USE OF ANTIBIOTICS IN LIVESTOCK PRODUCTION IN UGANDA

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Executive Summary

Introduction:

Uganda-specific estimates on commonly available antibiotics, quantities used, frequency, distribution channels and sources of information on disease management are generally unavailable and when available This is, in part, due to the poor documentation by both farmers and livestock-health practitioners and the weak enforcement of policies on antimicrobial use (Musoke et al 2021). This poses a great risk of drug misuse by farmers whose practices are mostly unchecked leading to building of antimicrobial resistance, a rising global threat to both human food safety and environmental conservation (Nayiga et al., 2020). Based on our literature search, no study in Uganda has addressed the information gap on the frequency of antibiotics use and its driving factors, main sources of information on antibiotics among, the prevalence of antibiotics self-prescription among livestock keepers, and the major drivers of this growing malpractice. The inadequate information poses a great risk of drug misuse by farmers whose practices are mostly unchecked leading to building of antimicrobial resistance, a rising global threat to both human food safety and environmental conservation (Nayiga et al., 2020).

Understanding use and frequency of use of antibiotics and the factors driving these decisions is critical information in designing appropriate interventions to guide suitable use of antibiotics and prevent or slow the development of antimicrobial resistance. In addition, understanding the level of antibiotics' self-prescription and its drivers is critical information in designing appropriate interventions to curb it. This information will allow description of farmers likely to involve in the malpractice and feed into the design of proper antibiotics use campaigns by targeting livestock keepers most likely to get involved in antibiotics' self-prescription. Furthermore, promoting appropriate use of drugs through accurate and reliable data tracking is very crucial in the design of evidence-based policies and decisions in livestock disease management and overall production. The identification and recommendations to address the broader underlying causes of antibiotics self-

prescription is imperative in achieving food security and improved nutrition in a healthy environment.

1. *What are the* ***drivers*** *of antibiotics use in livestock production?*
   The drivers are: a) believing that antibiotics will remain effective; b) the gender of the household head; c) More educated households and d) the source of information on antibiotics Information access from either professional sources (veterinary officers) and personal judgement positively influenced the decision to use antibiotics in livestock production. This study found that believing that antibiotic will remain effective even with continuous use significantly influenced the decision to use antibiotics. The study also found a positive association between gender of the household head and the decision to use antibiotics. Male headed households were more likely (4%) to have used antibiotics than their female counterparts. In addition, household heads who had completed at least lower secondary education (13 years or more in school) were also more likely (3%) to have used antibiotics.

2. *How often do livestock keepers use antibiotics?*
   Most (87%) livestock keepers had occasionally (less than once a month) used antibiotics. The results show that most intense users were among households keeping some exotic animals where 20% of the livestock keepers keeping exotic animals used antibiotics at least once a month or more frequently. Keepers of exotics animals were followed by households residing in the Eastern region (19%), keeping pigs (18%) and poultry keeping (14%) households. We note that although there were many users in the north, most (89%) were only occasionally using antibiotics.

3. *What are the drivers of the frequent use of antibiotics in livestock production?*
   The drivers of frequent use are: a) Households keeping cattle and pack animals, shoats, poultry, or any exotic animal were more likely to use antibiotics frequently; b) Geographical location, that is households in the Eastern and Northern regions were significantly more likely to use antibiotics frequently than their counterparts in the Western and Central regions; and c) Perceptions, that is livestock keepers with perceptions that antibiotics will remain effective even with continuous use were significantly more likely to use antibiotics frequently.

4. *What is the main source of information about antibiotics used by the farmers?*
   The main sources of information are veterinary practitioner (Public or private veterinarian) and/or non-veterinarian personnel such as extension service provider (public or private) and input dealer). Results revealed that livestock keepers interchanged between the mentioned sources of information such that one household could get information from multiple sources

5. *What influences the choice of source of information on antibiotics use?*

The factors that influence the choice of source of information are: a) the frequency of antibiotic use in poultry; b) the perception a livestock keeper has on the loss of effectiveness of antibiotics if frequently used, c) using antibiotics for preventive and curative purposes, and d) the regional households in central, Eastern and Northern regions.

6. *What factors determine whether one seeks professional advice or self-prescribes antibiotics to be used?*
   The factors determine whether one seeks professional advice or self-prescribes antibiotics are: a) gender of the household head, b) household keeping cattle, shoats and poultry, c) households being located in the northern region. About 77% of livestock keepers using antibiotics were involved in self-prescription at one point and nine in every ten antibiotics users engaged in self-prescription only occasionally used antibiotics.

This study concludes that although a significant number of livestock keepers are using antibiotics (one in every three), most only occasionally use antibiotics. This still presents a window of opportunity to regulate use moving forward. This study further concludes that antibiotics use in Uganda, though not yet as high as in developed countries, has reached levels that require intervention to streamline its use if antimicrobial resistance is to be managed. To curb non-judicious antibiotic use to check the buildup of the antimicrobial resistance in livestock and human populations, this study recommends as follows.

