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Pascal Nyabinwa
a) Department of Animal Sciences, Faculty of Agriculture, Egerton University, P.O. Box 536-20115, Egerton, Kenya
b) Rwanda Agriculture and Animal Resources Development Board, P.O. Box 5016, Kigali-Rwanda

Olivier Basole Kashongwe
a) Department of Animal Sciences, Faculty of Agriculture, Egerton University, P.O. Box 536-20115, Egerton, Kenya.
b) Department of Engineering for Livestock Management, Leibniz Institute for Agricultural Engineering and Bioeconomy, Max-Eyth-Allee 14469 Potsdam

Claire d'Andre Hirwa
Rwanda Agriculture and Animal Resources Development Board, P.O. Box 5016, Kigali-Rwanda

Bockline Omedo Bebe
Department of Animal Sciences, Faculty of Agriculture, Egerton University, P.O. Box 536-20115, Egerton, Kenya

Corresponding Author:
Pascal Nyabinwa
a) Department of Animal Sciences, Faculty of Agriculture, Egerton University, P.O. Box 536-20115, Egerton, Kenya
b) Rwanda Agriculture and Animal Resources Development Board, P.O. Box 5016, Kigali-Rwanda

Influence of endometritis, cow- and herd-levels factors on milk yield and reproductive performance of zero-grazed dairy cows on smallholder farms in Rwanda

Pascal Nyabinwa, Olivier Basole Kashongwe, Claire d'Andre Hirwa and Bockline Omedo Bebe

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Abstract
Suboptimal milk production and reproductive performance manifest in postpartum dairy cows likely reflect associations with the characteristics of the dairy herd management conditions and endometritis infection. The hypothesis was that endometritis, cow- and herd-levels variables, and the combination of all these variables are associated with suboptimal milk yield and reproductive performance of postpartum zero-grazed dairy cows managed on smallholder farms. This research was conducted in Gasabo district, Rwanda, to the smallholder dairy farmers from September 2018 to August 2019. The survey was used to collect the data from 370 farms on 466 cows, sampled by snowball technique. Regression models and the general linear model were used in the analysis. The results showed that in a decreasing magnitude, the milk yield was predicted by cow breed [regression coefficient (β): −2.6, $p < 0.001$], endometritis infection (β = −1.1, $p < 0.001$), poor body condition (β = −1.0, $p < 0.05$), and mastitis positive case (β = −0.8, $p < 0.05$). For reproductive performance, an increase of one case of anoestrous postpartum and one endometritis positive case was associated with a delay of 64 and 21 days to days- not pregnant, respectively ($p < 0.001$). Anoestrus postpartum case was more likely to increase by 1.3% if endometritis case increases by 1.0% ($p < 0.001$). These results reveal the important predictor variables of endometritis, reduced milk yield, and suboptimal fertility performance in postpartum dairy cows. This should inform the basis of management interventions for improved milk production and reproductive performance towards smallholder dairy herd profitability and sustainability.

Keywords: Anoestrus postpartum, dairy herd, days- not pregnant, endometritis, risk factors

Introduction

Endometritis is a postpartum uterine disease that affects the reproduction and productivity of dairy cows [1]. The disease manifests as clinical endometritis (CLE) and/or subclinical endometritis (SCLE) [2]. The cows positive for endometritis had longer days-not pregnant, prolonged calving intervals, low conception rate at first service, high cost of medication, drop in milk production, and reduced calf crop, resulting in reduced profitability of the dairy herd [1, 3, 4]. Globally, the prevalence of endometritis vary between 3.6 to 69.8% for CLE [5, 6], and between 6.7 to 89.0% for SCLE [7, 8].

In Rwanda, 92.0% of herds are managed under the smallholder zero-grazing system. Endometritis disease is prevalent in smallholder zero-grazed dairy herds. The prevalence is as great as 71.1% at the herd-level and 70.2% at the cow-level, with CLE reaching 68.1% at the herd-level and 67.2% at the cow-level while SCLE is 34.4% at the herd-level and 31.8% at the cow-level [2]. This high prevalence resulted in suboptimal fertility performance and lower milk production. Endometritis positive cows had longer days-open (95.5 vs 63.0 days), lower pregnancy rate at first service (16.5 and 32.7%, respectively), more services per pregnancy (1.3±0.1 and 1.1±0.0, respectively), and more anoestrus postpartum cows (48.4 vs. 11.7%) compared to endometritis negative cows [9]. Relative to endometritis negative cows, endometritis positive cows can drop milk production by 15.3%, about 1.4 litres/cow/day [10]. To minimize these adverse effects, it is, therefore, desirous for extension service and smallholder dairy farmers to implement four-group endometritis prevention and control plan [11].

