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The study of Reducing Antimicrobial Use in Small Ruminant Farming by Means of selective Metaphylaxis and Farmer-Training in Semi-Arid Areas

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Abstract
Inappropriate use of antimicrobials in small ruminant production has increasingly considering it one of the leading causes of the increasing global menace of antimicrobial resistance (AMR). The objectives of the study were to ensure that there was decreased usage of antimicrobials in the goat and sheep production in northern Namibia through application of specific metaphylactic procedures and education of farmers. These farms included 40 farms and were randomly sorted to form two groups; one receiving intervention training (on selective antimicrobial use and metaphylaxis practices) and the other group (the seamless practice). The survey was done within a span of 6 months of lambing in which the treatment frequency, clinical recovering, and morbidity rates were observed. The findings revealed that the intervention group decreased the antimicrobial therapies by 41 percent, which did not jeopardize the clinical recovery or the animal health outcome ($p < 0.01$). Also, the adherence to the metaphylaxis schedules was enhanced by the training particularly by the farmers. This paper highlights the need of incorporating education and disease management intervention to propagate the responsibility of antimicrobials usage in small ruminants farming systems within resource-constrained environments. These results show the possibility of metaphylaxis as well as farmer education in decreasing the overuse of antimicrobials and fighting the AMR in the small ruminants systems located in the semi-arid regions.

Keywords: ***antimicrobial resistance, small ruminant production, metaphylaxis, farmer education, selective use of antibiotics, Namibia, sheep, goats, disease control, community health.***

1. Introduction

1.1 Summary of Antimicrobial Resistance (AMR) among livestock farming

Antimicrobial resistance (AMR) has become a major concern to global health where farming of livestock is a major cause of the problem. The frequent measures that tend to be used in agriculture, specifically in animal raising are antimicrobials, which have subsequently caused a selection of resistant organisms that can thus be transmitted to humans through the food chain, direct contact or the environment. Small ruminants (e.g. goats and sheep) which are highly valued sources of protein and revenue in most developing areas, are often exposed to antibiotics and antimicrobials to control diseases and combat infection. Nevertheless, improper and excessive use of these medications may lead to emergence of AMR, which undermines the efficacy of antimicrobial medicines against animals and people.

The sensitivity of AMR is far reaching in terms of animal health, food security and public health. Animals and humans also find it difficult and expensive to treat infections as the pathogens get resistant to the popular antibiotics. An infection that could once be treated easily may end up being chronic or even decline in death causing a greater morbidity rate and the loss of animals, and a greater threat to the health of the people. This results in management of AMR in livestock system being an essential part of veterinary public health as well as antimicrobial stewardship internationally.(1)

1.2 Dangers of the Inappropriate Appropriate Use of Antimicrobial in Small Ruminants

The extensive (or misuse) of antimicrobials in small ruminant farming; is also of a great concern because of intensive medication applied in preventing diseases outbreaks, or treating infections. Farmers in the semi-arid areas usually lack veterinary services and can also end up being self-diagnosing or administering antibiotics prophylactically to healthy livestock, instead of using antimicrobials to treat an illness. Such non selective antimicrobial administration leads to development of resistant pathogens that are not easily curbed thus posing bad health outcomes to the animals and being unable to contain infectious diseases.

Such an administration of antimicrobials in small ruminants may cause grave effects to the health of the population. Birds and other animals may transmit the antimicrobial-resistant bacteria to humans by direct transmission, ingestion of infected animal foods or the environmental routes. Human diseases may be treated with resistance

strains of bacteria, while zoonotic diseases become difficult to handle. Regions with a small ruminant farming such as northern Namibia, where the commodity plays a fundamental role in the economy demonstrate how uninhibited application of antibiotics can produce disastrous effects on the wellbeing of livestock and human beings.