- Design of programs to counter livestock keepers ‘perceptions towards continued use of antibiotics. This can be done through development key messages on the potential effects of continuous, improper and or non-medically prescribed use of antibiotics to animals, livestock and the environment in general because perceptions influenced.
- Programs campaigning for judicious use of antibiotics need to target more educated livestock keepers, keepers of exotic livestock and households in the northern and central regions. These were associated with higher likelihood of use and frequency of use

Key words: Antibiotics; Livestock; Uganda

1.0 Background

Livestock is an important component of livelihoods in 57% of the 70% of Ugandan households that depend on agriculture as a source of food, income, employment, and improved social status (FAO, 2019). Where the land terrain is favorable, livestock provide additional benefits in the form of draught power for cultivation and transport. Fifty-seven percent of agricultural households, most of them smallholder farmers, in Uganda depend on livestock for their livelihoods (FAO, 2019). Despite the number of people involved in the livestock production, the sub sector only contributed 3.8% to the national GDP in 2019 (UBOS, 2020). Livestock rearing presents an opportunity to address the high poverty levels among smallholder farmers (Benson et al., 2013, UBOS, 2016) if appropriate investments are made and persistent bottlenecks curtailing the growth of the sub sector are addressed. Persistent constraints in Uganda livestock production include livestock parasites, infectious diseases, limited institutional and policy support to livestock farmers, and below-optimum management practices among farmers (Turner, 2005). These combined with emerging issues of climate change and turbulence in the international livestock markets continue to hold back the sector from reaching its true potential.

Livestock diseases such as, Contagious Bovine Pleuropneumonia (CBPP), Foot and Mouth Disease (FMD), New Castle, or tick-borne diseases like East Coast Fever (ECF) have presented the greatest challenge to producers due to their highly infectious and fast spreading nature (Byarugaba et al., 2015). These have led to economic losses to farmers which affects total supply of livestock products for both home consumption and sale. Notable though are the bacterial diseases such as blackleg and mastitis in cattle, avian coliba cillosis in poultry and salmonellosis related diseases in all livestock in general, for which the use of antibiotics has seen a sharp increase to abate them. However, anecdotal evidence has revealed that condition showing the symptoms of fever (e.g., east coast fever, tick fever, babesiosis or heartwater) may be treated with antibiotics even though they are not bacterial infections (UNAS et al., 2015). In addition, the requirement to meet the current demand for animal-origin food in a cost-effective manner has necessitated ensuring production of early maturing animal protein sources especially in chicken and piggery. Enhancing feed conversion ratios and managing diseases for optimum productivity have, to a significant extent, driven the emerging demand for and increased use of antimicrobial agents.

The wide availability of antimicrobials coupled with limited regulation by the mandated authorities has led to the proliferation of self-prescription and administration of antibiotics by livestock keepers (Dione et al., 2021). Most of these farmers have been found to lack the knowledge and expertise on their proper use and application (Byarugaba & Sewankambo, 2015; Mikecz et al., 2020; MoFPED, 2021; Nayiga et al., 2020). As such, they often run the risk of either giving the wrong dose (over- or under-estimate) or using the same antibiotic even when it is no longer effective. For instance, incongruous use of antibiotics by livestock farmers in Lira and Mukono districts was reported by Dione et al.(2021), while Bashahun et al. (2015) highlighted the excessive use of antibiotics as growth promoters among poultry farmers in Wakiso district.

Uganda-specific estimates on commonly available antibiotics, quantities used, frequency, distribution channels and sources of information on disease management are generally unavailable and when available cover a few districts (Kimera et al., Musoke et al., Nayiga et al.), have limited samples, and tend to be livestock specific (Ikwap et al., 2015; sasanya et al., 2005) thus not nationally representative. This is, in part, due to the poor documentation by both farmers and livestock-health practitioners and the weak enforcement of policies on antimicrobial use (Musoke et al., 2021). This poses a great risk of drug misuse by farmers whose practices are mostly unchecked leading to building of antimicrobial resistance, a rising global threat to both human food safety and environmental conservation (Nayiga et al., 2020). Based on our literature search, no study in Uganda has addressed the information gap on the frequency of antibiotics use and its driving factors, main sources of information on antibiotics among, the prevalence of antibiotics self-prescription among livestock keepers, and the major drivers of this growing malpractice.

Understanding use and frequency of use of antibiotics and the factors driving these decisions is critical information in designing appropriate interventions to guide suitable use of antibiotics and prevent or slow the development of antimicrobial resistance. In addition, understanding the level of antibiotics' self-prescription and its drivers is critical information in designing appropriate interventions to curb it. This information will allow description of farmers likely to involve in the malpractice and feed into the design of proper antibiotics use campaigns by targeting livestock keepers most likely to get involved in antibiotics' self-prescription. Furthermore, promoting appropriate use of drugs through accurate and reliable data tracking is very crucial in the design of evidence-based policies and decisions in livestock disease management and overall production. The identification and recommendations to address the broader underlying causes of antibiotics self-prescription is imperative in achieving food security and improved nutrition in a healthy environment.

1.2 Motivation of the study

It is estimated that livestock production accounts for about 70% of global antibiotics administered (Ganan, 2017) . Livestock owners and veterinarians use antibiotics as administered drugs or feed additives to increase the growth rates and efficiency of farmed animals. Necessity of antibiotics when used judiciously as administered drugs to prevent or cure bacterial diseases remains largely unchallenged. On the contrary, the use of antibiotics in animal feed has generated interest among public health professionals due to the possibility of promoting the selection of antibiotic resistance in bacterial populations leading to antimicrobial resistance in livestock and human populations. The argument of potential public health threats arising from use of antibiotics as feed additives has already generated some legislative and policy change in developed countries (Ganan, 2017; Salim et al., 2018). For instance, the use of antibiotics as growth promoters was banned in Europe and South Korea since 2006 and 2011 respectively while the United States Federal Drug Authority issued industry guidelines on the use of antibiotics as feed additives or growth promoters (Salim et al., 2018). Even with growing concerns about the emergence of antibiotic-resistant strains around the world and tangible actions being taken in the developed world, little to no work is being done in the developing world, especially sub-Saharan Africa. One way to solve the resistance problem is to develop strategies to control the overuse of antibiotics through appropriate regulations, policies and industry guidelines. The starting point for developing appropriate strategies is understanding the scale of antibiotics use in these countries.

