

Research Article

Association of Cow Drying off Practices with Milk Yield and Udder Health Outcomes in Peri-Urban Smallholder Dairy Herds

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Abstract

In peri-urban smallholder dairy herds, farmers face challenges in drying off cows due to a lack of evidence-based recommendations. This study examined the associations between cow drying-off practices, mean milk yield at drying off and during early successive lactation, and the odds of mastitis and udder leakage cases in herds around Nakuru city, Kenya. A cross-sectional survey of 232 cows across 172 herds was conducted. Mean milk yield was determined using a general linear model, while the odds ratios for mastitis and udder leakage were estimated using a binary logistic regression model, with drying-off practice, cow breed, and dairy management intensification as explanatory variables. All the three explanatory variables were significantly associated ($p < 0.05$) with mean milk yield at drying off, early successive lactation, and the occurrence of mastitis and udder leakages. Cessation of milking (57.3%) was more common than abrupt cessation (42.7%). Mean milk yield was 2.6 liters/day at drying off and 13.4 liters/day during early successive lactation. Teat sealants were applied to cows producing more than 5 liters/day, while gradual reduction in milking, complete cessation of milking, or dry-cow therapy was used for cows producing less than 3 liters/day. During early successive lactation, cows dried off using teat sealant, salt application, stopping concentrate feeding, or gradual reduction in milking produced more milk (14 liters/day) than those dried off by abrupt cessation or dry-cow therapy (10-12 liters/day). Relative to abrupt cessation, the odds of mastitis and udder leakage were lower ($p < 0.05$) with dry-cow therapy (odds ratio 0.12; 0.12), gradual cessation of milking (odds ratio 0.22; 0.29), or stopping concentrate feeding (odds ratio 0.14; 0.26). The study found that gradual reduction in milking (47%) and abrupt cessation of milking (22%) were the most common drying-off practices. These methods are effective for cows producing less than 3 liters/day at the start of drying off and do not result in milk loss during early successive lactation. However, abrupt cessation of milking is more likely to result in poor udder health outcomes. Though teat sealant was rarely used (3.9%), it proved effective for cows producing more than 5 liters/day, maintaining milk production and udder health during early successive lactation. These findings provide crucial insights for farmers on selecting appropriate drying-off practices to optimize milk yield and udder health.

Keywords

Smallholders, Dairy Intensification, Milk Production, Cow Welfare, Mastitis, Udder Leakages

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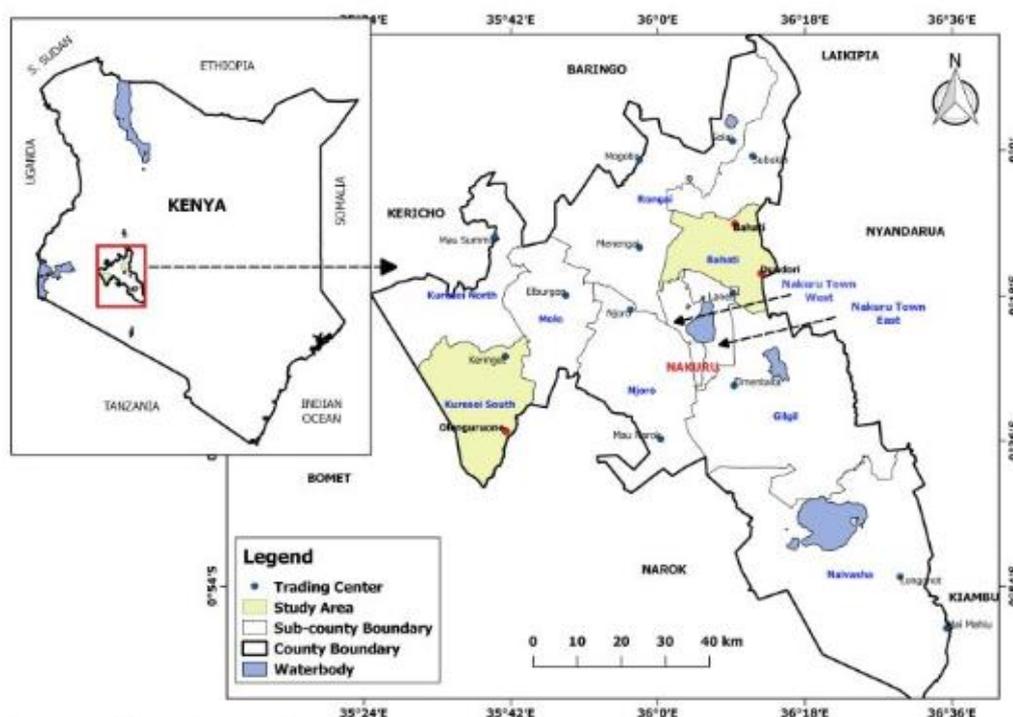
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1. Introduction