1.3 The Significance of Metaphylaxis and Farmer Education in the Antimicrobial Stewardship

Metaphylaxis is the course of action of using antimicrobials to treat a group of animals in which one or more of them has been diagnosed to have a disease, yet the majority of the group members are not yet showing signs. It is an extreme program that seeks to forestall the spreading of diseases among the animals in a herd or flock without necessarily taking prophylactic measures to a wide range of agents. Metaphylaxis practice has proven to save on the total quantity of antimicrobials used since only animals at risk get the treatment instead of treating the whole population using antibiotics.(2)

But effectiveness of use of metaphylaxis rests on farmer acceptance and understanding. Teaching of farmers is a very important role in eurosieving that the usage of antimicrobials is used properly and that there is a change in the attitude towards excessive use of them. It is vital that farmers receive training to be able to identify clinical signs of illness and apply target metaphylaxis, and realize the meaning of accuracy of dosage and withdrawal cycles that will be essential in minimizing the consumption of antimicrobial agents. Education programs also help acquire knowledge about AMR risks and allow promoting the best practices in disease management.

1.4 Study Objective

This study aimed at determining the efficacy of a combined intervention combining targeted metaphylaxis with farmer education in minimizing antimicrobial use in the farming systems of small ruminants in the semi-arid areas of northern Namibia. Namely, the objective of the study was to estimate whether the introduction of selective approaches in antimicrobial use training of farmers and metaphylactic protocols might result in lower rates of antimicrobial treatment that would not affect animal health outcomes. Aims of the study also aimed to provide a measure to determine the effect of the intervention against non-compliance of farmers and to determine the sustainability of the antimicrobial stewardship practices within resource-limited farming communities.

This study hopes to enhance the livestock health, decrease antimicrobial resistance and ensure better sustainability of the farming process in small ruminant production system by working on the practice of disease management and antimicrobial stewardship.(3)

2. Design of the Study and Choice of Farm

2.1 Characterization of the Cohort Design

The article was based on a cohort design; it aimed to determine the successfulness of a combined, integrated intervention consisting of farmer education and specific metaphylaxis in the minimization of antimicrobials in small ruminant farming. A cohort design is especially appropriate whenever the outcomes of a long-term test in the real world are to be measured, because this is when there can be two different groups compared one to another: an intervention and a control group.

A total of 40 farms was strategically sampled in this research study; and the sampled farms were categorised into two samples namely, intervention and control group of farms, where each group consisted of 20 farms. The control group was allowed to carry on with their practices, including regular, non-selective antimicrobial interventions, whereas the intervention group was trained in the implementation of selective antimicrobial use and metaphylactic protocols of controlling eruptions of the disease. The research was in 6 months during which the frequency of treatment, clinical recovery and morbidity could be gauged on both groups.

The cohort design allowed the collection of data in real life settings that would reflect the common farming practice and it gave a chance to determine the effectiveness of the intervention in a semi arid area. The prospective study taking a long period of time enabled the assessment and follow-up of behaviour changes and effects of education and training on outcomes of the antimicrobial utilisation and the welfare of livestock.(4)

2.2 Selection criteria of the 40 Goat and sheep farms

The farms used in the study were selected after consideration of a number of criteria that were meant to make the farms representative of farming systems of small ruminants in northern Namibia. The principal selection criteria to be applied were:

1. **Farm Size:** The units which were used to study were small-scale producers and on average they looked after less than 200 animals, which is common in this type of small holder farming in this region.

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2. **Livestock Type:** A selection was done to have only the goats and sheep farms so that the results could be applicable to the most reared livestock in the semi-arid parts of northern Namibia.
3. **Current Antimicrobial Administration:** The priority was given to such farms where the routine administration of antimicrobials had been observed especially during the preventive treatment procedures and prophylaxis. This enabled a well-defined comparison between the normal way of doing things and the intervention that is meant to influence the reduction of unnecessary use of antimicrobials.(5)
4. **Farmers willfulness and participation:** Farmers will be chosen on the willingness to be part of the study wherein they are comfortable with learning new management practice and will learn metaphylactic protocols. The assistance of the farmers was also essential to contact valid information and make the training and intervention effective.
5. **Geographic Distribution:** This was done in relation to geographic areas: the selected farms were located in various geographic areas within the semi-arid areas of northern Namibia, so that to a degree geographical distribution of farms was achieved and the findings representative of various environmental and management circumstances was evidenced.

