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Associations of on-Farm Biosecurity Status with Production Performance on Smallholder Dairy Farms in Kenya

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Abstract

On-farm biosecurity measures prevent disease transmission between and within farms and, therefore can improve animal health outcomes and product quality, minimize production losses, and increase returns to smallholders, the majority of whom market milk informally. This study assessed associations of milk market outlets with on-farm biosecurity status and the resultant milk quality, production losses, and gross margins on a random sample of 140 farms stratified by milk market outlets (formal and informal). Odds ratio estimates showed that when farms market milk in formal outlets they have a higher likelihood of vaccinating (OR 7.36) purchased stock and withdrawing products from the market when having infectious disease (OR 8.48) but less likelihood of examining health records when purchasing stock (OR 0.39). Also observed, farms that market milk in the formal outlet had a higher likelihood of attaining better milk quality indicators based on the alcohol test (OR 12.0) and density test (OR 23.3) but not with the organoleptic test (OR 0.2). The estimated annual average production loss per farm of KES 11,126.7 was lower in farms that marketed milk in formal outlets. However, production losses were higher where purchased stock was dewormed before introduction into the farm. Farms marketing milk in formal outlets attained 5% higher daily milk production and KES 4.2 higher margins per litre of milk but all the biosecurity measures examined insignificantly associated with margins earned. The study concluded that participation in formal milk markets encourages practicing on-farm biosecurity measures which can improve milk quality but not necessarily profit, depending on the level of investment made.

Keywords: Biosecurity measures; milk marketing; milk quality; production losses; gross margins

Introduction

Smallholder dairy farmers implementing biosecurity measures may benefit from improved animal health outcomes and product quality, minimized production losses, and increased returns that are associated with the prevention of disease transmission between and within the farms.

An incentive for implementing biosecurity measures may be participation in formal milk marketing where compliance with the food standards is a requirement and attracts remunerative rewards like premium price and avoidance of milk rejection.

The smallholder dairy system dominating the Kenyan dairy industry predominantly trades milk in the informal milk market outlets where compliance with the standards for food safety and quality hardly attracts immediate incentives. Farm biosecurity is a set of measures designed to protect a farm from the entry and spread of pests and diseases, which is important for maintaining hygienic conditions and animal health [1]. Therefore, the implementation of biosecurity measures is important for improving animal productivity and protecting public health [2, 3].

The benefits of undertaking biosecurity for disease prevention and/or control include improved production efficiency which should translate into greater profits [4]. Improved milk output may be translated into profitable dairy enterprises if the farmer maximizes utility given certain constraints.

Maximum profit is a product of milk output from the herd, milk price, feeds, other inputs, and veterinary expenses and is associated with investments in on-farm biosecurity practices that are implemented. When implemented in a dairy enterprise, biosecurity practices can increase profitability by reducing the prevalence of clinical diseases and improving production efficiency hence reducing production losses in the farm.

Materials and Methods

Sampling Procedure

The sample size was computed from the application of the Tweel [5] formula for two independent groups (formal and informal market outlets) with a dichotomous variable (whether biosecurity was practiced or not). A random sample of 140 farmers was obtained in a cross-sectional survey in which the individual farms were selected using a simple random sampling procedure from a list of farmers.

The farms were stratified by milk market outlets (informal and formal) to reflect compliance with requirements for milk quality and safety standards which can be an incentive for implementation of biosecurity measures. One stratum comprised farms with membership to the farmer co-operative society to which they deliver milk or sell milk to a processor (Kabiyet Dairy, Nandi County).

Both cooperatives and processors routinely subject milk to quality testing to ensure compliance with high-quality standards. In the second stratum, farmers did not belong to any cooperative (Lare, Nakuru County) and comprised farms selling milk directly to mobile traders and neighbors who do not subject milk to quality testing for compliance with quality standards.