1.3 Research questions

1. What are the drivers of antibiotics use in livestock production?
2. How frequent do livestock keepers use antibiotics?
3. What are the drivers of the frequent use of antibiotics in livestock production?
4. What is the main source of information about antibiotics used by the farmers?
5. What influences the choice of source of information on antibiotics use?
6. What factors determine whether one seeks professional advice or self-prescribes antibiotics to be used?

1.4 Structure of the report

The rest of this report is presented in three major sections. The first section presents the methodological approach for each objective. The second section presents, interprets, and discusses the results from the analysis. The last section provides a summary of the findings, draws conclusions, and presents both data related and policy relevant recommendations.

2.0 Methodology

2.1 Sources and type of data used

The study used the Annual Agricultural Survey[1] (AAS) 2018 data set which is a nationally representative Household survey that was implemented by the Uganda Bureau of Statistics (UBOS) and the FAO. Unlike the AAS 2017 and the other rounds of AAS, in 2018, an antimicrobial use module was integrated into the survey to collect information on antibiotic use in livestock production. The AAS was administered to a sample of 7,157 agricultural households but excluded the non-household sector (UBOS, 2020). The livestock questionnaire in the AAS was administered during the post-harvest visit of the second season in which data on livestock stock, production and input is collected for the previous 12 months. In the livestock module, five questions which included the type of antibiotics used, the purpose of using antibiotics, the frequency of usage, who advises on the use of antibiotics, farmer's opinion on whether frequent use of antibiotics can alter the effect of the drugs are asked. These were the main questions used by this study consequently both dependent variables (use and frequency of use) and some independent variables (knowledge and perceptions, and information seeking and access) were derived from these questions. Table 1 present the summary of variables used in the analysis.

[1] A detailed description of the AAS data especially the antimicrobial related data has already been published by Mikecz et al. (2020)

Table 1: summary of variables used in the analysis

Variable	Percent/Mean	Std. Dev.
Dependent variable		
Household used any antibiotic in the last 12 months (1=Male; 0=Female)	34.27%	
Frequency of antibiotics use		
Never	61.62%	
Occasionally (less than monthly)	33.17%	
Regularly (At least once a month or more frequent)	5.21%	
Independent variables		
Household head is a youth (aged 35 years or below) (1=Yes; 0=No)	11.06%	
Gender of the household head (1=Male; 0=Female)	76.97%	
Household kept cattle and pack animals (1=Yes; 0=No)	65.00%	
Household kept pigs (1=Yes; 0=No)?	30.18%	
Household kept poultry (1=Yes; 0=No)	67.06%	
Total tropical livestock units[2] of both local and exotic animals owned	1.39	4.53
Number of livestock types kept by the household	2.10	1.08
Proportion of land under crop	0.71	0.31
Region		
Central region	15.70%	
Eastern region	25.67%	
Northern region	34.21%	
Western region	24.43%	
Household has at least one exotic livestock species (1=Yes; 0=No)	12.51%	
Household's main economic activity is agriculture (1=Yes; 0=No)	82.50%	
Household's members belong to a farmer group (1=Yes; 0=No)	13.65%	
Household head completed at least secondary school (1=Yes; 0=No)	25.87%	
Household believes antibiotics will not become less effective even with continuous use (1=Yes; 0=No)	16.08%	
Information about antibiotics comes from private/public extension (1=Yes; 0=No)	4.58%	
Information about antibiotics comes from farmer to farmer (1=Yes; 0=No)	14.17%	
Information about antibiotics comes from word of mouth/other peers (1=Yes; 0=No)	10.38%	
Distance to nearest input shop is greater than 5 kilo meters (1=Yes; 0=No)	67.73%	
Farmer sought information from veterinary officer (1=Yes; 0=No)	20.81%	
Farmer did not seek advice from any source--self-administration (1=Yes; 0=No)	10.13%	
Household accessed loan for agricultural purposes (1=Yes; 0=No)	11.71%	
Number of households in the sample keeping livestock	4,407	

Source: microdata from the 2018 AAS (UBOS)

[2]Tropical Livestock Units are livestock numbers converted to a common unit.

2.2 Data processing

The data was accessed from UBOS[3] and processed using Stata software version 17. Data processing included cleaning, variable recoding, calculation, and new variable generations to fit the purpose of the study

2.3 Data Analysis

The study used both descriptive and econometric methods of analysis to address the set objectives. All data analysis was done using Stata 17 analysis Software except graphs and illustrations where Microsoft Excel software was used. Weighted percentages were mostly reported for descriptive data while model output coefficients, standard errors, and p-value were reported for econometric analysis. Where statistical tests of differences were performed, p-values were reported. All hypotheses were tested at the 95% and 99% significance levels.