2.3 Geographic and Climatical pretext of the semi arid areas in Northern Namibia

The research was done in the dry parts of northern Namibia, the area that is marked by low rainfall, high temperatures and variability of the seasons. The climatic condition in these regions is categorized as semi arid whereby rainfall during the year is below 500 mm in most quarters. Such climatic background poses special problems on the farming of small ruminants where some areas supply adequate and quality forage during wet seasons and inadequate and poor quality during the dry seasons, and water may be scarce during dry seasons.

The semi arid nature enhances the stress on livestock which in turn makes the livestock prone to diseases and infections. This means that in most cases, farmers in these areas result in the regular use of antimicrobials in order to treat a disease or prevent it, enhancing the chances of antimicrobial resistance. The current research focused on those issues by investigating the effectiveness of targeted metaphylaxis, along with the education of the farmers, in the reduction of broad-spectrum antimicrobial treatment rates and the increased health outcomes of livestock.

The geographical setting of northern Namibia also forms an applicable background to the study because most semi-arid places of sub Saharan Africa share common challenges concerning the use of antimicrobials, animal management, and diseases. This study may thus have a potential solution to the problem of antimicrobial resistance in small ruminant farming in other parts of the world based on the study carried out.(6)

3. Metaphylaxis (Procedure) And Educational Intervention

3.1 Farmer Training Sessions Material and Methods

The educational intervention was intended to provide farmers with knowledge and capacity to minimize the use of antimicrobial agents without compromising the health of animals with such measures as selective treatment and targeted metaphylaxis. The training material was written to be applied, situation, and needs-specific to the small ruminant farmers in PVSAs.(7)

The main aspects taught during the training sessions were the following:

1. **Learning about Antimicrobial Resistance (AMR):** Farmers learned about the issue of AMR globally, the effects it has on animal and human wellbeing, and the role the misuse of antimicrobials plays in the perpetration of the problem. This area was intended to sensitize people on the importance of responsible use of antimicrobials so as to provide future treatments.
2. **Principles of Metaphylaxis:** Principles of metaphylaxis was introduced which was the use of antibiotics on animals that perhaps exposed to disease before the disease manifests itself. The meeting highlighted that it helped it to avert the transmission of contagious diseases without over-treating healthy animals.
3. **Selective Regimen of Antimicrobial Use:** Farmers were taught on the methods of identifying ill animals that needed treatment and the methods of administering selective application of antibiotics in individual animal or small groups, instead of using the conventional methods of applying the selective antibiotics to the entire farm, whether sick or not.
4. **Health Management:** Under the general animal health management technique, the training discussed the importance of vaccination, parasite control and nutritional management as methods of reducing occurrence of diseases and antimicrobial therapy.

The delivery mode was to be through interactive workshops, in which farmers were to engage in practical activities through case studies, role-play and demonstrations. These sessions were kept as small groups so that there could be an individualized interaction and discussion of a community. Further, a handout and visual aids were used to support important ideas. Local languages were used in carrying out the training to allow understanding and clarity.

3.2 Recommendations on Selective, Targeted Antimicrobial Practice

The farmers were equipped with guidelines on the selective usage of antimicrobials where the following recommendations were helmed:

1. **Observation and Diagnosis:** Farmers learned how to notice early symptoms of diseases, how to distinguish between prevention and curative treatment options, and how to rely on clinical symptoms to provide the guidance in the treatment choice.
2. **Antimicrobial Protocols:** There was a designated protocol of metaphylaxis, the details regarding the need and use of the antibiotics in the at-risk animals depending on the clinical symptoms, the risk of the disease transmission, and local patterns of the diseases. This protocol was meant to reduce redundant treatments and cause disease outbreaks successfully.
3. **Dosage and withdrawal periods:** The right importance should be given to dosage and both to avoid the presence of antimicrobial residues in animal products and allow consumers to be satisfied with safety.

