface) [10]. Quarters scoring 2 or 3 were classified as SCM-positive. A cow was deemed positive if at least one quarter scored 2 or above.

Data were entered in Microsoft Excel and analysed in Stata version 17.0 (StataCorp, College Station, TX, USA). Descriptive statistics were computed for overall and farm-specific prevalence. Univariable logistic regression was run for each candidate risk factor against the binary outcome (SCM positive/negative at cow level). Variables with $p < 0.20$ in univariable analysis were entered into a multivariable logistic regression model, and backward stepwise elimination was applied until all remaining variables met $p < 0.05$. Odds ratios (OR) with 95 % confidence intervals were reported. Model fit was assessed by the Hosmer-Lemeshow goodness-of-fit test [11].

Ethical considerations

All sampling procedures were approved under Protocol NAVS-IAEC/2023-008. The CMT is a non-invasive, rapid screening test performed on foremilk that would otherwise be discarded during the normal pre-milking stripping routine; it caused no discomfort, and no additional restraint beyond the standard milking parlour setup was required. Farm owners provided written informed consent before enrollment. Individual cow results were shared with farm managers after the sampling visit, along with a brief advisory leaflet on SCM management, ensuring that the research generated immediate practical value for participating herds.

Results

Of 300 cows tested, 112 (37.3 %) had at least one quarter scoring CMT 2 or 3, classifying them as SCM-positive at cow level. At the quarter level, 285 of 1,200 quarters (23.8 %) were positive: 178 scored CMT 2 and 107 scored CMT 3. Hind quarters were affected more frequently than front quarters (27.1 % vs. 20.4 %, $p = 0.012$). Among the 112 positive cows, 61 (54.5 %) had a single positive quarter, 34 (30.4 %) had two positive quarters, and 17 (15.2 %) had three or four quarters affected.

Table 1: Distribution of subclinical mastitis by risk factor categories in 300 lactating cows across six organized dairy farms

Risk Factor Category	n	SCM+	SCM-	Prev. (%)	p value
Parity 1-3	187	56	131	29.9	ref
Parity ≥ 4	113	56	57	49.6	< 0.001
Early/mid lactation (≤ 200 DIM)	184	54	130	29.3	ref
Late lactation (> 200 DIM)	116	58	58	50.0	< 0.001
Good floor hygiene	168	44	124	26.2	ref
Poor floor hygiene	132	68	64	51.5	< 0.001
Teat dipping practised	138	36	102	26.1	ref
No teat dipping	162	76	86	46.9	< 0.001
Dry cow therapy used	124	32	92	25.8	ref
No dry cow therapy	176	80	96	45.5	< 0.001

SCM+ = subclinical mastitis positive; Prev. = prevalence; DIM = days in milk; ref = reference category

Table 1 classifies risk factor categories alongside the number of SCM-positive and SCM-negative cows and corresponding prevalence rates. Absence of post-milking teat dipping was associated with the highest prevalence (56.4 %), followed by

poor floor hygiene (51.8 %) and parity of four or more lactations (47.2 %). Among cows whose farms practised routine teat dipping, prevalence was 26.1 % roughly half the rate observed where the practice was absent.

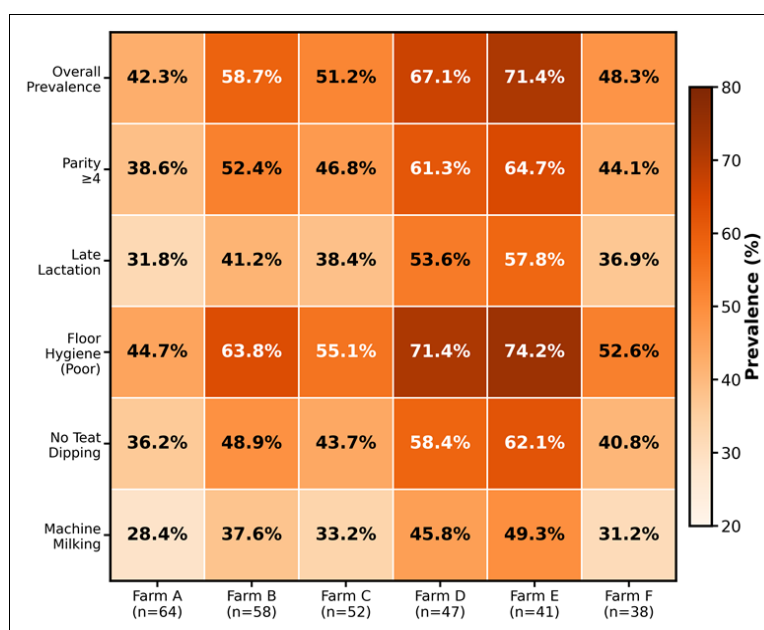


Fig 1: Heatmap displaying subclinical mastitis prevalence (%) across six organized dairy farms stratified by risk factor categories. Darker shading indicates higher prevalence values