Research question 1 seeks to determine the are the drivers of antibiotics use in livestock production. The dependent variable was antibiotics use or non-use. This study used a Probit model to determine the odds of the decision to use antibiotics and the drivers of antibiotics use. The specification of the Probit model is the same as the one used in objective addressing objective 6 and a detailed specification is presented under objective 6.

Research question 2 seeks determine how frequently livestock keepers use antibiotics while **research question 4** asks for the main source of information about antibiotics used by the farmers. Both research questions were addressed using descriptive analysis methods and weighted sample percentages were reported. The frequency of antibiotics use and sources of information about antibiotics was analyzed at household (production unit) level. Households were characterized based on how often (never, occasionally, or often) they used antibiotics and where they got their information from. This was disaggregated by gender of the main livestock keeping decision maker to understand the gender dynamics in the use of antibiotics. The same data was also disaggregated by age to unveil any roles by the youth or the elderly in the use of antibiotics. Statistical tests of differences (student's t-tests and chi-square tests) were conducted to confirm any statistical significance wherever applicable.

Research question 3 on the drivers of the frequent use of antibiotics in livestock production was addressed using econometric analysis (regression) approach. The study also sought to determine the factors that influence the frequency at which antibiotics are used once the decision to use antibiotics has been made. The dependent variable (frequency of use) had three possible outcomes, that is, never used, occasionally used (less than monthly), and frequently used (at least once every month or more). The outcomes were discrete but ordered hence an ordered response model (Probit or Logit) could be appropriate for such a dependent variable. However, in exploring the relationship between frequency of antibiotic use and the factors influencing it, it is critical to note

[3] Ethical Consideration: We obtained anonymized data from UBOS and thus have no concern of respondent anonymity. We have also maintained the highest standard of impartial reporting of results as they were generated. We hold no conflict of interest in the work produced

that although frequency of use assume non-negative discrete and ordered values, it is also characterized by a considerable proportion of zeros—non-users (Fávero, Hair, Souza, Albergaria, & Brugni, 2021). This is because a significant number of livestock keepers (over 65%) were found not to be using antibiotics (Mikecz et al., 2022) and these would register a zero in the dependent variable. Hence data on antibiotics frequency of use showed an over-representation of the zeros (non-users).

Due to the nature of the smallholder livestock keepers ranging from very few units (e.g., only 3 chickens), this study believed that the people in the non-user category may be structurally different. There may be a category of people who have never used and might never use antibiotics-think of people who do not invest in livestock disease management. The rest could be people who have used in the past but were non-users at the time of the study or have not yet used but might use in the future—true non-users. The standard ordered Probit model would fit the behavior of antibiotics users, taking the non-use category to be homogeneous. The zero inflation arises because the non-user's category now includes those who have never used it and might never use and those who have never used and might never use. Existence of the latter group could lead to inflation of the proportion of non-users. Standard ordered Probit models cannot account for the great number of zero observations when the zeros relate to an extra, distinct source (might never use) Harris and Zhao (2007). Thus, the zero-inflated ordered Probit model (ZIOP) was used to determine the drivers of antibiotics use frequency. ZIOP models are used for ordered response variables when the data exhibit a high fraction of observations at the lowest end of the ordering (0 or non-use). The concept of zero-inflation has its origin in Poisson models of count data with an overabundance of zeros. ZIOP applies this idea to ordinal data, where the numeric value of the lowest category need not be zero. The study used Stata's zioProbit command to fit the model (Harris and Zhao, 2007). Literature review (Manyi-Loh, Nayiga, Musoke, Mikecz) guided on the identification of key variables to use as independent variables in the model

Zero-inflated ordered Probit model specification

We follow specification by Maddala (1983) for equations 1 to 5, and thereafter follow Harris and Zhao (2007) for equations 6 and onwards to specify the zero-inflated ordered Probit model Let r denote a binary variable indicating the split between Regime 0 (with $r = 0$ for non-antibiotic users) and Regime 1 (with $r = 1$ for antibiotic users). r is related to a latent variable r^* via mapping: $r = 1$ for $r^* > 0$ and $r = 0$ for $r^* < 0$. The latent variable r^* represents the extent of antibiotic use and is given by equation 1.

$$r^* = x'\beta + \varepsilon \qquad (1)$$

where x is a vector of covariates that determine the choice between the two regimes, β is a vector of unknown coefficients and ε the error term. Therefore, the probability that a livestock keeper is in Regime 1 is given by equation 2 (Maddala, 1983).

$$\Pr(r = 1|x) = \Pr(r^* > 0|x) = \emptyset(x'\beta) \qquad (2)$$

where $\emptyset(.)$ is the cumulative distribution function *(c.d.f.)* of the univariate standard normal distribution.

Conditional on $r = 1$, frequency of use under Regime 1 are represented by a discrete variable $\breve{y}(\breve{y} = 0,1, \dots . j)$ that is generated by an ordered Probit model via a second underlying latent variable $\breve{y}^*$:

$$\breve{y}^* = z'\gamma + u, \qquad (3)$$

with z being a vector of explanatory variables with unknown weights γ, and u an error term following a standard normal distribution. The mapping between $\breve{y}^*$ and $\breve{y}$ is given by

$$\tilde{y} = \begin{cases} 0 \ \ if\ \breve{y}^* \le 0. \\ j \ \ if\ u_{j-1} < \breve{y}^* \le u_j \ \ (j = 1, \dots . j-1) \\ J \ \ if\ u_{j-1} \le \breve{y}^*, \end{cases} \qquad (4)$$

where u_j $(j = 1, \dots . j-1)$ are boundary parameters to be estimated in addition to γ(unknown weight of parameters to be estimated), and we assume throughout the paper that $u_0 = 0$. Note that, importantly, Regime 1 also allows for zero consumption. Also, there is no requirement that $x = z$. Under the assumption that u is standard Gaussian, the OP probabilities are specified as in equation 5 (Maddala, 1983).