Previous studies have shown the risk factors such as retained placenta, body condition score, season of calving, cow breed, and parity that are associated with poor reproductive performance and reduced milk yield [12, 13, 14, 15]. These risks were also considered as a potential for endometritis occurrence [8, 16, 17]. Analyzing concurrently the effect of these variables and endometritis on production and reproductive performance could give the insights on which one has the greatest association with reduced milk yield and/or suboptimal fertility performance of dairy cows. Knowing these relative weights could help extension service and smallholder farmers in making informed decisions on appropriate corrective management interventions targeting high-risk factors and therefore improve herd health and profitability. For researchers, these relatives may indicate priorities for further research and development. Unfortunately, the effect of the combination of cow– and herd-characteristics and endometritis on milk yield and reproductive performance of dairy cows is less studied. However, they have implications for the success of the herd health management program, profitability, and sustainability. This study is pioneering in estimating the contribution of cow- and herd- variables and endometritis on milk production and reproductive performance of zero-grazed dairy cows managed on smallholder farms in Rwanda.

Materials and methods

Data source

The data for this study was collected from smallholder zero-grazed dairy farms in Gasabo district, Rwanda. The study area is approximately within latitude 1°52' S and longitudes 30°06' E and at an elevation of 1800-meter above sea level. The area has a bimodal rainy fall pattern that averages 1000 mm annually, with an annual mean temperature of 22°C [18]. The district was chosen because of more prevalent dairy zero-grazing farms than the other districts [19] and a high prevalence of endometritis [2]. A full detailed description of the sampling procedures is described in [2]. Briefly, the study involved a total of 370 dairy farms selected through snowball sampling. Four hundred sixty-six (466) cows within their 21-60 dpp at sampling were enrolled.

Data collection

On each farm visited, all sampled cows and herds were examined for endometritis and risk factors thought to influence the occurrence of endometritis. The milk production and reproductive performance data were collected in a prospective observational design for 30 days post-endometritis diagnosis and up to 210 dpp, respectively. A full detailed description of the data collection procedures is described in [2, 10, 11, 17].

Data analysis

Cow- and herd-variables, endometritis, fertility, and milk variables were the model inputs to estimate the influence of endometritis and cow- and herd-variables on the production and reproductive performance of smallholder zero-grazed dairy cows. The regression coefficients were from the regression models fitting the cow- and herd-variables and endometritis as explanatory variables for fertility measures or daily milk yield (DMY) as an outcome. In this study, days-not pregnant (DNP) and anoestrous postpartum (ANPP) were considered as overall indicators of reproductive efficiency status in dairy cows [20, 21, 22].

Cows were categorized as having low or high DMY, based on whether they were below or above the median 30-day milk yield of the study cows (7.5 litres) in the lactation after endometritis diagnosis.

Linear regression models were run using SPSS procedures to assess the relationship between predictor variables (cow- and herd-variables and endometritis status) and the response variable (DNP or DMY). The model was specified as follows:

$$Y_i = \beta_0+\beta_1 X_{i1} + \beta_2 X_{i2} + \beta_3 X_{i3} + \cdots + \beta_n X_{in} + \beta_e X_e + \varepsilon_i$$

Where Y is predicted or response variable (DNP or DMY), β_0 is the common intercept parameter, β_1 to β_n are the regression coefficients for X_{i1} to X_{in} (predictor variables: cow-level and herd-level variables) included in the model, n is the number of predictor variables included in the statistical model, β_e is the regression coefficient for endometritis status (X_e), and ε is the random error term. From this analysis, the predictor variables with the most contribution ($p< 0.05$) to the observed variations in predicted variable were selected for subsequent analysis using the general linear model procedure to determine differences in DNP or DMY between the level of the predictor variable.