Dairy farming is a source of regular nutrition and income for smallholder farmers and these benefits are from milk in herds which often comprise of just one or two cows. Under a production circumstance of just a cow or two, the level of milk yield that is optimal for drying off a cow is a challenging decision to farmers because milk is a source of daily high-quality food and a continuous stream of income. This implies that cow drying off, a stressful phase of lactation during which milking is ceased briefly to prepare a cow for the next lactation cycle, presents managerial challenges to smallholder farmers [1]. Drying off triggers several physiological responses with implications on stimulation of the immune system, udder health and welfare status, cow fertility, and milk production [2, 3]. During dry-off when transitioning from a lactating to a no-lactating phase, is a sensitive, stressful phase for dairy cows that signals heightened sensitivity to intermammary infection [4, 5]. The cow drying off phase can magnify production, health and welfare concerns, and therefore choice of a drying off practice present managerial challenges to farmers. The managerial challenges of cow drying off could be greater in the peri-urban smallholder dairy herds where farmers are intensifying production to attain high lactation milk yield [6].

Smallholder peri-urban dairy production around Nakuru city in Kenya have been described as more entrepreneurial and market-orientated but with limited production factors and scarcity of fodder, replacement heifers, and labor [7]. Their entrepreneurial and market-orientated can impact on their cow

drying off management decisions, evidence by application of variable production strategies. Some of the farmers are described as being economically positive deviants while some remain typical in their management practices [8]. With production orientated to high input use for high output and high productivity per cow, cow drying off practices is an important management decision for farmers that needs evidence informed intervention [9]. Better market access and higher milk prices in the peri-urban areas encourage good husbandry practices, but empirical evidence is lacking on whether the good husbandry practices are mainstreamed in cow drying off practices [10]. Though the evidence shows potential associations of drying off practices with milk production and udder health the nature of associations in smallholder peri-urban dairy cows remains a knowledge gap [11]. Yet there are several cow drying off practices that extension service advises farmers to implement, but with rare or without accessible empirical evidence relevant to smallholder dairy production circumstances. Closing this knowledge can better inform effective cow drying off management strategies for attaining optimal productivity and udder health, especially incidence of mastitis and udder leakages [12]. These consequential concerns motivated this study to determine the associations that drying off practices has with mean milk yield at drying off and during early successive lactation and with the odds for cases of mastitis and udder leakages.



Source: Google Maps

Figure 1. Map of the peri-urban areas of Nakuru County, Kenya.

2. Material and Methods

2.1. Study Area

The research was carried out in four wards (Lanet, Njoro, Kabatini, and Lare) around the peri-urban areas of Nakuru City, as illustrated in [Figure 1](#). Lanet and Kabatini are within the Bahati sub-county which covers an area of 375.4 km² while Njoro and Lare are wards within the Njoro sub-county with an area covering 713 km². Bahati sub-county lies between longitudes 35 °28' and 35 ° east and Latitude 0 °13' and 10 °10' South at an altitude of about 1912 meters above sea level. This sub county covers an area of 375.4 km² with an estimated population of 141,352 (KNBS, 2019). Njoro sub-county lies between latitude 00 ° 19' 00" S and longitude 36 ° 06' 00" E in Low Highlands (LH3) and Upper midlands (UM4) ecological zones with an altitude of 2168m to 2800 m above sea level. The temperatures range from a minimum average of 10°C during the cold months of July to August and 20°C during the hot months (January to March). Rainfall is bimodal, with long rains (March to April) and short rains (October to December).