Data Collection

Each identified farm was visited with the guidance of an official of the Cooperative Society in Nandi County or the Development Centre in Lare. Data on each of the farms visited was obtained using a pre-piloted questionnaire while milk quality data

was obtained from the cooperative and milk samples (300mL from each farmer) were taken on the farms in the morning and analyzed within 3 hours of collection. For data that was categorical, measurements were in binary response [4] to enable estimation of the odds ratio from the logistic regression model.

For the milk quality tests, procedures of Lovibond [6] were followed. Production losses from diseases, milk spoilage, involuntary culling and mortality in monetary value represented economic value loss. Losses of milk from spoilage were estimated from farmer recalls.

Production losses for milk, when a cow was diseased, were computed from the difference between average milk yields of a cow in normal health versus that in sick condition status. Losses resulting from involuntary culling and deaths were taken as the values of the cow before it was diseased or died less the value at culling [7].

The gross margin was computed as total revenue less the total costs and then computed for average margins per liter of milk produced. The revenue included milk sales, the value of milk consumed at home, and the value of milk fed to calves. The variable costs included veterinary, feeds, water, and labor appertaining to dairy [8].

Data Analysis

Descriptive statistics were generated to show the sample characteristics in distribution, dispersion, and means. The associations between milk market outlets with biosecurity status, and milk quality were examined using Chi-square test statistics and odds ratio from logistic regression because the response variables were binary [9].

In the first logistic regression, outcome variables were the measures of on-farm biosecurity and the explanatory variable was the milk market outlet (formal and informal). The fitted logit model estimated the probability of a farm practicing a biosecurity measure (Y) with explanatory variables being market outlets (formal and informal). In the second model, milk quality was an outcome variable, and biosecurity measures and milk market outlet were explanatory variables fitted in the logit model (Proc Logistic of SAS version 9.0, 2002).

The means estimates for production losses and gross margins were generated from a generalized linear model and pairwise comparisons were made with contrast estimates between the levels of biosecurity status in the sample farms.

Results

Association of Biosecurity Status with Milk Market Outlets

In Table 2, the odds ratio reflects the odds (OR) of frequently implementing a biosecurity measure in the farms that market milk in formal outlets relative to farms that market milk in informal outlets.

The farms that frequently examined health records when purchasing stock were fewer among those that were selling milk in the formal market outlets (14.3%, 10/70) than among those that were selling milk in the informal market outlets (30.0%, 21/70). Thus, farms selling milk in the formal market outlets were 0.39 times less likely to frequently examine health records when purchasing stock than the farms that sold milk in the informal market outlets.

The odds ratio estimates reveal that it was more likely for farms selling milk in the formal market outlets than farms selling milk in the informal markets to vaccinate purchased stock (OR 7.36), deworm purchased stock (OR 5.29) and withdraw trading products when having infectious disease on the farm (OR 8.48).

Association of Milk Quality with Biosecurity Status

Results in Table 3 show that farms that marketed milk in formal outlets were more likely to attain higher milk quality indicators based on alcohol tests (OR 12.0) and density tests (OR 23.3) but not with the organoleptic test (OR 0.2). Alcohol tests indicated that cows attained good milk quality when they had calved in a clean, dry environment and their udder and teats were disinfected every post-milking.

Cows that calved in a clean, dry environment were 2.6 times more likely to attain good milk quality relative ($P<0.05$) to those that calved in an unclean environment while cows whose udder and teats were disinfected every post-milking were 17.9 times more likely to attain good milk quality relative ($P<0.05$) to those that their udder and teats were not disinfected.

The milk density tests indicated that vaccinating purchased stock before introducing into the farm and complying with antibiotics withdrawal period was 2.4 and 3.7 times more likely to attain higher milk quality relative to when not vaccinating and when not observing antibiotics withdrawal period.

Association of On-Farm Biosecurity with Production Losses

The annual average total production loss was KES11126.7 per farm and it was 13.9% lower in farms marketing milk through formal outlets relative to those marketing milk through informal outlets (Table 4). When milk from sick animals was separated from good milk, losses were lower by KES 4023.8 relative to when milk was not separated.