$$\Pr(\tilde{y}) = \begin{cases} \Pr(\tilde{y} = 0|z, r = 1) = \emptyset(-z'\gamma), \\ \Pr(\tilde{y} = j|z, r = 1) = \emptyset(u_j - z'\gamma) - \emptyset(u_{j-1} - z'\gamma) \quad (j = 1, \dots . j-1) \\ \Pr(\tilde{y} = J|z, r = 1) = 1 - \emptyset(u_{j-1} - z'\gamma) \end{cases} \qquad (5)$$

while r and $\tilde{y}$ are not individually observable in terms of the zeros, they are observed via the criterion specified in equation 6.

$$y = r\tilde{y} \qquad (6)$$

That is, to observe a $y = r$ outcome we require either that $r = 0$ (the individual is a non-user) or jointly that $r = 1$ and $\tilde{y} = 0$ (the individual is a zero-use user). To observe a positive y, we require jointly that the individual is a user $r = 1$ and $\breve{y}^* > 0$. Under the assumption that ε and u identically and independently follow standard Gaussian distributions, the full probabilities for y are given by equation 7.

$$\Pr(y) = \begin{cases} \Pr(y = 0|z, x) = \Pr(r = 0|x) + \Pr(r = 1|x)\, Pr\ (y = 0\widetilde{|z, r} = 1) \\ \Pr(y = j|z, x) = \Pr(r = 1|x) \Pr\ (y = \jmath|z, r = \widetilde{1)}\ \ (\jmath = 1, \dots . . \jmath) \end{cases}$$

$$\begin{cases} \Pr(y = 0|z, x) = [1 - \emptyset(x'\beta] + \emptyset(x'\beta)\emptyset(-z'\gamma \\ \Pr(y = j|z, x) = [1 - \emptyset(x'\beta]\left[\emptyset(u_j - z'\gamma) - \emptyset(u_{j-1} - z'\gamma)\right] \ (j = 1, \dots . J-1) \\ \Pr(y = J|z, x) = [\emptyset(x'\beta)\ ][1 - \emptyset(\ u_{j-1} - z'\gamma]. \end{cases} \qquad (7)$$

In this way, the probability of a zero observation has been ‘‘inflated’’ as it is a combination of the probability of ‘‘zero use’’ from the ordered Probit process plus the probability of ‘‘non-use’’ from the split Probit model. Note that this specification is analogous to the zero-inflated/augmented count models, and that there may or may not be overlaps with the variables in x and z.

Research question 5 seeks to answer what influences the choice of source of information on antibiotics use: The variable of interest was choice of source of information on antibiotics. The motivation is to model the decision-making process in sourcing for information on use of antibiotics in livestock production. Preliminary data analysis revealed that a livestock keeping household i is faced with two possible sources of information: veterinary practitioner (V) and/or extension service provider (E)[4]. These are binary outcomes and univariate Probit would be a possible model candidate to model this kind of decision behavior. However, preliminary analysis also revealed that a decision maker could go with veterinary services in one round and extension services in another round thus nullifying a univariate Probit as a possible modelling path. Since the choices are not mutually exclusive, these decisions are jointly modelled as binary dependent latent variables (Y_1^* and Y_2^*) with an assumption that the disturbance error terms are correlated (Seyoum, 2018). This makes the bivariate response type of model the natural candidate for modelling this kind of behavior.

The Model is therefore specified as;

$$Y_1^* = X_1\beta_1 + \varepsilon_1 \quad (1)$$

$$Y_2^* = X_2\beta_2 + \varepsilon_2 \quad (2)$$

where ε_1 and ε_2 are unobserved joint normal error terms with zero means and correlation ρ.

$$\left\{\begin{matrix}\varepsilon_1 \\ \varepsilon_2\end{matrix} |X\right\} \sim N\left(\begin{bmatrix}0\\0\end{bmatrix}\begin{bmatrix}1 & \rho\\ \rho & 1\end{bmatrix}\right) \quad (3)$$

Thus, the bivariate Probit model specifies the observed outcomes to be.

$$Y_1 = \left\{\begin{matrix}1\ if\ Y_1^* > 0 \\ 0\ Otherwise\end{matrix}\right\} \quad (4)$$

$$Y_2 = \left\{\begin{matrix}1\ if\ Y_2^* > 0 \\ 0\ Otherwise\end{matrix}\right\} \quad (5)$$

The bivariate model is then written as

$$P(Y_1 = y_i, Y_2 = y_j\ |X_1X_2) = \Phi_2\ (\ X_1'\beta_1, X_2'\beta_2, \rho) \quad (6)$$

Furthermore, the coefficients are estimated (β_1, β_2, ρ) are estimated using the maximum likelihood estimation as;

$$P(Y_1 = y_i, Y_2 = y_j\ |X_1X_2) = \Phi_2\ (\ q_1X_1'\beta_1, q_2X_2'\beta_2, q_1q_{12}\ \rho) \quad (7)$$

[4] Veterinary service providers are normally trained in animal medicine thus more knowledgeable on animal disease management than extension workers who are mostly equipped with livestock management skills but limited knowledge on animal disease management.