Logistic regression analysis was used to assess the effect of predictor variables (cow- level variables, herd-level variables, and endometritis) on ANPP. It was also used to analyze the risk factors associated with endometritis. The model was specified as follows:

$$log\left(\frac{p}{1-p}\right) = \beta_0+\beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \cdots + \beta_n X_n + \varepsilon$$

where p indicates the probability of an event (predicted variable: ANPP or endometritis), $\frac{p}{1-p}$ is the odds ratio, β_0 is the common intercept parameter, β_1 to β_n are the regression coefficients of each X_i (predictor variables) included in the model, n is the number of predictor variables included in the statistical model, and ε is a random error term. A regression coefficient value shows a change in response variable associated with a unit change in the predictor variable [23]. These analyses were performed using Statistical Package for the Social Sciences (SPSS) version 20.0 for Windows package software [24]. The significance was set at alpha 0.05 level.

Results

Predictors of endometritis cases in smallholder zero-grazed dairy cows

Table 1 presents the predictor variables of endometritis case. The results indicate that rainy season, dystocia, and dirty cowshed were important predictors ($p< 0.001$) of endometritis cases. The other predictor variables were poor body condition (BCS<3), retained placenta, mastitis, cow breed (improved breed), not using bedding materials, mastitis, and earthen floor in the cowshed. Holding all other predictors constant, endometritis case was more likely to increase by 1.8% if cows calving in the rainy season increases by 1.0%. The improved breed positively ($p< 0.05$) influences endometritis cases. Thus, increasing the number of improved breed by one improved breed is likely to increase endometritis by 0.9%. Endometritis cases were more likely to increase by 0.6% if mastitis case increases by 1.0%. Increasing the number of dirty cowshed by 1.0% increases endometritis cases by 2.8%. Endometritis cases were more likely to increase by 1.7% if the number of cowshed with mud floors increases by 1.0%. Also, increasing the number of cows with dystocia cases by 1.0% increases endometritis cases by 1.2%, holding other factors constant.

In contrast, variables such as sex of the calf, cow parity, twin births, herd size, farm size, farmers' experience in dairy farming, and calving pen were not significant ($p > 0.05$) predictors of endometritis cases in zero-grazed dairy cows managed on smallholder farms.

Table 1: Cow's characteristics and herd management practices predicting endometritis case in zero-grazed dairy cows

Predictor variables	β	S.E (β)	P-value
Calving pen (presence vs. Absence)	-0.1	0.7	0.917^{NS}
Season of calving (rainy vs. dry)	1.8	0.3	0.000***
Twin births (yes vs. no)	0.2	1.3	0.741 ^{NS}
BCS at 21-60 dpp (BCS<3 vs. BCS>3)	1.2	0.4	0.001**
Retained placenta (Occurrence vs. non-occurrence	1.1	0.4	0.010*
Stillbirth (Occurrence vs. non-occurrence)	0.9	0.7	0.019*
Cow breed (Improved vs. local)	0.9	0.4	0.027*
Famers' experience in dairying (≥8 vs. <8 years)	0.1	0.3	0.661 ^{NS}
Bedding materials (not using vs. using)	0.9	0.4	0.020*
Mastitis (positive vs. negative)	0.6	0.3	0.041*
Herd size (≥3 vs. <3 cows)	0.3	0.3	0.442 ^{NS}
Cow parity (primiparous vs. multiparous)	0.1	0.3	0.741 ^{NS}
Cleanliness of cowshed (dirty vs. clean)	2.8	0.4	0.000***
Sex of the calf (Female vs. male)	-0.1	0.3	0.792 ^{NS}
Cowshed flooring (earthen vs. concrete)	1.7	0.4	0.001**
Farm size (≥3 vs. <3 acres)	-0.3	0.3	0.366 ^{NS}
Dystocia (occurrence vs. non-occurrence)	1.2	0.3	0.000***
Intercept	-0.9	1.1	0.490 ^{NS}

***$p < 0.001$, **$p < 0.01$, *$p < 0.05$, ^{NS} $p > 0.05$, β = regression coefficient, *S.E* = Standard error of the regression coefficients.

Predictors of days-not pregnant in smallholder zero-grazed dairy cows

The influence of different predictor variables of days- not pregnant (DNP) is shown in Table 2. The most important predictors of DNP were endometritis (p = 0.001) and anoestrous postpartum (p = 0.001). An increase of one case of endometritis was associated with a delay of 21 days to DNP, while when anoestrus postpartum case is increased by one, DNP is delayed by 64 days. In contract, milk yield, mastitis, BCS, parity, cow age, retained placenta, season of calving, dystocia, cow breed, and stillbirth were not significant ($p > 0.05$) predictors of DNP.