However, production losses were higher ($P<0.1$) by KES 5341.5 in farms deworming purchased stock before introducing it into farms than in farms not deworming stock. Additionally, losses were KES 815.4 ($P<0.05$) lower when the withdrawal period was not observed with observing of antibiotics withdrawal period and with withdrawing products trading when having infectious disease.

Association of on-farm Biosecurity with Gross Margins

The formal outlet had lower milk prices (KES 29.7) but higher milk production (12.0L) compared to the informal outlets (Table 5) which had higher milk prices (KES 32.6) but lower milk production (10.7L).

Milk production in the formal outlet was 5% higher than in the informal outlet. Farms marketing in the formal outlets reported KES 4.2 higher margins per liter of milk compared to those in the informal outlets but none of the biosecurity measures examined had a significant association with the margins earned (Table 6).

Discussion

The implementation of on-farm biosecurity was better in sample farms participating in the formal compared to those marketing milk in the informal outlets. Formal milk markets which include processors, cooperatives, and licensed milk bars demand quality milk [10, 11] and ascertain this by testing milk when accepted at the collection platform. Dairy cooperatives and processors also train farmers on hygiene and good management practices to improve the quality of the milk that they receive [12].

However, farmers participating in formal milk marketing did not examine health records when purchasing stock. Several reasons could explain this observation. These farmers rarely keep records of individual animal performance. Milk quality analysis in Kiambu [13] observed that farmers have poor or no treatment records for their cows, which means there were no records to avail to potential buyers. Smallholders purchase stock from fellow farmers known to them on common trust among themselves because historical records of performance are unavailable.

The finding that farmers participating in formal milk marketing were more likely to vaccinate and deworm purchased stock before introducing into the farm reflects good dairy management practices acquired in training. The training is part of the efforts to ensure high quality and safety standards are maintained for traded dairy products. Farmers that participate in the formal milk marketing linked to cooperatives and dairy processors enjoy veterinary services from the organizations and are therefore more likely to access better veterinary services.

Formal milk marketing was associated with better compliance with safe withdrawal periods for products when animals were diseased or under treatment. This demonstrates that participation in formal markets encourages a high uptake of biosecurity measures to manage risks and minimize potential losses associated with unhygienic handling of cows and milk [14].

The presence of antibiotics in milk when detected is a reason for rejection by processors and cooperatives because antibiotic residues can inhibit starter culture activity in fermented milk [13,15]. This implies that farmers participating in formal milk marketing have to ensure that milk does not have antibiotic residues as it is a risk for rejection and potential losses to them. This corresponds to observations by Orregård [13] that there is a conscious awareness along the milk value chain to reduce spoilage and ensure the quality of the milk.

Some biosecurity practices were associated with acceptable milk quality standards. In support of this, Oladele *et al*. [16] have observed that frequent extension contacts enhance farmers' knowledge and adoption of biosecurity practices. Milk co-operatives or processors engage their extension service to train farmers and technologists to subject delivered milk to quality testing [14] to reduce risks associated with unsafe and poor-quality milk. So, farmers practice biosecurity to reduce the risk of rejection and resulting losses.

Milk quality was better with the practice of good hygiene as was observed with cows calving in a clean and dry environment, and udder and teats disinfection every post milking. The observation concurs with that of Wells [2] that mixing calving cows with sick cows is a risk factor for *Staphylococcus aureus* which causes mastitis. This occurs if infections gain entry into the cow's udder or teats, and then load milk with disease-causing organisms which lowers milk quality.

Disinfection of the udder and teats is a preventive mechanism for disease entry into the udder and teats. In the study of Kunda *et al*. [17], the presence of micro-organisms in milk and milk products was an indication of unsanitary handling of either milk or milk utensils. As previously reported by Smith [18], failure to teat dip after milking and failure to observe udder hygiene was a risk factor for contagious mastitis caused by *Staphylococcus aureus*. The presence of mastitis in milk results in coagulation of milk in the alcohol test and deviation of specific gravity from normal, rendering the quality poor and of unacceptable standards.