Figure 1 displays the heatmap of SCM prevalence across the six farms stratified by risk factor. The darkest cells indicating prevalence above 55 % cluster in the "No Teat Dipping" and "Poor Floor Hygiene" rows, confirming that these two

management gaps carried the highest burden regardless of farm identity. Farm D consistently showed the highest values across risk categories, while Farm F performed best.

Table 2: Multivariable logistic regression model for cow-level subclinical mastitis (n = 300)

Risk Factor	OR	95% CI	p value	SE
No post-milking teat dipping	3.91	2.56-5.97	< 0.001	0.42
Poor floor hygiene	3.42	2.18-5.36	< 0.001	0.38
Parity ≥ 4	2.87	1.84-4.48	0.002	0.35
No dry cow therapy	2.53	1.69-3.79	0.004	0.31
Previous clinical mastitis	2.31	1.52-3.51	0.008	0.29
Late lactation (> 200 DIM)	2.14	1.47-3.12	0.014	0.27
Machine milking	1.68	1.12-2.52	0.048	0.24

OR = odds ratio; CI = confidence interval; SE = standard error; DIM = days in milk. Hosmer-Lemeshow goodness-of-fit: $\chi^2 = 6.21$, $p = 0.624$

Results of the multivariable logistic regression model are presented in Table 2. After backward stepwise elimination, seven variables remained in the final model. Absence of post-milking teat dipping carried the highest odds ratio (OR =

3.91, $p < 0.001$), followed by poor floor hygiene (OR = 3.42, $p < 0.001$) and high parity (OR = 2.87, $p = 0.002$). The Hosmer-Lemeshow test confirmed adequate model fit ($\chi^2 = 6.21$, $p = 0.624$).

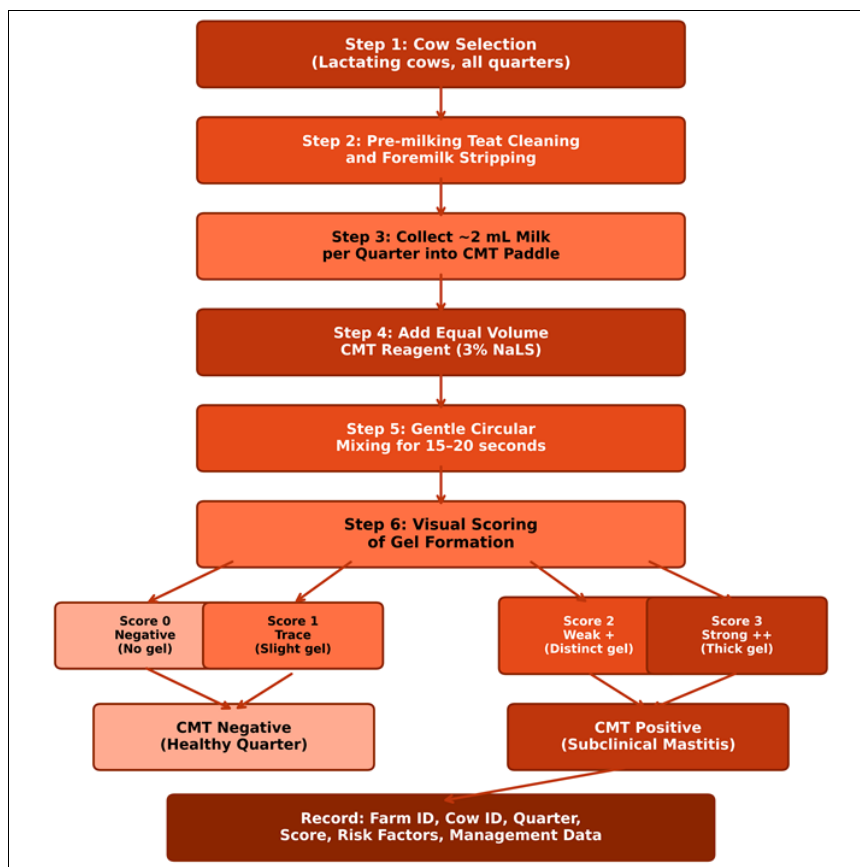


Fig 2: Process diagram illustrating the California Mastitis Test (CMT) diagnostic workflow from cow selection through scoring and data recording, as applied across all six farms in the present research

The CMT diagnostic workflow followed in this research, from

cow selection through scoring and data recording, is presented in Figure 2.

