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Milk yield losses and cost of clinical mastitis in Friesian × Bunaji crossbred dairy cows in Zaria, Nigeria

NH Moru[1]*, JU Umoh[2], BV Maikai[3], PP Barje[1] & P Amuta[4]

[1.] *National Animal Production Research Institute, Ahmadu Bello University, Zaria, Nigeria*

[2.] *Akwa Ibom State University, Obio Akpa Campus, Akwa Ibom. Nigeria*

[3.] *Faculty of Veterinary Medicine, Ahmadu Bello University, Zaria. Nigeria*

[4.] *College of Veterinary Medicine, Federal University of Agriculture, Makurdi, Nigeria*

*Correspondence: Tel.: +2348065399517; E-mail: morunana@rocketmail.com

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Abstract

Bovine mastitis is regarded as the most costly disease of dairy cows. Estimating its economic impact therefore gives farmers and veterinarians an insight into the costs of the disease at herd level and helps them make appropriate decisions regarding its control. The aim of this study was to determine the costs of clinical mastitis in Friesian × Bunaji crossbred dairy cows. Passive data collected between 2000 and 2015 was retrieved from the Dairy Research Programme of the National Animal Production Research Institute, Shika-Zaria, Nigeria and this was used to determine the input parameters for a simulation model. The parameters included the lactation and seasonal prevalence of clinical mastitis, average daily milk yield of cows, average illness period and the proportion of cows in each parity. Stochastic (Monte Carlo) simulation modelling of milk yield losses due to clinical mastitis was done using Microsoft® Excel with @Risk 7 add-in. The cost of a case of clinical mastitis at a base risk incidence of 35.2% was ₦5,005.85 ($15.87). The costs increased by 7.5% in a herd with 10% higher milk yield, while revenue generated was higher by 10.2%. The cost was 1.64% higher in a herd with fifty per cent of it cows in first parity than a herd with fifty per cent of its cows in third parity. 1.01% higher net revenue was generated from herds with fifty per cent of it cows in third parity than the herd with fifty per cent of its cows in first parity. Improving milk production potential of cows resulted in more cases of clinical mastitis, although the increase in revenue overshadows the added costs of clinical mastitis, successful control of mastitis will also significantly reduce production costs and improve the farm revenue.

Keywords: Clinical mastitis, Cost, Cows, Friesian x Bunaji, Losses, Milk yield

Introduction

Bovine mastitis is an infectious disease with significant impact on the economy of milk production (Halasa *et al*., 2007; Awale *et al*., 2012). It is regarded as the most costly disease of dairy cattle (Anaya-Lopez *et al*., 2006). Estimation of the economic impact of mastitis gives farmers an insight to the costs of the disease in a herd and help them take appropriate decisions to control and possibly eradicate the disease.

The largest milk producing country in West Africa is Nigeria and they are third largest in cow milk production in Africa (FAO, 2011). Though, the white Fulani (Bunaji) cows are the principal milk producers (Adeneye, 1989), the introduction of Friesian sire into Nigeria has produced stabilized crossbred Friesian × Bunaji cows whose dairy performance has been adjudged to be higher than the pure Bunaji cows (Alphonsus *et al*., 2008).

Several studies have been carried out on the economics of mastitis and mastitis management in many countries of the world (Seegers *et al*., 2003; Halasa *et al*., 2007). Only a few of these have estimated the costs of mastitis in the sub-Saharan African countries (Schepers & Dijkhuizen, 1991; Ravaomanana *et al*., 2004; Mungube *et al*., 2005; Tesfaye *et al.,* 2010). A number of farms have resorted to the use of Friesian × Bunaji cattle breeds for improved milk because of their high production potentials. However, there are no published reports on the economic impact of mastitis in dairy herds in Nigeria. This study was conducted to estimate the milk yield losses associated with clinical mastitis and the costs of clinical mastitis in Friesian × Bunaji dairy cows in a research farm in Zaria, Nigeria.