Table 2: Final model for outcome variable DNP, parameter β, standard error, and probability for predictor variables

Predictor variables	β	S.E (β)	P
Intercept	190.5	30.6	0.001***
BCS (<3 vs. ≥3)	−1.7	6.1	0.779^{NS}
Mastitis (positive vs. negative)	−4.6	4.4	0.298^{NS}
Parity (primiparous vs. multiparous)	0.8	4.9	0.866^{NS}
Cow age (<5 vs. ≥5)	2.5	5.8	0.670^{NS}
Retained placenta (occurrence vs. non-occurrence	12.5	9.3	0.182^{NS}
Endometritis (positive vs. negative)	21.3	5.8	0.001***
Season of calving (rainy vs. dry)	−3.4	5.9	0.562^{NS}
Dystocia (occurrence vs. non-occurrence)	2.4	4.7	0.614^{NS}
Cow breed (improved vs. local)	1.2	4.9	0.806^{NS}
Daily milk yield (high vs. low)	−0.1	0.7	0.938^{NS}
Anoestrus postpartum (yes vs. no)	64.1	5.1	0.001***
Stillbirth (Occurrence vs. non-occurrence)	6.4	7.9	0.422^{NS}

^{NS} not significant ($p > 0.05$), ***$p < 0.001$

Table 3 presents the differences in DNP between the levels of the important predictors of DNP. There was a significant difference in DNP between cows positive and negative for endometritis. Cows positive for endometritis had a delay of almost 35 days to DNP relative to negative ones. The difference was also significant between cows that experienced anoestrous postpartum and cows that did not. Cows that experienced anoestrous postpartum had 70 more days to conception than those that did not.

Table 3: Effect of significant variables on DNP

Predictor variables	Days not pregnant, Mean±SEM	P-value
Endometritis		
Positive	104.1±5.0	***
Negative	69.5±3.9	
Anoestrus postpartum		
Yes	134.1±4.2	***
No	64.0±2.5	

***$p< 0.001$.

Predictors of anoestrus postpartum in smallholder zero-grazed dairy cows

Variables influencing ANPP are presented in Table 4. The result revealed that only endometritis was an important predictor ($p< 0.05$) of ANPP case. Thus, ANPP was more likely to increase by 1.3% if endometritis case increases by 1.0%. Variables such as mastitis, parity, age of cow, retained placenta, season of calving, dystocia, and cow breed were not significant ($p> 0.05$) predictor of ANPP case.

Table 4: Final model for outcome variable anoestrus postpartum, parameter β, standard error, and probability for predictor variables

Predictor variables	β	S.E (β)	P
Intercept	−0.8	0.1	0.001***
Endometritis (positive vs negative)	1.3	0.2	0.001***
BCS (<3 vs ≥3)	−1.7	6.1	0.779^{NS}
Mastitis (positive vs negative)	−4.6	4.4	0.298^{NS}
Parity (primiparous vs multiparous)	0.8	4.9	0.866^{NS}
Age (<5 vs ≥5)	2.5	5.8	0.670^{NS}
Retained placenta (occurrence vs non-occurrence	12.5	9.3	0.182^{NS}
Season of calving (Dry vs rainy)	−3.4	5.9	0.562^{NS}
Dystocia (occurrence vs non-occurrence)	2.4	4.7	0.614^{NS}
Cow breed (Local vs improved)	1.2	4.9	0.806^{NS}
Daily milk yield	−0.1	0.7	0.938^{NS}
Stillbirth (yes vs no)	6.4	7.9	0.422^{NS}

^{NS} not significant ($p> 0.05$), ***$p< 0.001$

There was a significant difference ($p< 0.05$) in the anoestrous postpartum case between cows positive and negative for endometritis (48.4% and 11.7%, respectively).

Predictors of daily milk yield in smallholder zero-grazed dairy cows

Table 5 presents the predictor variables of DMY. Cow breed, poor body condition (BCS<3), mastitis, and endometritis were important ($p< 0.05$) predictors of DMY. As mastitis case increases by 1.0%, DMY decreases by 0.8%. Similarly, increasing the number of endometritis positive cases by one positive case is likely to decrease DMY by 1.1%. The cow breed positively ($p< 0.05$) influences DMY. Thus, increasing the number of indigenous local breed by one indigenous local breed is likely to decrease DMY by 2.6%. Parity, age, and calving season did not affect DMY ($p> 0.05$). Similarly, the presence of dystocia and stillbirth cases did not influence DMY ($p> 0.05$).