In the study area, dairy cattle may be managed under free-grazing, semi-zero-grazing or zero-grazing, which in that order represent an increasing level of dairy intensification management. Milk may be marketed through formal or informal market outlets. Mastitis infections are prevalent and cow drying-off practices are variable, with use or without use of antimicrobial drugs [13].

2.2. Study Design and Sampling Process

This research was conducted in four peri-urban wards (Lanet, Njoro, Kabatini, and Lare) around Nakuru city, Kenya. An inventory of the target dairy farms was prepared in consultation with the local ward livestock extension staff. A total of 232 cows with successive lactations were sampled in a cross-sectional survey of 172 herds. In the study area, uptake of dairy cattle breed is high, utilized as pure or crossbreed genotype. Dairy cattle are managed under free-grazing, semi-zero-grazing or zero-grazing, which in this order represent an increasing level of dairy intensified management. Milk is predominantly marketed through informal market outlets. Mastitis infections are prevalent and farmers deploy different cow drying off practices, with or without use of antimicrobial drugs [14].

The study was a cross-sectional observational survey in which the sample unit was a cow with immediate successive lactations. To access the lactating cows, dairy herds were selected randomly from the list availed by the local extension officers who also facilitated access to the selected herds. In each herd visited, all cows present with successive lactations after drying off were examined. This is because smallholder dairy farms in the peri-urban area of Nakuru have a mode of

just one cow on the farm [15]. The owners of selected herds were individually contacted to explain the purpose of the study and to request consent for their participation. This helped to ensure that informed consent is obtained from the farmers to guarantee their willingness to participate and share information details needed on their lactating cows for this study.

2.3. Data Collection

A structured questionnaire was administered to farm owners during the farm visit. The data of interest was cow drying off practice for a cow with immediate successive lactation. When found, each cow was then examined by direct observations, examining farm records, and probing for history of drying off practice, milk yield at the moment of commencing drying off and during early subsequent lactation, the breed or genotypes, and management intensification. Further probing was deliberately directed to identifying cases of mastitis and udder leakages observed in in the present lactation. This approach was to improve the quality of data captured on milk production, cases of mastitis and udder leakage.

2.4. Data Analysis

The data was enter in excel for cleaning and verification process and later exported to SPSS for analysis. The milk yield at drying off and during early successive lactation were fitted to general linear model with drying off practice, breed of cow and intensified management being specified fixed factors. For count data on mastitis or udder leakage cases, a logistic regression model was specified to estimate the odds ratio of positive binary outcome with predictors being also of drying off practice, breed of cow and intensified management.

3. Results

3.1. Sample Description

The description of the sample cows by intensified management, breed, drying off practice and cases of mastitis and udder leakage is presented in [Table 1](#). About half of the herds (44.5 percent) were managed at high intensification level (under semi-zero- and zero-grazing) and slightly more than half (55.0 percent) managed at low intensification level (free-grazing). In these herds, the large dairy cattle breeds (Holstein Friesian and Ayrshire) predominated (78.9 percent) over the small dairy breeds (6.9 percent) and cross breeds which included Sahiwal (14.2 percent).

About two thirds (66.8 percent) of the cows were dried off under 60 days, more frequently by a gradual reduction of milking (47.0 percent) or a complete stop of milking (22.0 percent). Results reveal that less than one fifth of the cows tested positive for mastitis (17.7 percent) or experienced udder leakage (21.1 percent) during early successive lactation.

The descriptive statistics of production variables of the sample cows (Table 2) reveal that on average, a farm had just one cow with successive lactations, with large variation in milk

yield. At the drying off the average milk yield per cow was 2.6 l/day and during early successive lactation was 13.4 l/day.

Table 1. Description of the sample cows by intensified management, breed, drying off practice and cases of mastitis and udder leakage.