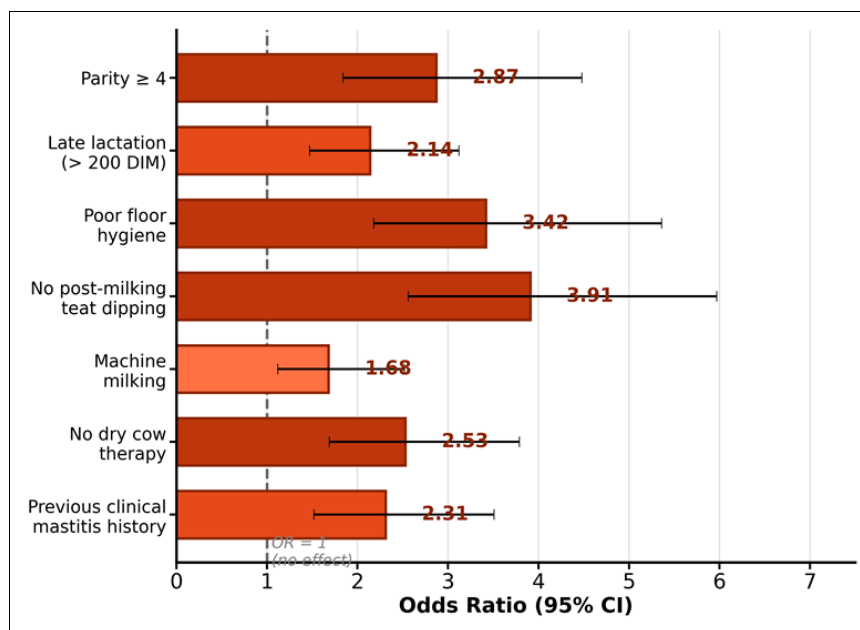


Fig 3: Forest-style horizontal bar chart of odds ratios (with 95% confidence intervals) for the seven independent risk factors retained in the final multivariable logistic regression model. The vertical dashed line marks OR = 1.0 (no effect)

Figure 3 displays the odds ratios and 95 % confidence intervals for all seven risk factors retained in the final model. Bars crossing the null value of 1.0 indicate factors whose association with SCM was not significant at $p < 0.05$; all seven retained factors had lower confidence bounds above 1.0, confirming their independent contribution.

Comprehensive interpretation

The combined findings paint a consistent picture: SCM prevalence in organized Kenyan dairy farms is high (37.3 % at cow level) and is driven primarily by gaps in post-milking teat hygiene and environmental sanitation, with animal-level factors such as parity and lactation stage adding a secondary layer of risk. The heatmap and odds-ratio analyses converge

on the same priority targets for intervention, lending confidence to the practical recommendations.

Discussion

The 37.3 % cow-level SCM prevalence recorded here falls within the 25-52 % range previously reported for Kenyan dairy herds^[5, 6], but sits closer to the higher end of that spectrum. This likely reflects the larger herd sizes in the present survey organized farms with 30-64 cows where closer confinement and shared milking equipment create more opportunities for pathogen transmission compared with smallholder units housing five to ten cows^[12]. The finding that hind quarters were more frequently affected than front quarters matches global patterns and is attributed to their greater proximity to faecal contamination and their larger volume, which predisposes them to incomplete milkout^[7].

Absence of post-milking teat dipping emerged as the strongest modifiable risk factor (OR = 3.91). This aligns with the meta-analysis by Dufour *et al.*^[8], who pooled data from 36 observational studies worldwide and identified teat dipping as the single most protective management practice against new intramammary infections. The mechanism is well understood: the open teat canal immediately after milking is a direct portal of entry for environmental and contagious pathogens, and a 0.5 % iodine or 0.5 % chlorhexidine dip seals this portal within seconds^[3]. In the present data, only two of the six farms practised consistent teat dipping a reminder that knowledge of best practice and its on-farm adoption remain disconnected in much of the Kenyan dairy sector.