Materials and Methods

Study location

This study used data collected from the Dairy Research Programme of the National Animal Production Research Institute (NAPRI) Shika, Zaria, Nigeria. Shika is geographically situated (11^{o} $12^{'}$ $42^{''}$ N and 7^{o} $33^{'}$ $14^{''}$ E) at an altitude of 650m above sea level. Shika has an average annual rainfall of 1100 mm usually lasting from May to October, peak rainfall is recorded between July and September. Shika has a mean relative humidity of 72 %, while the harmattan season lasts from November to February with mean daily temperatures ranging from 15 – 36 °C and mean relative humidity of between 20 – 37 %.

Data collection

Data collected include; cases of clinical mastitis (CM), treatment records and daily milk yield (DMY), recorded from January, 2000 to April, 2015 from the Dairy Research Programme of NAPRI, Shika-Zaria. The daily milk yield was organized into mastitic and non-mastitic lactations - defined as lactation period during which clinical mastitis occurred, and lactation period without an occurrence of clinical mastitis respectively. Parities observed were 1^{st}, 2^{nd}, 3^{rd} and 4^{th} parities. The data covered 446 lactations from 155 cows (averaging 2.88 lactations /cow). The mastitis data considered included only clinical mastitis cases detected either by veterinary clinicians or the milkers during milking - usually indicated by the presence of clots in the milk, swollen or hard udder. Calendar dates of mastitis onset, duration of mastitis (based on cure rate) and parity were also recorded. Based on stage of lactation, cases were grouped as ‘early’ (0-14 weeks) or ‘late’ (15-44 weeks). Cases were also grouped based on season (rainy or dry).

Herd management

The cows were housed in a free stall barn and taken out daily to graze on natural pastures and fed concentrate supplement during milking. The cows were hand-milked twice daily (morning and evening). Clinical mastitis cases were treated with antibiotics administered systemically.

Simulation model

Based on the data collected, a stochastic (Monte Carlo) simulation model was developed using @Risk 7 (PALISADE, 2015), an add-in software for Microsoft Excel, to estimate the milk yield losses due to clinical mastitis in the studied herd under different scenarios. Input parameters for the model are shown in Table 1. The model simulates an entire lactation for a single cow (i) in weekly time steps (j) beginning with the first week of lactation. Milk production and clinical CM related events occur by parallel and interlinked processes within the time steps. The processes begin with each cow at the point of calving being randomly assigned a parity from a discrete distribution and a random lactation value from a normal distribution - both of which determine her 305-day milk production. The occurrence of CM and its effects on milk production are determined in the course of the lactation. A CM status is stochastically derived for the cow in each time step based on the average lactation incidence of CM (adjusted by the parity of the cow, the season of the year and the stage of lactation). Milk yield losses calculated as ‘discarded milk’ due to CM was determined based on the average daily milk production at the point of occurrence of CM. A herd consisted of 348 milking cows.

Estimating the costs of clinical mastitis

The costs of clinical mastitis were determined according to the pattern used by Wolfova *et al*. (2006). Economic consequences considered include; the costs of milk discarded, drugs, veterinary services and labour.

Table 1: Parameters for modelling milk yield loss and cost of clinical mastitis in Friesian and Bunaji crossbred dairy cows in a dairy herd in Zaria, Nigeria

Parameters	Values
Pcow1	0.4878
Pcow2	0.2114
Pcow3+	0.3008
YMIL1	30.43
YMIL2	32.2
YMIL3+	42.86
Drug cost (₦/CM case)	640
CVs (₦/hr.)	2,500
Vet Time (hrs.)	0.5
Herdsman's time (hrs.)	1
Milk price (₦/kg)	90
Price of herdsman's time (₦/hr.)	66.7
ADMY (kg)	5.88
AIP (days)	6

Key: PCOW1, 2 and 3 = the proportion of cows in parities 1, 2 and 3 respectively, $YMIL$ 1, 2 and ≥3 = the prevalence of clinical mastitis in lactations 1, 2 and ≥3, CVs = the cost of Veterinary services, ADMY = average daily milk yield, AIP = the average illness period