3.3 Surveillance and Tactics of Compliance

To follow the effective passing of the educational intervention, monitoring and compliance system was developed:

- **Farmer Records:** They advocated the keeping of minuted farm records which contained information on disease outbreaks, medications used, dosage and dates by farmers. These records were useful to track adherence to protocols and allow subsequent assessment of how successful treatments can be.
- **Farm Visits and Follow-Ups:** To ensure the absorbency of the implemented methods, trained veterinary technicians would visit the farms regularly to check up on the farm and ensure that the metaphylaxis protocols were being followed and in case of any occurrence of problems, make correctional advice or help
- **Feedback and Adjustment:** Farmer participants in the intervention would receive constant feedback of their progress and changes to the intervention would be introduced were problems recorded during follow up visits. This guaranteed that the practices towards antimicrobial stewardship improved.

These cumulative efforts were intended to foster long-lasting adherence with fewer antimicrobials with the maintenance of the optimum livestock health in low resource farming systems. The final objective was to develop a sustainable model of an antimicrobial stewardship in small ruminant production systems that could be reproduced in a similar environment in sub-Saharan Africa as well as in other parts of the world.(8)

4. Methods of Data Collection and Health Outcomes Measures

4.1 Measures of Parameters: Antimicrobial Treatment Frequency, Clinical Recovery and Morbidity Rates

The outcome of the research study was to evaluate the effects of the intervention on antimicrobial use and the improvement of health outcomes in small ruminant systems, tackling some of the primary parameters in terms of both the treatment practices and animal welfare.

1. **Frequency of antimicrobial Treatments:** The number of antimicrobial treatments given at the farms was primary outcome of the effectiveness of intervention. This was taken into account by the number of treatments an animal received due to the occurrence of some disease either preventatively as well as curatively. This was a measure that would enable a comparison to be made regarding the frequency of antimicrobial treatment in the intervention and control groups. The targeted metaphylaxis intervention was supposed to improve the antimicrobial utilization by reducing it in the intervention group because of the strategic intervention and the selective antibiotic usage.(9)
2. **Clinical recovery:** As an indicator that the change in reduced antimicrobial use did not have an adverse impact on the health of the animals, clinical recovery of treated animal was monitored as a secondary measure. The evaluation of recovery was carried out according to the clinical response of animals treated, such as: decrease in fever, start of feeding, and normal activity. The level of recovery was also observed after the treatment period at a constant interval, usually after 7 days of the administration.
3. **Morbidity Rates:** Morbidity rates, that is, the number of disease incidences on each farm, were also kept closely. This involved following up any outbreak or incidences of rising number of sick animals both in

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the intervention and the control groups. The morbidity rate is given as the proportion of the affected animals per herd to the number of animals in that farm. This indicator was used to estimate the effectiveness of the intervention to prevent the disease and the health of the flock in general.

4.2 Farm records validation and recording tools

The farmers were offered straightforward recording devices that should monitor antimicrobial consumption, recuperation, and cases of disease. Such tools were:

- **Treatment logs**: Farmers were supplied with standardized logbook wherein each antimicrobial treatment given should be recorded i.e. disease diagnosed, type of treatment, dose and administration date. This was able to monitor the treatment frequency and was also able to give some valuable info as to whether the targeted metaphylaxis protocols were being adhered to.(10)
- **Health monitoring Sheets:** A health monitoring sheet (different sheet) was used to measure the clinical recovery and morbidity rates. This document enabled farmers to make their notes regarding symptoms, curative results, and new sceneries of disease occurrence that they witnessed, with a clear report of the health of animals per day.

As part of the program to maintain accuracy and reliability of the data, visiting of the farms was carried out intermittently by veterinary technicians. These visits involved examination of the records with comparison between the data of treatment and clinical observations to maintain consistency.

4.3 Datas Collection Timeline Within 6 Months Period of Lambing

The lambing period was 6 months and it was during this period that data collection was done as it gave a wide coverage of health outcomes during a vitality period of production. The history was separated in to two parts:

- **Pre-Lambing Phase (02 months):** Using collected information on antimicrobial use, morbidity, and health management provided a baseline data of treatment pattern.
- **Lambing and Post- Lambing phase (3-6 months):** The prevalence of treated no more lambing was documented and frequent follow-up on morbidity rates and clinical improvement noted. The attention at this stage was on the outbreak of disease, effective treatments and whether there was any significant decrease on the usage of antimicrobial in the intervention group compared to the control.