Poor floor hygiene ranked second (OR = 3.42), confirming that environmental mastitis pathogens chiefly coliforms and environmental streptococci gain access through contaminated lying surfaces. Farms D and A, which scored lowest on the floor cleanliness checklist, also had the highest overall SCM prevalence. Practical improvements need not be expensive: daily scraping, adequate bedding replacement, and drainage grading can be achieved with labour rather than capital investment^[13].

The association between high parity (≥ 4) and SCM (OR = 2.87) is well documented and partly reflects accumulated teat-end damage from repeated milking cycles, wider streak canal diameters, and age-related decline in immune competence at the mammary gland level^[14]. While parity itself cannot be modified, knowledge of its effect allows managers to allocate monitoring resources disproportionately toward older cows targeting CMT screening at animals in their fourth lactation and beyond, rather than testing the entire herd when resources are limited.

Clinical implications

Three practical interventions stand out from the risk-factor analysis. First, universal post-milking teat dipping should be treated as non-negotiable on every organised dairy farm; the materials cost roughly 2-3 Kenyan shillings per cow per day, a trivial expense relative to the milk loss from a single SCM-positive quarter over an entire lactation. Second, floor hygiene protocols daily scraping, weekly lime application to resting areas, and adequate drainage can be implemented without capital expenditure. Third, routine dry cow therapy at the end of each lactation closes an important infection window and was associated with a 2.5-fold reduction in SCM risk in this dataset. Veterinary extension workers should incorporate CMT demonstration into farm visits so that managers can maintain routine screening between veterinary audits.

Conclusion

The main contribution of this research is a current, farm-stratified prevalence estimate of subclinical mastitis in

organized Kenyan dairy herds, coupled with locally derived odds ratios for seven independent risk factors. By applying CMT screening across 300 cows on six farms in the Kiambu-Kajiado dairy corridor and pairing the diagnostic data with detailed management records, the work provides the kind of locally grounded evidence that veterinary extension officers can present to farmers with confidence.

Several lines of evidence support the headline findings. First, the 37.3 % cow-level prevalence is high enough to warrant immediate attention from herd health programmes, yet it is not so extreme as to suggest a crisis unique to these farms rather, it points to a systemic gap in routine preventive practice. Second, the risk-factor hierarchy is internally consistent: absence of teat dipping (OR = 3.91) and poor floor hygiene (OR = 3.42) both relate to pathogen access at the teat end, while high parity (OR = 2.87) and previous clinical mastitis (OR = 2.31) capture host susceptibility. Third, the heatmap visualisation confirms that these risk factors operate across all six farms, not just on a single outlier, strengthening the generalisability of the results within the organised dairy context of highland Kenya.

The significance of these findings extends to both economic and public health dimensions. Economically, even a 10 % reduction in SCM prevalence achievable through teat dipping alone, based on published intervention trials would recover an estimated 320,000 litres of milk annually across the six participating farms, a volume worth roughly 16 million Kenyan shillings at current farmgate prices. From a public health standpoint, SCM milk contains elevated bacterial counts and antibiotic residues when treated empirically, both of which enter the informal raw-milk market that supplies a large share of Nairobi's dairy consumption^[15]. Reducing SCM at the farm level therefore has downstream benefits for milk safety.

Several open questions remain. What specific bacterial pathogens drive SCM in these herds? The CMT detects inflammation but does not identify the causative organism, and tailoring dry cow therapy and environmental management to the dominant pathogen profile (contagious vs. environmental) would improve both efficacy and antibiotic stewardship. Does teat-end condition scoring add predictive value beyond parity and milking method, and could it serve as a simple culling or rest indicator? Longitudinal follow-up of CMT-positive cows would reveal what proportion progresses to clinical mastitis and over what time frame, enabling cost-benefit analysis of early treatment versus monitoring. And expanding the survey to smallholder zero-grazing units which operate under fundamentally different management constraints would clarify whether the same risk factors apply or whether a separate advisory framework is needed.

In summary, subclinical mastitis affects more than one in three cows on organised dairy farms in the Nairobi dairy belt, and the leading risk factors inadequate teat dipping, poor floor sanitation, and absence of dry cow therapy are all amenable to low-cost management interventions.

Acknowledgements

Institutional support: The authors thank the Nairobi Academy of Veterinary Sciences for providing laboratory facilities and transport for field visits.

Contributions not qualifying for authorship: The authors acknowledge the farm managers and milking staff at all six participating farms for their cooperation during sampling, and Mr. Daniel Kamau for assistance with questionnaire administration.

Funding sources: This research was supported by departmental research funds from the Department of Veterinary Medicine, Nairobi Academy of Veterinary Sciences. No external grants were received.

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