Cost of discarded milk***:*** The cost of discarded milk (CDm) was determined by multiplying the discarded milk per cow (Dm_i) by the price of milk (Pm) for the entire herd of 348 cows according to equation [1]:

$$CDm = \sum_{I=1}^{348} Dm_i \times Pm \quad [1]$$

Cost of drugs: Since all cases of CM (CM_{cases}) on the farm were treated, the cost of drugs (CR_x) at herd level was determined as follows:

$$CR_x = CM_{cases} \times PR_x \quad [2]$$

Where PR_x represents the price of the drugs for a single case of CM.

Cost of veterinary services: CM_{cases} received veterinary attention and the cost of veterinary services (CVs) for the herd is dependent on the price of veterinary services per hour (PVs) and the time spent on each case by the veterinarian (TVs) as follows:

$$CVs = \sum_{I=1}^{CM_{cases}} PVs \times TVs \quad [3]$$

Cost of labour: CM_{cases} also required extra attention by care givers for reasons such as restraining, isolation, manual expression of milk from the affected quarter(s) etc. Hence, the opportunity cost of the additional time spent on mastitic animals in the herd is referred to as the 'cost of labour' (CL). It is determined as a function of the price of labour per hour (*PL*) and the estimated time spent on each case of CM (*TL*) as follows:

$$CL = \sum_{I=1}^{CM_{cases}} PL \times TL \quad [4]$$

Costs of cm: Since all the contributing cost variables were estimated at herd level, the herd level costs of CM (HC_{CM}) was estimated as the sum of the cost variables as follows:

$$HC_{CM} = CDm + CR_x + CVs + CL \quad [5]$$

While the cost of a single case of CM (C_{CM}) was determined as follows:

$$C_{CM} = \frac{HC_{CM}}{CM_{cases}} \quad [6]$$

Mastitis-adjusted farm revenue: The revenue from the farm (R_{MA}) was calculated as a function of the average lactational milk production per cow (MP_i), the Pm and the HC_{CM} as shown below:

$$R_{MA} = [\sum_{i=1}^{348} MP_i \times Pm] - HC_{CM} \quad [7]$$

Data analysis

The output parameters such as the lactation milk yield, discarded milk and incidence of clinical mastitis for the different scenarios were analysed for significant differences using one-way ANOVA and a post-hoc Tukey-kramer paired-wise test of JMP-SAS (2010). Farm gate price of milk was used in the calculation of financial costs of clinical mastitis.

Sensitivity analysis

A sensitivity analysis was conducted on input parameters pertaining to production, disease dynamics and economics by creating different 348-cow dairy farm scenarios based on the parameters. This was to assess the level of impact of each of these parameters on the overall costs of CM.

Mastitis-adjusted marginal financial effects of the scenarios were obtained by comparing their respective revenues with the mastitis-adjusted revenue of the default (base risk) scenario. Scenarios for which this sensitivity analysis was done include: High MProd (+10% milk production potential), Low MProd (-10% milk production potential), High MPrice (+10% milk price), Low MPrice (-10% milk price), High Risk (+20% risk of CM), Low Risk (-20% risk of CM), No Risk (0% risk of CM), 50% 1par (50% of the cows in 1st parity) and 50% 3par (50% of the cows in 3rd parity).