Variables	Frequency	Percent
<i>Intensified management</i>		
Free grazing	128	55.2
Semi-zero grazing	25	25.8
Zero grazing	19	19.0
<i>Types of Breeds</i>		
Large breeds	183	78.9
Other	33	14.2
Small breeds	16	6.9
<i>Length of drying of period</i>		
≤60 days	155	66.8
> 60 days	77	33.2
<i>Drying off practices</i>		
Gradual reduction of milking	109	47.0
Complete stop of milking	51	22.0
Dry cow therapy	28	12.1
Stop feeding concentrates	24	10.3
Apply salt	11	4.7
Apply teat sealant	9	3.9
<i>Cases of mastitis</i>		
Negative	191	82.3
Positive	41	17.7
<i>Cases of udder leakage</i>		
Negative	183	78.9
Positive	49	21.1

Table 2. Descriptive statistics of production variables for the sample cows (n=232).

Variables	Units	Mean	SD	Min	Max
Cow with successive lactation	Number/farm	1.3	0.1	1.0	5.0
Milk yield at drying off	Litres/day	2.6	1.9	0.5	13.0
Milk yield during early successive lactation	Litres/day	13.4	5.2	1.0	33.0

3.2. Milk Yield at Drying off and During Early Successive Lactation Associated with the Different Drying off Practices

Table 3 presents the least square means of milk yield at the moment of drying off and during early successive lactation by the different drying off practices, breed of cow and intensified management. Mean milk yield differences ($p < 0.05$) were observed with drying off practices, breeds and the intensified management. A general pattern that emerges is that cows producing more 5 litres/day were dried-off by applying teat sealant while those that were producing less than 3 litres/day were dried-off by a gradual reduction in milking, a complete stop of milking or application of dry-cow therapy. Cows that were producing between 3 and 5 litres/day were dried-off by stopping feeding concentrate or applying salt. At drying off, the larger breeds were producing more than 3 litres/day while the small breeds (Guernsey and Jersey) and the other cattle breeds (Sahiwal and crossbreeds) were producing less. Cows

managed at high intensified management (zero-grazing) were dried off when producing more than 3 litres/day while those managed at low intensified management (free-grazing) were dried-off when producing less than 3 litres/day.

Milk yield during early successive lactation cycle also showed differences ($p < 0.05$) with drying off practices, breed of cow and intensified management. During early successive lactation, cows previously dried-off by applying teat sealant, salt, stopping feeding of concentrate or a gradual reduction in milking produced more milk (14 litres/day) while those that had been dried-off by a complete stop of milking or dry cow therapy produced less (10 - 12 litres/day). The large dairy breeds produced more milk than the small dairy breeds or the other cattle breeds (16 vs 10-13 litres/day). At high intensified management (zero-grazing) cows were producing more milk (14.9 l/day) than those managed at low intensified management represented by free-grazing (12.7 litres/day).

Table 3. Milk yield (litres/day) at drying off and during early successive lactation associated with the different drying off practices, breeds of cow and intensified management.

Factors	n	At drying off	During early successive lactation
<i>Drying- off practices</i>			
Gradual reduction of milking	109	2.3±0.2 ^a	14.4±0.6 ^{b, c}
Complete stop of milking	51	2.4±0.3 ^a	10.4±0.8 ^a
Dry cow therapy	28	2.3±0.4 ^a	12.2±0.1 ^a
Stop feed concentrate	24	3.2±0.4 ^b	15.3±1.1 ^c
Apply salt	11	4.8±0.6 ^b	15.0±1.5 ^c
Apply teat sealant	9	5.3±0.3 ^c	15.1±1.6 ^c
<i>Types of Breeds</i>			
Large breeds	183	3.4±0.2 ^a	16.1±0.5 ^a
Small breeds	16	2.6±0.4 ^b	13.3±1.3 ^b
Other breeds	33	2.1±0.5 ^b	10.2±0.9 ^b
<i>Intensified management</i>			
Free grazing	128	2.4±0.3 ^b	12.7±0.7 ^b
Semi-grazing	66	2.6±0.3 ^b	13.7±0.9 ^{a, b}
Zero grazing	44	3.4±0.3 ^a	14.9±0.9 ^a

Means with different letter superscripts within a fixed factor differ at $p < 0.5$