During the trial, to record the real-time results related to health outcomes, and estimate the adherence of farmers to the metaphylaxis schedules, as well as determine whether the training produced long-term changes in the antimicrobial stewardship practices, the trial included weekly follow-ups, visits to the farms and interviewing practicing farmers.(11)

The information obtained made it possible to thoroughly compare the intervention and control groups and give the most valuable information as to the efficiency of education of farmers and selective metaphylaxis concerning the prevention of overuse of antimicrobials without affecting animal health within the framework of semi-arid farming systems.

5. Results

5.1 Fewer Antimicrobial Use in the Intervention Group

In the intervention group (the targeted metaphylaxis protocols and the education of farmers), the defrayal of antimicrobial treatments was noted at a considerably reduced rate as opposed to the control group. During the lambing season (6 months), the proportion of antimicrobial treatment by the intervention group was down significantly (by 41%; $p < 0.01$). This reduction was mostly anchored on embracing the principles of selective use of antibiotics in animals, meaning the usage of antibiotics was only allowed on specific animals prone to an illness, but not on all herds.

Conversely, the control group did not realize any significant decline in the frequency of treatment; given that they still adhered to conventional guidelines of routine antibiotic application. These estimations show that significant decreases in unnecessary antimicrobial use may be achieved with targeted interventions like metaphylaxis to reduce unnecessary antimicrobial use aims and farmer education to help address antimicrobial resistance without putting animal health at risk.(12)

Table 1: Antimicrobial Treatment Frequency Comparison

Group	Baseline Treatment Frequency (treatments/animal)	Final Treatment Frequency (treatments/animal)	Percentage Reduction	p-value
Intervention Group	2.75	1.62	41%	<0.01
Control Group	2.78	2.76	0%	NS

5.2 No Adverse Clinical Outstantics

Even though the number of times that antimicrobial treatment occurred was reduced, it did not adversely affect clinical outcomes in the treatment group. The morbidity rates and the rates of clinical recovery were comparable in the intervention and the control groups. The animals in the intervention group where targeted metaphylaxis was given exhibited clinical recovery analogous to the control group where 95 percent of animals in the CL group had recovered and so also in the treated animals using metaphylax.(13)

Also, the morbidity levels in both the groups were within the limits of the morbidity index in lambing season and no statistical significance is found between the groups ($p > 0.05$). Based on these results we can assume that selective treatment and metaphylaxis reduction of antimicrobial use did not result in reduced animal health outcomes or incidence of increased disease.

Table 2: Clinical Recovery and Morbidity Rates

Group	Clinical Recovery Rate (%)	Morbidity Rate (%)	p-value
Intervention Group	95	8.4	NS
Control Group	95	8.7	NS

5.3 Improvement in Farmer Adherence to Treatment Schedules

The farmer adherence to the metaphylaxis protocols significantly improved following the educational intervention. Initially, farmer compliance with the scheduled antimicrobial use was low, with many farmers in the intervention group using antibiotics more frequently than necessary. However, after training, compliance with treatment schedules increased by 50% ($p < 0.05$), with farmers more consistently following the metaphylaxis guidelines and using antimicrobials only when necessary.(14)

Farmers also demonstrated improved understanding of the clinical signs of disease, leading to better decision-making about when and how to treat animals. The increased adherence to protocols was validated through farm visits and record inspections.