Results

Simulation model output

The model output which includes lactation milk yield, incidence of CM and discarded milk due to CM in Friesian x Bunaji cows are shown in Table 2. Average milk yield from a cow with no risk of clinical mastitis was 1,857.86kg/cow/lactation. For a base risk herd (BR) with CM incidence of 0.352, the lactation milk yield was averagely 1,858.30kg/cow/lactation. The lactation milk yield and CM incidence varied for the different scenarios presented (Table 2). The model output showed that an increase in milk yield potential of the cow was associated with a significant ($p<0.05$) increase in incidence of clinical mastitis, though the revenue generated also increased significantly. The herd with 50% of its cows in 3rd parity had a significantly higher average milk yield of 1,873.70kg/cow/lactation ($p<0.05$) and significantly lower incidence of clinical mastitis (0.348) compared to the BR values. While a herd with 50% of its cows in 1st parity had an average milk yield of 1,855.30kg/cow/lactation and significantly higher incidence of clinical mastitis (0.357) compared to the BR values. Increasing milk production potential of cows in the herd by 10% generated a significantly higher incidence of clinical mastitis of 0.356, higher milk yield of 2,047.00kg/cow/lactation and higher discarded milk of 13.33kg/cow/lactation compared to the BR values. Lowering milk yield potential of cows by 10% resulted in a significant decrease in incidence of CM (0.352), milk yield of 1,670.30kg/cow/lactation and a decrease in discarded milk (11.94kg) compared to the BR values (Table 2).

Costs of clinical mastitis

The costs of clinical mastitis in a dairy herd with default risk (BR) of CM was estimated to be ₦614,017.88, while the costs per case of CM and the costs per cow in a herd were estimated to be ₦5,005.85 and ₦1,764.42 respectively (Table 3). The herd-level costs were higher by 11.97% in a herd with 20% higher risk of CM and by 7.47% in a herd with 10% higher milk production potential than the BR herd. However, the costs were less by 12.2% in a herd with 20% lower risk of CM and by 6.19% in a herd with 10% lower milk production potential than the BR herd. The herd with 50% of the cows in 3rd parity recorded significantly lower costs of mastitis and higher revenue than the herd with 50% of the cows in 1st parity (costs of CM were ₦609,157.58 and ₦619,322.48 respectively, while the revenues were ₦58,075,199.71 and ₦57,488,483.37 respectively).

Table 2: Simulation output of incidence of clinical mastitis, lactation milk production and discarded milk due to clinical mastitis for the Friesian×Bunaji dairy cows in a dairy farm in Zaria, Nigeria

Variables	Lactation milk production (kg)	Incidence of CM	Discarded milk per cow due to CM (kg)
No risk	1857.86^{d}	0^{f}	0^{h}
Base risk	1858.30^{c}	0.352^{c}	11.94^{d}
Low risk	1858.43^{c}	0.309^{e}	10.49^{g}
High risk	1856.13^{e}	0.394^{a}	13.38^{a}
50% 3par	1873.70^{b}	0.348^{d}	11.87^{e}
50% 1par	1855.29^{f}	0.357^{b}	12.01^{c}
HMP	2047.00^{a}	0.356^{b}	13.33^{b}
LMP	1670.26^{g}	0.352^{c}	10.73^{f}
High MK price	1858.30^{c}	0.352^{c}	11.94^{d}
Low MK price	1858.30^{c}	0.352^{c}	11.94^{d}

Key: No risk = no risk of clinical mastitis, Base risk = base risk of clinical mastitis, Low risk = low risk of clinical mastitis, High risk = high risk of clinical mastitis, 1par = parity-1 cows, 3par = parity-3 cows, HMP = high milk production, LMP = low milk production MK price = milk price.

a, b, c, d, e, f and g means within the same column with different Superscripts are significantly different

Table 3: Mastitis-adjusted economic output for different scenarios as generated by Monte Carlo Stochastic simulation modelling based on data from friesian x bunaji crossbred dairy cows in a dairy farm in Zaria, Nigeria