3.3. Udder Health During Early Successive Lactation Associated with the Different Drying off Practices

The odds ratio estimates presented in Table 4 reveal that occurrence of mastitis cases was associated ($p < 0.05$) with the drying off practice, breed of cow and intensified management. Mastitis cases were less likely to occur with dry-cow therapy (odds ratio 0.12), gradual stopping of milking (odds ratio 0.22)

or stopping feeding concentrate (odds ratio 0.14) relative ($p < 0.05$) to complete stop of milking. Application of salt or teat sealant had no association with occurrence of mastitis case. The cows of large breeds (odds ratio 0.21) and other breeds (odds ratio 0.24) were less likely to have mastitis cases compared to the cows of small dairy breeds. Also, cows in high intensified management (semi-zero- and zero-grazing) were less likely to have mastitis cases (odds ratio 0.22 -0.29) compared to cows in low intensified management (free-grazing).

Table 4. Cases of mastitis during early successive lactation associated with the different drying off practices, cow breed and intensified management.

Predictor variables	Frequency	Percent positive	Odds ratio	95% CI	Sig
<i>Drying off Practices</i>					
Apply salt	11	27	0.38	0.10—1.41	0.147
Apply teat sealant	9	33	0.50	0.13—1.20	0.327
Dry cow therapy	28	10.7	0.12*	0.04—0.40	0.001
Gradual reduction of milking	109	21.1	0.27*	0.17—0.42	0.001
Stop feeding concentrate	24	12.0	0.14*	0.04—0.48	0.002
Complete stop of milking	51	11.6	Ref		
<i>Types of Breeds</i>					
Large breed	184	17.4	0.21*	0.14—0.31	0.001
Other breeds	33	15.0	0.24*	0.10—0.63	0.004
Small breed	15	26.7	Ref		
<i>Intensified management</i>					
Free grazing	128	15.2	Ref		
Semi-zero-grazing	60	18.3	0.22*	0.12—0.43	0.001
Zero grazing	44	22.7	0.29*	0.15—0.59	0.001

*Significant association $p < 0.05$

From Table 5 results, udder leakage cases were associated ($p < 0.05$) with drying off practice that farmer deployed, breed of cow and intensified management. The cases of udder leakage were less likely to occur with dry-cow therapy (odds ratio 0.12), gradual reduction of milking (odds ratio 0.29) and stopping feeding concentrates (odds ratio 0.26) compared to complete stop of milking. Application of salt or teat sealant showed no association with udder leakage cases. Also, cases

of udder leakage were less likely among the large dairy breeds (odds ratio 0.27) and among other breeds (odds ratio 0.22) relative to small dairy breeds. The odds ratio further indicate that cases of udder leakages were less likely for cows managed under high intensification (odds ratio of 0.12 to 0.33 in semi-zero and zero-grazing) in comparison to cows managed under low intensification (free-grazing).

Table 5. Cases of udder leakage during early successive lactation associated with the different drying off practices, breeds of cow and intensified management.

Predictor variable	Frequency	Percent positive	Odds ratio	95% CI	Sig
<i>Drying off Practices</i>					
Apply salt	11	18.2	0.22	0.05—1.03	0.054
Apply teat sealant	9	33.3	0.50	0.13—2.00	0.327
Dry cow therapy	28	10.7	0.12*	0.04—0.40	0.001
Gradual reduction of milking	109	22.9	0.29*	0.19—0.46	0.001
Stop feeding concentrate	24	20.8	0.26*	0.10—0.71	0.008
Complete stop of milking	51	21.6	Ref		
<i>Types of Breeds</i>					
Large breed	184	21.2	0.27*	0.19—0.38	0.001
Other breeds	33	18.0	0.22*	0.09—0.54	0.001
Small breed	15	26.0	Ref		
<i>Intensified management</i>					
Free grazing	128	16.0	Ref		
Semi-zero- grazing	60	28.3	0.12*	0.07—0.200	0.001
Zero grazing	44	25.0	0.33*	0.17—0.66	0.002

*Significant associations $p < 0.05$

4. Discussion

In the study sample, about half of the herds (44.8 percent) being intensified dairy management (semi-zero- and zero-grazing) is an indication of a trend to intensify dairy production in the peri-urban areas. Intensification of dairy management is characterized by high use of external input directed to attaining high milk productivity [9]. Accelerating the uptake of intensified dairy management is better market access and higher milk prices in the peri-urban areas. Attaining high milk productivity could however present management decision challenges for farmers regarding determining the optimal level of milk yield when to dry off a cow because milk is a source of continuous stream of quality nutrition and income [10].