Where; $q_1 = 2y_1 - 1$ and $q_2 = 2y_{21} - 1$ implying that $q_1 = 1$ if $y_i = 1$ and -1 if $y_i = 0$ for i=1 and 2

Additionally, the binary Probit is estimated in establishing the factors underlying the non-advice seeking behavior for livestock keepers who used antibiotics but sought no information from either a veterinary or extension worker.

Research question 6 was on the factors determine whether one seeks professional advice or self-prescribes antibiotics to be used**.** In this study, sources of advice on antibiotic use were grouped into three categories and these are veterinarian, extension, and self. This implies that there are some farmers who never sought advice to use antibiotics. We therefore choose to study the factors that influence choice of advice on antibiotic use for farmers who sought advise as well as the factors that influence the non-advice seeking behavior on antibiotic use by livestock keeping households. Naturally, when a dependent variable y is binary and takes on the values of zero and one with mutually exclusive and exhaustive outcomes, a Probit model should be motivated (Kimberly L M, 2001). The motivation of the binary Probit model for this study is in the response probability P as shown in equation (1)

$$P(y = 1|\mathrm{X}) \; = \; P(y = 1|\; \chi_1, \chi_2, \ldots\ldots, \chi_\kappa) \qquad (1)$$

The study assumes that the response probability P is linear in a set of parameters β_j taking on the form;

$$P(y = 1|\mathrm{X}) \; = \; G(\beta_0 + \beta_1\chi_1 + \ldots\ldots + \beta_\kappa\chi_\kappa) \; = \; G(\beta_0 + \mathrm{X}\beta) \qquad (2)$$

Where $\mathrm{X}\beta = \beta_1\chi_1 + \ldots\ldots + \beta_\kappa\chi_\kappa$ and G assumes a standard normal cumulative distribution function (cdf) taking on values between zero and one i.e., 0< $0 < G(\mathcal{Z}) < 1$ for all real numbers z and is expressed as an integral:

$$G(\mathcal{Z}) \; = \; \Phi(\mathcal{Z}) \equiv \int_{-\infty}^{z} \Phi(v)dv, \qquad (3)$$

And $\Phi(\mathcal{Z})$ is the standard normal density

$$\Phi(\mathcal{Z}) = \; (2\pi)^{-1/2} exp(-z^2/2) \qquad (4)$$

The probability model is then derived from an underlying latent variable y^* specified as

$$y^* = \beta_0 + \mathrm{X}\beta + \varepsilon, \;\; y = 1[y^* > 0] \qquad (5)$$

Where ε are normally distributed independent error terms such that.

$$P(y = 1|\mathrm{X}) \; = P(y^* > 0|\mathrm{X}) \;\; = P[\; \varepsilon > -(\beta_0 + \mathrm{X}\beta)|X]$$

$$= 1 - G[-(\beta_0 + \mathrm{X}\beta)] = G(\beta_0 + \mathrm{X}\beta)$$

The marginal effects of the response probability are then derived as;

$$\frac{dp(x)}{dx_j} = g((\beta_0 + \mathrm{X}\beta)\beta_j, \text{ where } \mathrm{g(z)} \equiv \frac{dG(x)}{dZ}(\mathcal{Z}) \quad (6)$$

3.0 Results

Research question 1: How often do livestock keepers use antibiotics?

3.1. Use of antibiotics by livestock farmers in Uganda

We found that 25% of livestock farmers in Uganda were using antibiotics for either curative, preventive, vaccination, or growth promotion purposes. Mikecz, et al., (2020), using the same AAS data, found that 35% of livestock farmers in Uganda were using antibiotics. Nayiga et al. (2020) studied whether households had ever used antibiotics to treat animals in one Eastern district (Tororo) and one Central district (Wakiso) in Uganda. Their study found 33% use in Eastern district compared to 25% found in this study. However, their study found 99% use (over the period they could recall) in Central district, which could be due to the small sample size (215) compared to this study. The results of our study confirms the concerns of UNAS et al. (2015) that antibiotics use in Uganda was no longer limited to humans but had expanded to the livestock sector as well. This supports the efforts of the government of Uganda to streamline the use of antibiotics not only in humans but in livestock production too.

Table 1 below shows the percentages of livestock keepers using antibiotics disaggregated by livestock type, whether exotic animals were kept, the region and sex of the household head. The results indicate that there was significantly (absolute z-score equal to 25.591 greater than 1.96 which is the threshold for significance at 5% level) more antibiotics use in cattle (76.6%) and pack animals and in shoats. In addition, there were significantly more households with exotic breed animals in the antibiotics user's category. The results also indicate that there were more male headed households (78.3%) in the use category compared to the non-use category (75.6%).

The results indicate that there was significantly more households using antibiotics in shoats (76.2%), and in cattle and pack animals (72.6%). In addition, there were significantly more households with exotic breed animals in the antibiotics user's category (16.5%) compared to the non-users (9.7%). The results also indicate that there were more male headed households (78.3%) in the use category compared to the non-use category (75.6%). In terms of regions, the highest share of households using antibiotics was recorded in the North and the East regions (50 and 24% respectively). There were significantly more non-users than users in the West and Central.