Scenarios	Cost of clinical mastitis/herd (₦)	Revenue from milk sales(₦/herd)	Revenue Difference as Compared to No Risk Scenario (₦/herd)	Cost/Case (₦)	Cost/Cow (₦)
No risk	-	58,188,154.90	-	-	-
Base risk	614,017.88	57,587,983.43	600,171.47	5,005.85	1,764.42
Low risk	539127.93	57,666,816.33	521,338.57	5,009.09	1,549.22
High risk	687,502.27	57,446,340.16	741,814.741	5,008.39	1,975.58
50% 3par	609,157.58	58,075,199.71	112,955.19	5,023.98	1,750.45
50% 1par	619,322.48	57,488,483.37	699,671.53	4,983.28	1,779.66
High MProd	659,886.28	63,452,116.78	-5,263,961.88	5,325.37	1,896.22
Low MProd	575,986.16	51,736,446.47	645,1708.43	4,699.63	1,655.13
High MPrice	651,418.79	63,370,782.66	-5,182,627.75	5,310.77	1,871.89
Low MPrice	576,616.98	51,805,184.21	638,2970.70	4,700.94	1,656.95

Key: MPrice=Milk Price, MProd=Milk Production, 50% 1par=50% of cows in herd are 1st parity cows, 50% 3par=50% of cows in herd are 3rd parity cows, Base Risk=Current average risk of Clinical Mastitis (35.16%), No Risk=0% Risk of Clinical Mastitis, High Risk=20% Increase in Base Risk of Clinical Mastitis, Low Risk=20% Decrease in Base Risk of Clinical Mastitis

Figure 1 shows the percentage contribution of each cost component to the overall costs of CM. Discarded milk made the highest contribution to the costs of CM at 61%, while that of veterinary services contributed 25%, cost of drugs contributed 13% and cost of labour contributed only 1%.

Sensitivity analysis

The results of the sensitivity analysis (Figure 2) show milk production potential of cows in a herd to be the most important parameter. A 10% increment in milk production potential improved the mastitis-adjusted revenue of a herd of 348 cows by ₦5,864,133.35, while a 10% reduction in milk production potential lowered the mastitis-adjusted revenue in a similar herd by ₦5,851,536.96. The price of milk had a very similar effect with a 10% increment or reduction in price affecting revenue by ±₦5,782,799.23. Parity and risk of CM showed a lower effect on revenue. In fact, lowering the risk of mastitis by 20% in a herd of 348 cows only improved the mastitis-adjusted annual revenue by ₦78,832.90, while eliminating CM totally improved annual revenue by ₦600,171.47.

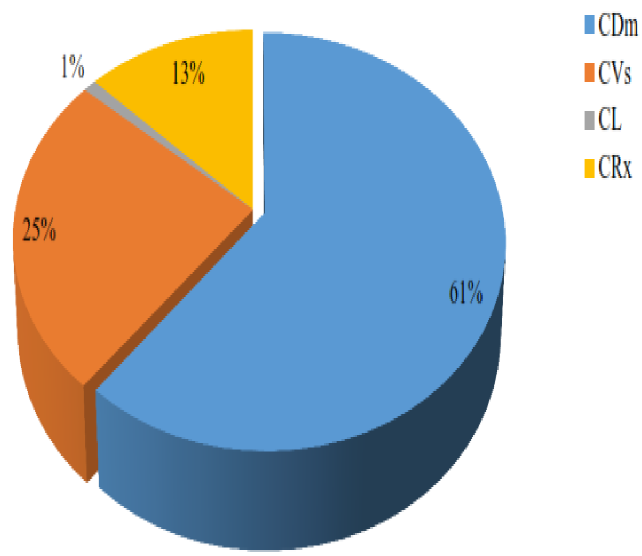

Figure 1: Contribution of each component to the cost of clinical mastitis in Friesian Bunaji crossbred dairy cows in a dairy farm in Zaria

Component Key: *CDm*= the cost of diacarded milk, *CVs* = the cost of veterinary services, *CL*=the cost of extra labour, *CDx*= the cost of drugs

Discussion

The model showed that the incidence of clinical mastitis (CM) increases with increased milk yield potential of the crossbred cows. Sinha *et al.* (2014) inferred from their study that crossbred cows are more susceptible to mastitis. When the milk yield potential of such breed is increased, the risk of clinical mastitis (CM) might also increase.