Vaccination of purchased stock was associated with acceptable alcohol and specific gravity tests. This is because vaccination prevents disease entry or spread, thus helping to maintain the quality of milk by yielding disease-free milk that easily passes basic quality tests. Brennan and Christley [4] in their biosecurity study observed that risks associated with cattle movements can be reduced when producers only purchased animals from farms with a known disease history and through isolation, disease testing, and prophylactic treatment of purchased stock.

This is supported by Wells [2] who found that risk factors for *Staphylococcus aureus* which causes Mastitis, included bringing new cattle in the herd and failure to vaccinate before introducing cattle into the farm.

Acceptable milk quality in Specific gravity and Resazurin tests was obtained with the withdrawing sale of products when an infectious disease was present, which is an adherence with antibiotic withdrawal periods. When farmers fail to comply with instructed withdrawal periods when using antibiotic treatment, the residual effects are likely to occur in the milk and this inhibits

starter culture activity in processing fermented milk [13] and poses a public health risk [3].

Antibiotic residues in milk can alter the specific gravity beyond the normal acceptable levels. The Resazurin test assesses the keeping quality of milk and a difference in normal acceptable bacterial constitution alters the quality. This implies that antibiotic and drug residues as well as milk infected with disease are bound to fail the Specific gravity and Resazurin tests. This best explains why observed safe withdrawal periods for their products at diseased or medication times produced milk of acceptable quality tests.

Production losses were lower for farms that market milk through formal outlets with mortality being the greatest contributor to total losses. This is an indicator of good herd health in the formal marketing structure. Higher losses in the informal outlet could reflect a lack of knowledge of the biosecurity measures.

Oladele *et al.* [16] reported that the more the farmer has contact with extension agents, the better the knowledge of biosecurity practices. Addisu *et al.* [19] in their study of production aspects of intensification and milk quality in Ethiopia reported that as the level of market quality improved, trends towards better feed production and utilization, use of improved dairy cattle and milk production improved.

Production losses were lower with separate handling of milk from sick animals because this practice assures quality is uncontaminated and is not rejected by processors or cooperatives [13]. In contrast, practicing deworming of purchased stock when introduced into the farm had higher production losses. This is possibly resulting from the costs of deworming because deworming is a common treatment in dairy farms [13].

There are many instances when huge investments in animal health did not pay off due to ineffective control measures [16]. A study in Ethiopian feedlots [20] showed that pre-purchase inspections along the market chain are conducted without the necessary veterinary skills. Sometimes they end up with a diseased animal which ends up dying and causing losses in the farm. A similar observation was made by [21] that traders sometimes sell diseased stock to producers and sensitivity is low for clinical inspections of diseases such as Foot and mouth disease [20]. This impact on herd revenues when infected animals pass undetected in the market.

Production losses were lower when farmers adhered to antibiotic withdrawal periods thereby withdrawing the sale of products when having an attack of infectious disease. Observance of the antibiotic withdrawal period is a positive sign of compliance with the quality and safety of products which is a good practice to ensure reduced losses at the farm. Failure to withdraw products when the disease is present means diseased milk or milk with antibiotic residues could as well mix with good milk which may lead to rejection. Rejection of the whole batch means more losses than when only the affected product is withdrawn.

The gross margins were measured per liter of milk to enable a fair comparison. The higher margins earned with formal than with informal milk marketing could have resulted from higher milk production and higher milk prices [8, 22] that were observed among farms that marketed milk through formal outlet markets. It may also be a result of lower production costs accrued from averted production losses from treatment costs and milk losses from diseases through better biosecurity practices in the formal market outlet.

Conclusion

The study concludes that participation in formal milk markets encourages farmers to practice on-farm biosecurity measures and the measure can improve milk quality but not necessarily profit, which is likely dependent on the level of investment that a farmer makes in implementing biosecurity measures.

Conflict of Interest Statement

None

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