Table 3: Farmer Compliance with Metaphylaxis Protocols

Group	Baseline Compliance (%)	Post-Training Compliance (%)	p-value
Intervention Group	56%	84%	<0.05
Control Group	55%	56%	NS

5.4 Analysis of Variance and Significance Values

To compare the results obtained with the help of the intervention and the control groups, the data were analyzed with the help of paired t-tests and Chi-square tests regarding categorical data. All of the main outcome measures, which included the frequency of antimicrobial treatment, clinical recovery, and morbidity rates, were improved by the intervention and reached a statistically significant difference ($p < 0.01$ in regard to the frequency of antimicrobial treatment and $p > 0.05$ in regard to healthcare outcomes). The intervention group also had increased adherence by farmers ($p < 0.05$), thus demonstrating greater effects of farmer education and training on metaphylaxis procedures.(15)

The findings show that specific antimicrobial use and education of farmers is a good method of promoting a decrease in antimicrobial use without affecting animal health. The study has arguments that the incorporation of education with strategies of combating diseases would help advance accountability in the use of antimicrobial in centring farming systems against antimicrobial resistance globally.

6. Conclusion

6.1 Performance of Farmer Education Plus Targeted Metaphylaxis

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The current study has shown that combined method of farmer education and metaphylaxis specific could be very efficient in terms of decreasing the use of antimicrobials in small ruminant farming systems without impacting on animal health. Training and the use of selective antimicrobial usage in the form of metaphylaxis protocols resulted in a 41 percent decrease in the antimicrobial treatments provided by the intervention group ($p < 0.01$); this considerably reduced the use of antibiotics. Notably, the clinical recovery and morbidity rates remained unchanged compared to the control group, which proves that smaller exposures to antimicrobials did not adversely impact the health outcomes of the animals.

The trainer sessions with farm owners played a vital role in making the farmers learn the consequences of selective therapy as well as implement the metaphylaxis procedures efficiently. The increase by half of the proportion of farmer adherence to treatment schedules (50% after training) demonstrates that education is an important tool in modifying the behavior and encouraging responsible use of antimicrobial agents. The results indicate the great potential of having a proper organization of education of the antimicrobial stewardship concept even in such a resource-limited environment, where infrastructure and access to veterinary medicine can be reduced.

6.2 Antimicrobial Stewardship implications in Low Resource Animal Farming Systems

Findings of this research are of great significance in the field of antimicrobial stewardship in low-resource and smallholder animal production systems, particular with semi-arid areas such as northern Namibia. The issue of antimicrobial resistance (AMR) has increasingly become a concern in most developing areas, and proper use of antimicrobials remains one of the keys in ensuring that they remain effective in the treatment of infections in animals and human beings alike. This study provides a future model of a sustainable livestock health management mechanism since it establishes that metaphylaxis can help to limit antimicrobial use without affecting the health of the animals.

In overly simplistic terms, farmers who use antimicrobials on a regular basis out of necessity can also be educated to practice targeted approaches to specific diseases as alternatives to routine antimicrobial use in low resource settings, where the risk of transmission to humans is high. The method also underlines the role of education of farmers about how they can maintain the wellbeing of livestock to ensure that this translates into the sustainability aspect of the farming process in the long view.

6.3 Recommendations on expansion of the intervention to other areas with similar agro-ecological zones

With a view to up-scaling this intervention into other areas with an identical agro-ecological zone, following points must be taken into consideration:

- **Training Programs:** Ensure that the programs of farmer education in the topics of selective utilization of antimicrobials, disease control, and sustainable management strategies are expanded. The programs must fit in local agro-ecological situations as well as the livestock management practices.
- **Collaborating with Veterinary Services:** The partners have to collaborate with the veterinary extension services to make sure that there are adequate technical support and advice to the farmers in the course of implementation. Veterinary practitioners may contribute largely by checking compliance and providing more options in managing the disease.
- **Government/Policy** Support: Support policies that promote the responsible use of antimicrobials, including government subsidized training or financial rewards to farmers that apply good management.
- **Scale-Up:** The strategy that is being piloted in northern Namibia can be tailored and applied to other Semi-arid areas that share similar farming systems and issues involving antimicrobial usage.

When this integrated method is scaled up, precision metaphylaxis and farmer education can become a part of the national agricultural plan of other countries to significantly decrease AMR spread and drive sustainable and efficient farming systems toward small ruminants in sub-Saharan Africa and beyond.

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Conflicts of interest

The authors have no conflicts of interest to declare

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