Table 5: Final model for outcome variable DMY, parameter β, standard error, and probability for predictor variables

Predictor variables	β	S.E (β)	P
Intercept	8.4	1.9	0.001***
Cow breed (local breed vs improved)	−2.6	0.4	0.001***
BCS (<3 vs ≥3)	−1.0	0.4	0.016*
Parity (primiparous vs multiparous)	−0.4	0.3	0.133^{NS}
Mastitis (positive vs negative)	−0.8	0.3	0.019*
Age (<5 vs ≥5)	0.4	0.4	0.268^{NS}
Retained placenta (yes vs no)	−0.5	0.6	0.377^{NS}
Endometritis (positive vs negative)	−1.1	0.3	0.001***
Season of calving (dry vs rainy)	−0.4	0.3	0.172^{NS}
Dystocia (yes vs no)	−0.5	0.3	0.101^{NS}
Stillbirth (yes vs no)	0.1	0.6	0.891^{NS}

^{NS} not significant ($p> 0.05$),***$p< 0.001$, *$p< 0.05$.

Table 6 presents the differences in DMY between the levels of variables that mostly contribute to DMY ($p< 0.05$). There was a significant difference in DMY between cows positive and negative for endometritis. The difference was also significant between mastitic and non-mastitic cows ($p< 0.05$), cows in poor and good condition ($p< 0.05$), and between local and improved breeds ($p< 0.05$).

Table 6: Effect of significant variables on daily milk yield

Variables	Daily milk yield, Mean±SEM	P-value
Endometritis		*
Positive	7.5±0.2	
Negative	8.9±0.3	
Mastitis		
Positive	7.1±0.3	*
Negative	7.9±0.3	
Cow breed		
Local	5.4±0.4	***
Improved	8.5±0.2	
Body condition score		
≥3	9.4±0.4	***
<3	7.7±0.2	

*$p< 0.05$, ***$p< 0.001$

Figure 1 presents the relationships between significant cow- and herd-levels variables, endometritis, anoestrous postpartum, days- not pregnant, and daily milk yield. Some predictor variables (dystocia, stillbirth, bedding materials, cowshed flooring, retained placenta, season of calving, and cleanliness of cowshed) were specific for endometritis cases. In contrast, mastitis, and body condition score were common predictors between endometritis and DMY. Cow breed was a predictor variable for DMY but was neither predictor for endometritis, ANPP, nor DNP. Endometritis was a predictor variable of DNP ($\beta = 21.3$, $p< 0.001$) and ANPP ($\beta = 1.3$, $p< 0.001$) that, in turn, was a predictor of DNP ($\beta = 64.1$, $p< 0.001$).