Table 2: Level of antibiotics use-prevalence

Variable	Use	No Use	Z-statistic
Livestock kept			
Cattle and pack animals	72.6%	30.9%	**-25.591**
Shoats	76.2%	59.5%	**-9.276**
Pigs	25.9%	30.7%	1.856
Poultry	64.3%	67.8%	-0.941
Rabbits	1.4%	1.9%	1.104

At least one exotic animal	16.5%	9.7%	**-7.495**
Region			
Central	12.7%	16.4%	1.321
East	24.5%	25.1%	**-2.765**
North	50.7%	28.7%	**-11.511**
Western	12.1%	29.8%	**12.790**
Male head	78.3%	75.6%	**-3.706**

Source: microdata from the 2018 AAS (UBOS)

Research question 2: What are the drivers of antibiotics use in livestock production?

3.1.1 Factors that influence the decision to use antibiotics

This study used a Probit model to determine the correlates of antibiotics use status among livestock keepers in Uganda. The results (Table 2) indicate that production systems (keeping cattle, keeping exotic livestock, and herd size), socio economic and demographic (gender of the head and education levels) and regional/geographical, and institutional (access to information and distance to service providers) factors influenced the decision to use antibiotics. In addition, this study also found that livestock keepers that perceived antibiotics to retain their effectiveness even with continuous use were more likely to use antibiotics than their counterparts who perceived the opposite.

Information access from either professional sources (veterinary officers) and personal judgement positively influenced the decision to use antibiotics in livestock production. The marginal effects show that livestock keepers who did not seek any information before using antibiotics (self-administration – 35.8%) and those that sought from extension staff 6.3% . These findings are consistent with Ekakoro et. al. (2019) who found that livestock keepers admitted to relying on a mix of their own experience, knowledge, or judgment when deciding to use antimicrobials in their cattle, sometimes consulted other producers and if cases were difficult to manage, then veterinarians' expertise would be sought. In addition, Musoke et al. (2021) found that some farmers who consulted veterinary officers before using antibiotics would later use previous prescriptions from veterinary officers to purchase and administer antibiotics to their ailing livestock. This implies that the number of farmers relying on personal judgement to use antibiotics could be potentially higher. Farmers who purchase antimicrobials without consulting veterinary practitioners are more likely to wrongly prescribe them (Musoke et al. 2021) which could lead to higher antimicrobial resistance build up.

Results from our study indicated that believing that antibiotic will remain effective even with continuous use significantly influenced the decision to use antibiotics. Households believing that antibiotics will remain effective even with frequent use were 14.3% more likely to use antibiotics than their counterparts that believed otherwise. This underscores the importance of livestock keepers' perceptions and thus the need of mindset change in influencing sustainable use of antibiotics in livestock production. The study also found a negative association between gender of the household head and the decision to use antibiotics. Male headed households were significantly less likely (-3.8%) to have used antibiotics than their female counterparts. In addition, household heads who had completed at least lower secondary education (13 years or more in school) were also more likely (3.1%) to have used antibiotics. Manyi-Loh et al. (2018) found that antibiotics use was positively correlated with farmers' socioeconomic status.

Table 3: Probit model marginal effects of the factors influencing decision to use antibiotics

Household used antibiotics in the last 12 months	Coefficient	std. err.	dy/dx	std. err.	P>t
Socioeconomic and Demographic factors					
Respondent is aged 35 years or below	-0.017	0.129	-0.002	0.019	0.896
Household head is male	-0.260	0.083	-0.038	0.012	0.002
Household's main economic activity is agriculture	0.080	0.116	0.012	0.017	0.491
Household's members belong to a farmer group	-0.036	0.098	-0.005	0.014	0.712
Education-Household head completed at least secondary school	0.212	0.093	0.031	0.014	0.023
Production system and environment					
Household kept cattle and pack animals	0.224	0.117	0.032	0.017	0.056
Household kept pigs	-0.187	0.107	-0.027	0.016	0.082
Household kept poultry	0.069	0.103	0.010	0.015	0.503
Total tropical livestock units of both local and exotic animals owned	0.052	0.014	0.008	0.002	0.000
Number of livestock types kept by the household	0.119	0.071	0.017	0.010	0.096
Proportion of land under crop	-0.169	0.139	-0.024	0.020	0.227
Household has at least one exotic livestock species	0.208	0.105	0.030	0.015	0.049
Region					
Western Region	-0.009	0.102	-0.001	0.015	0.930
Central Region	0.200	0.110	0.029	0.016	0.069
Northern Region	0.532	0.098	0.077	0.014	0.000
Perceptions towards antibiotics use					
Household believes antibiotics will not become less effective even with continuous use	0.984	0.113	0.143	0.016	0.000
Institutional factors					
Information about antibiotics comes from private/public extension	0.434	0.137	0.063	0.020	0.002
Information about antibiotics comes from farmer to farmer	0.416	0.101	0.060	0.015	0.000
Distance to nearest input shop is greater than 5 kms	-0.284	0.074	-0.041	0.011	0.000
Farmer sought information from veterinary officer	2.160	0.082	0.314	0.009	0.000
Farmer did not seek advice from any source--self-administration	2.465	0.138	0.358	0.018	0.000
Constant	-1.623	0.251			0.000