The cost of clinical mastitis obtained in this study was lower than estimates by other researchers such as Bar *et al.* (2008), whose estimate of cost of CM/case was $179 (₦53,836 as at 2016), also, Rollin *et al.* (2015) estimated an overall cost per case of CM in the first 30 day of lactation to be $444(₦133,536 as at 2016). Variation in these studies could be due to difference in factors included in calculating the cost of mastitis, breed of cow hence production potential, method of analysis, as described by Halasa *et al.* (2007). To the best of our knowledge no study in Nigeria have determined the cost of clinical mastitis (CM), this made comparison difficult.

From the model high milk production potential cows had higher cost of CM than low milk production potential cows this could be due to possible incomplete milking from hand milking of the higher milk yielding cows. This provides suitable medium for growth of mastitis pathogens, therefore increasing the incidence of CM, hence, increased cost of CM.

Reduced cost and incidence of CM observed in a herd with 50% of it cows in 3rd parity could be due to better adaptation of the 3rd parity cows to hand milking process making it less stressful on them compared to 1st parity cows. Stress in cows might compromise immunity of the cow thereby reducing the cow's chance to fight pathogens and increasing the chances of proliferation of mastitis causing pathogen among such cows, hence, increased mastitis incidence.

The model sensitivity analysis indicates that high milk yielding cows with high mastitis risk gave greater net revenue than low yielding cows with low mastitis risk. This indicates that for the Friesian×Bunaji cows, mastitis constitutes a cost for every occurrence (which adds to production costs) and should receive appropriate attention to reduce the production cost, however, production potential of a cow should be given preference over risk of clinical mastitis in selecting dairy cows.

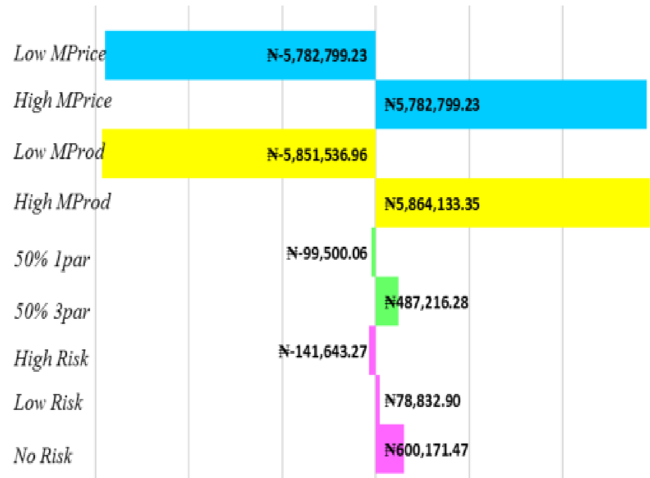

Figure 2: Turnado plot showing economic effects (in Nigerian Naira) of different farm scenarios by comparing the revenue of each scenario with that of the base risk scenario in which all other factors are normal. Negative values represent losses while the positive values represent gains as compared to the base risk scenario.

Key: *MPrice*=Milk Price, *MProd*=Milk Production, *50% 1par*=50% of cows in herd are 1st parity cows, *50% 3par*=50% of cows in herd are 3rd parity cows, *High Risk*=20% Increase in Risk of Clinical Mastitis, *Low Risk*=20% Decrease in Risk of Clinical Mastitis, *No Risk*=0% Risk of Clinical Mastitis

In conclusion, the cost of CM in a herd of Friesian×Bunaji dairy cows with incidence of CM of 0.352 ranged from ₦4,924.95 to 5,024.36/case of CM (average ₦5,005.85/CM case). Cost of CM was affected by milk production potential of cows, price of milk, parity of cows in the herd and the incidence of CM in the herd. Milk production potential of cows and the different parities of cows in the herd also affect the incidence of clinical mastitis. Production potential of a cow was found to have stronger effect on revenue generated from milk produced than other factors (Incidence of CM and parity of cows), therefore, it should receive higher priority in breeding and management considerations. Increasing production potential of a herd of cows was shown to increase CM occurrence within the herd, therefore, disease control strategies should always be properly put in place to reduce production cost.

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