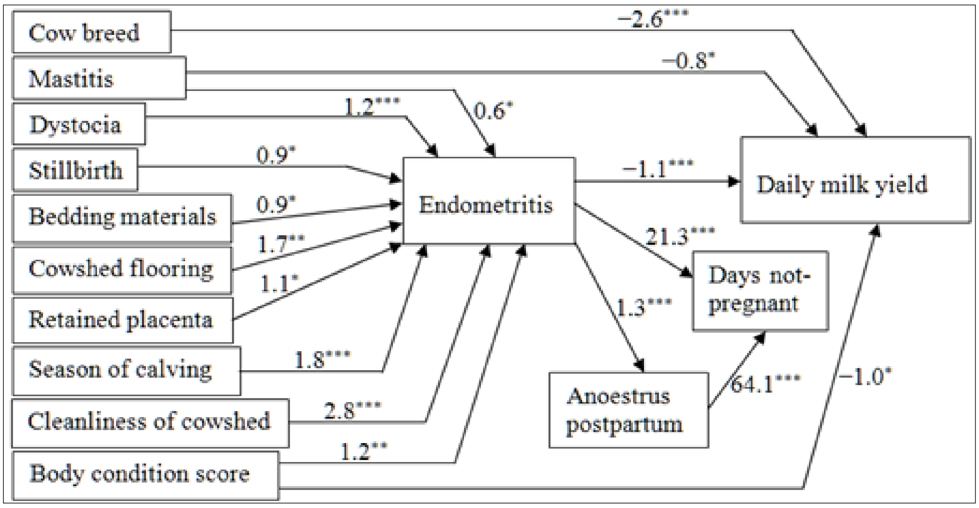

Fig 1: Relationship among dairy herd management conditions, cow characteristics, endometritis, daily milk yield, anoestrus postpartum and days- not pregnant in postpartum zero-grazed dairy cows managed on smallholder farms. *$p < 0.05$; **$p < 0.01$; ***$p < 0.001$. Arrow weight = regression coefficient value, which shows change in response variable associated with a unit change in predictor variable.

Discussion

This study has pioneered estimation of the effects of endometritis, cow- and herd-levels variables on milk yield and reproductive performance of zero-grazed dairy cows on smallholder farms in Rwanda. The association between mastitis, bedding materials, mud floors, rainy season, dirty cowshed, and endometritis case are, to a large part consequence of farmer's herd management practices due to knowledge gaps found in the sample farms, which implies how farmers may manage the disease in the herds [2]. They are likely to engage in some high-risk practices such not using bedding materials in the cowshed, cows are crowded together in dirty conditions, and hence the environmental pathogens tend to be concentrated and can ascend female genital tract and endometritis as a result [8]. In the present study systems, there was variation in hygienic standards of dairy environment and milk conditions as the cows were frequently kept in dirty and wet areas, which favours the proliferation and transmission of endometritis-causing organisms [25, 26]. These findings would suggest that applying good hygienic management practices in the transition period may help reduce contamination of the female genital tract and thus decrease cases of endometritis [9].

In this study, dystocia was found to be an important predictor of endometritis cases. This can be linked to the fact that in the sample farms, calvings are frequently assisted by farmers without wearing gloves, which represent a potential risk for causing injuries to the birth canal and increased risk of contamination of the female genital tract. This disruption of physical barriers might provide an opportunity for microorganisms to ascend the reproductive tract and increases the risk of endometritis to develop [27]. The current findings concur with those of [28, 29]. The observations suggest that minimizing the risk of endometritis is wearing gloves when assisting calving and to stress good hygiene by maintaining clean, dry environments, especially for calving areas. This is because the uterine pathogens, such as *Escherchia Coli*, *Enterococcus faecalis*, *Trueperella pyogenes*, *Prevotella melaninogenicus* and *Fusobacterium necrophorum* are likely derived from the environment that cows are kept or from the animal's skins, faeces or heavily soiled bedding materials [30, 31]. Similarly, the retained placenta was a predictor variable of endometritis cases, which agrees with previous observations [14, 16, 32]. This is probably due to the establishment of a uterine environment that promotes infection because retained placental membranes provide an excellent medium for bacterial growth [33].

The study revealed that stillbirth was an influential predictor of endometritis. This is likely to be associated with some degree of trauma and contamination of the female reproductive tract around the time of calving [34]. Therefore, management intervention such as utilizing sire and daughter calving ease information when selecting sires to breed heifers, and minimize stress before parturition should reduce stillbirth cases and consequently decrease endometritis cases in the dairy herd.

This study further revealed that poor body condition (BCS<3) was also an important predictor of endometritis case. This could be explained by nutritional imbalance due to poor feeding practices and low level of supplementation of the sample cows. They were fed mostly on Napier grass and banana fodder, sometimes supplemented with crop residues, and had limited access to commercial dairy meal and water [10]. These basal feeds are low in dry matter content, thus insufficient for providing nutrients required for maintenance and production [35]. These undernutrition conditions are evidence of poor BCS observed in the sample dairy cows, which makes them more prone to endometritis relative to cows in good body condition (BCS>3). The current findings concur with those of [36] in Brazil, [37] in Argentina, [8] in Ireland, and [38] in New Zealand. This indicates that more focused efforts, such as targeting dairy cows to good BCS through good feeding practices in the transition period, may help to reduce the risk of occurrence of endometritis.