Studies on dry period management in cows emphasize the importance of proper drying protocols because milk productivity, fertility, udder health and cow welfare are sometimes compromised [16]. In this study sample, cows were mostly dried off early, within 60 days duration (66.8 percent). The optimal length of drying off cows is between 42 and 70 days for yield and quality of milk, good udder health and reproductive performance [17]. Shorter or longer drying period than this is associated with reduced milk yield, poorer udder health and lower fertility rates during the successive lactation due to al-

terations in mammary gland function and metabolic processes [18]. Early drying off may have a favorable influence on milk yield in the successive lactations [19]. However, a decrease in milk production as a result of early drying off period and attributed this to less developed mammary gland [20]. The consistency in milk yield across the drying off periods may indicate stable conditions or effective management practices [21].

Cow drying off practices are either gradual cessation of milking (gradually reducing milking frequency and feeding concentrates) or abrupt cessation of milking (teat sealant and salt application, dry cow therapy, and completely stopping milking). In the sample herds, more frequent practice of gradual cessation of milking (57.3 percent) than abrupt cessation of milking (42.7 percent) could be that it assures continued access to milk for food and income in herds with just one lactating cow. With gradual cessation of milking, there is a gradual reduction in daily source of nutritious food and stream of income for the family under a production circumstance of just one lactating cow. Supporting this explanation is the prominent livelihood roles that dairy cows play in smallholder households [22].

With a production circumstance of a herd of just one cow piling pressure of assuring a continuous supply of milk, the decision to dry-off a cow in peri-urban smallholder dairy herds would seem to be about how to optimally cease milking without compromising milk supply. Therefore, frequently

drying off cows by gradual reduction of milking or complete stop of milking (69 percent) would seem the practices most fitting strategy of easing piling pressure for assuring a continuous supply of milk. These two drying off practices, deployed for cows producing less than 3 litres/day, seems to offer additional advantage of being associated with more milk (10 to 14 litres/day) during early successive lactation and associated with less likelihood of cases of mastitis and udder leakages (Tables 4 and 5).

Less frequently practiced was abrupt cessation of milking, which may be pointing to uncertainties about udder health outcome. Supporting this explanation is application of teat sealant to cows producing more than 5 litres/day while gradual reduction in milking was practiced for cows producing less than 3 litres/day. However, the choice between gradual and abrupt cessation of milking seems to present challenging managerial decision to farmers. A mix of gradual cessation of milking (gradual reduction in milking) and abrupt cessation of milking (completely stopping milking and applying dry-cow therapy) were practiced for cows producing less than 3 litres/day. The observation could also mean that drying off practice is decided on individual cow basis. However, supportive literature on cow drying off practices is scanty, even for industrial dairy herds [23]. As farmers find themselves under this prevailing situation, they do not receive from the extension service uniform recommendations on optimal cow drying off practices supportive to milk production and good udder health during successive lactation cycle.

In the sample herds, a strong association between certain drying-off practices with milk yield at drying off could be a pointer that farmers do consider milk yield when deciding on a drying off practice for individual cows. With both gradual and abrupt cessation of milking practiced for cows producing less than 3 litres/day of milk, this level of milk yield (3 litres/day) could be considered an indicative threshold for farmers' decision over which drying-off practice to deploy.