In the present study, breed of dairy cow was found to be a predictor variable of a reduction in milk yield. Increasing the number of indigenous local breed by one local breed is likely to decrease DMY by 2.6 litres. The current finding concurs with those of [39] in Ethiopia. However, the decrease in MY is higher than 2.0 litres/cow obtained in Ghana [12] and lower than 5.8 litres/cow/day in Ethiopia [40] and 3.9 litres/cow obtained in Uganda [41]. These variations in the decrease in milk yield might be due to the difference in the availability of feed resources and feeding practices, and characteristics of indigenous local cattle breeds [39]. They present low milk yield potentials and low maintenance requirements [42, 43]. Given the large differences in milk production between improved and indigenous local cattle breeds, crossbreeding seems to be a sustainable solution in smallholding environments to quickly improve indigenous cattle regarding milk production and increase farmer income [40, 44]. This has been widely used to combine the high milk yield potential of improved breeds with the adaptability of indigenous ones [45, 46]. In the same way, [47] reported that crossing of low milk production potential breeds with the high milk production ones leads to a dramatic improvement in the quantity of milk yield, presumably due to heterosis and breed complementarity.

In this study, endometritis was also a predictor variable for a decrease in MY, which agrees with previous studies [3, 48, 49]. The decrease in MY during endometritis infection has been explained as a result of reduced energy and protein intake due to the decline in feed intake in cows positive for endometritis; compromised welfare, and a prolonged period of endometrium inflammation [4, 50, 51]. The decrease is substantial to warrant the adoption and implementation of prevention and control measures for endometritis in the dairy herd [9], which help to mitigate the disease effects on the milk yield.

The findings of this study demonstrate that poor body condition (BCS<3) was a predictor of lower milk yield, which is consistent with the previous observations in Israel [52], New Zealand [53], and India [15]. The poor body condition could be related to inadequate feeding practices and low feed supplementation observed in the sample cows. Napier grass and banana fodder were the predominant energy source [10], which are generally of lower energy density and dry-matter intake compared with total mixed rations [39, 54]. Therefore, cows calving in poor BCS are likely to produce less milk as compared to cows in good body condition [61]. This can be managed with an adequate feeding strategy to meet the energy and protein requirements of dairy cows in the transition period to attain good BCS, which not only optimizes milk yield but also maximizes economic return for dairy farmers.

In the present study, mastitis positive case was a predictor of reduced milk yield, which affects farm revenues. This is consistent with the findings of [55] in Italy. The positive cases of mastitis may be due to the lack of mastitis control practices in the study farms, which has been proved to decrease the cases of mastitis and lower the decrease in milk yield [56]. Therefore, good hygiene and raising awareness of a mastitis control plan among farmers should be incorporated into herd management practices to effectively improve udder health and milk production of zero-grazed dairy cows in Rwanda.

Endometritis was positively associated with days not-pregnant (DNP) and with anoestrus postpartum (ANPP) that, in turn, was also positively associated with DNP. The fertility performance of postpartum dairy cows is a multifactorial trait, the DNP and ANPP being dependent on numerous influencing factors. Consequently, a multivariable analysis was performed to identify factors that are significantly associated with DNP and ANPP. In this model, ANPP was affected by endometritis, and DNP was affected by endometritis and ANPP. The findings indicate a strong association between endometritis infection and the suboptimal reproductive performance of dairy cows. This can be associated with inadequate and poor feeding practices largely observed in the study farms [10]. These feeding conditions may not only expose more cows to negative nutrient balance-energy and protein, which increases susceptibility to endometritis infection [57], but also explain the delay to return to normal ovarian cycle or disruption of the endocrine function leading to failure of ovulation, resulting in ANPP. A potential mechanism has been proposed that uterine infection interferes with fertility by creating suboptimal conditions for sperm cell transportation and storage, ovarian follicular growth, oocyte maturation, and ovulation, fertilization, implantation, and embryonic growth, rising the number of ANPP cows in dairy herds, thus prolonging the DNP [58, 59]. To manage this, dairy farmers are advised to implement management interventions for endometritis prevention and control [11] specifically improve feeding practices for improved reproductive performance of their cows.

Conclusion and recommendation

The results provide evidence of predictor variables of endometritis, DMY, ANPP, and DNP in zero-grazed dairy cows managed on smallholder farms of Rwanda. These predictors should inform the basis of endometritis management interventions, for instance, cleanliness of farmers or personnel assisting calving, use of assisted reproduction technologies, ensure the hygiene of the cows' environment, and improve feeding practices for improved milk production and reproductive performance towards smallholder dairy herd profitability and sustainability.

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