In the present study sample, mean milk yield of 5.3 litres/day at drying off likely indicate that some cows were dried off when milk yield is still high because the average milk yield in smallholder herds is less than 10 litres/cow/day [24]. For high milk yielders, abrupt cessation of milking is recommended because cows would produce more milk in the successive lactation [25]. In the present study sample, cows producing more than 5 litres/day were dried off deploying abrupt cessation of milking with teat sealant application. However, farmers rarely dry off cows using teat sealant (3.9 percent), though it can be applied for cows producing more than 5 litres/day without loss of milk production during early successive lactation and without adverse effects on udder health. During early successive lactation, a cow produced an average of 13.4 litres/day, with cows previously dried-off using teat sealant producing more milk (14 litres/day). Furthermore, application of teat sealant had no association with cases of mastitis and udder leakages occurring (Tables 4 and 5). The findings strongly suggest that for the study sample, farmers would realize higher milk

productivity with low risk to udder health during early successive lactation when drying off cows by either gradually reducing milking or abruptly stopping milking, but decision has to be on individual cow basis.

In the study sample, large breeds predominated (78.9%) over the small breeds (6.9%) and other breeds which included Sahiwal (14.2%). Farmers prefer large breeds for their high milk yield potential, which they associate with more incomes, as milk marketing in Kenya is on volume basis. The explanation corroborates with findings in the Kenya highlands where large breeds dominated (62 percent) over small dairy breeds (16 percent) and over other breeds (22 percent) [10]. Large breeds producing more milk than the small breeds at drying off and during early successive lactation is consistent with genetic potential for higher milk yield among the large dairy cattle breeds [26]. Though were high milk yielders, the large breeds had the advantage of being less likely to experience mastitis and udder leakages during early successive lactation. This can be explained by low milk yield at drying off of 3.4 litres/day.

Cows under high intensification management produced more milk than those under low intensification at drying off and during early successive lactation, which can be linked to better husbandry and feeding supplying concentrates and minerals, and energy conserved in the housing unit. The level of milk yield at drying off was low (3.4 litres/cow/day) to expose cows to risk of mastitis and udder leakages during early successive lactation.

Considerations about cow udder health outcome is an important component in cow drying off practice because udder infections can lead to higher somatic cell counts, incidences of mastitis, and bacterial contamination, with adverse impact on milk yield and quality. To follow on concerns about udder health, mastitis and udder leakages were selected proxy indicators of cow udder health outcome. The results suggest that cases of mastitis and udder leakage would be higher for cows dried-off with abrupt cessation of milking (complete stop of milking). Yet this was the second most frequent drying off practice that smallholder farmers deployed. Because mastitis prevalence in the peri-urban smallholder dairy herds can exceed 80 percent, choice of drying off practice can be considered one of the explanatory factors for high mastitis prevalence in these herds [13, 27]. High mastitis prevalence is indicative of poor husbandry practices, especially udder hygiene practices, and is a predisposing factor for development of antimicrobial resistance, which is associated with frequent treatment of mastitis infections [28]. In the study sample, application of salt or teat sealant for cow drying off had no association with occurrence of mastitis case, which suggest there are alternative good practices that farmers may adopt.

5. Conclusion

This study found that gradual reduction of milking and abrupt stopping are common drying-off practices in peri-urban smallholder dairy herds. While both can be used for cows producing less than 3 liters/day without affecting early lactation milk yield, abrupt stopping increases the risk of poor udder health. Teat sealants, though less commonly used, are effective for cows producing over 5 liters/day, maintaining milk yield and udder health. This information is valuable for dairy farmers and extension services.

Abbreviations

DCT	Dry Cow Therapy
DIM	Days in Milk
IMI	Intermammary Infection
SCC	Somatic Cell Count

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Author Contributions

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Disclosure Statement

The authors report no potential conflict in the publication of the manuscript.

Conflicts of Interest

The authors declare no conflicts of interest.

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Research Fields

Landing Sonko: Livestock Production Systems, Animal Health/Welfare Status, Antimicrobial Use in Livestock Production, Livestock Management Practices, Animal Nutrition, Animal Breeding

Bockline Omedo Bebe: Livestock Production Systems, Animal Health/Welfare Status, Antimicrobial Use in Livestock Production, Livestock Management Practices, Animal Nutrition, Animal Breeding

James Ombiro Ondiek: Animal Nutrition, Livestock Production Systems, Animal Health/Welfare