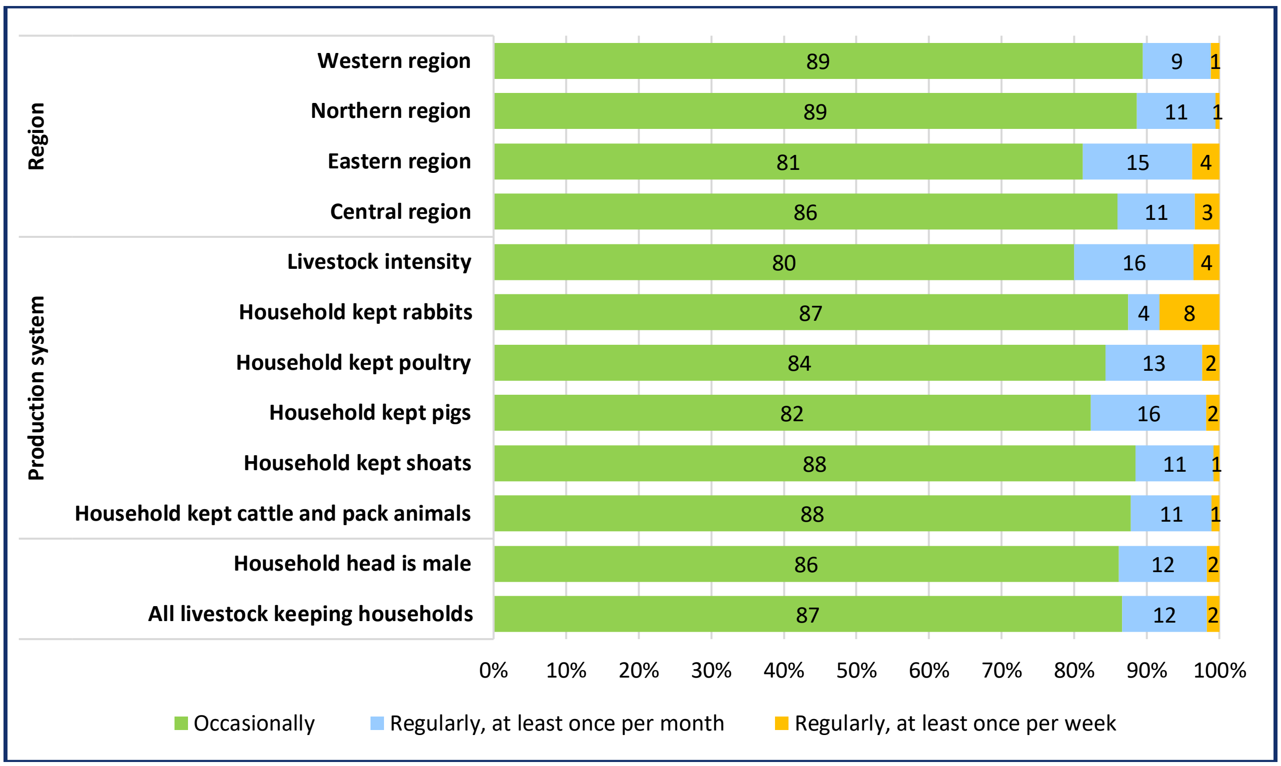
Source: microdata from the 2018 AAS (UBOS)

What is the Frequency of antibiotics use?

3.1.2 Frequency of antibiotics use

This analysis used a sub-sample including only those who had reported antibiotics use in the last 12 months. Figure 1 shows the frequency of antibiotics use disaggregated by gender of the household head, region, production intensity and type of livestock kept. On average, most (87%) livestock keepers had occasionally (less than once a month) used antibiotics in their livestock production activities over the one-year period preceding the data collection phase. The results show that most intense users were among households keeping some exotic animals where 20% of the livestock keepers used antibiotics at least once a month or more frequently. This category is followed by households residing in the Eastern region (19%), keeping pigs (18%) and poultry keeping (14%) households. The least intense use was observed in northern and western regions both at 11%. We note that also there were many users in the north, most were only occasionally using antibiotics.

Figure 1: Frequency of antibiotics use (in percentages)



Source: microdata from the 2018 AAS

3.1.3 Factors driving the frequency of antibiotics use in livestock production in Uganda

A zero-inflated ordered Probit model (ZIOP) was used to determine the drivers of antibiotics use frequency among livestock keepers in Uganda (Table 3). Two models were used to ensure robustness of the estimates, an ordinary ordered (see results in appendix II) and zero-inflated ordered Probit model. The Bayesian information criterion estimates indicated that the ZIOP model performed better than the ordinary ordered Probit model (see results in appendix 1). Model parameters reveal a significant model thus rejecting the null hypothesis that none of the included regressors determines the frequency of antibiotics use. The ZIOP (Table 3) results are used for the rest of this section.

The coefficient on the belief that antibiotics remain effective even with continuous use is positive and significant at 1% level. This indicates that households holding this belief were more likely to use antibiotics frequently than their counterparts who believed otherwise. The marginal effects show households holding the belief were 69.5% less likely to fall in the never-used category but 55.7% and 13.8% more likely to fall in the occasionally use and frequently use categories respectively.

Significant regional differences were observed to determine the frequency of antibiotics use. Specifically, households in the western and central region were found to significantly use antibiotics less frequently than their counterparts in the eastern region (base category) of the country. Marginal effects revealed that, comparing with the eastern region, households from the western and central region were 6% and 5% more likely to belong in the never use category, 1% (both) and 5% (both) less likely to fall in the occasional and frequent use categories respectively.

Source of information was found to also influence the frequency of use of antibiotics. The study found information from any source (external to the farmer) significantly reduced the frequency of antibiotics use. Marginal effects show that livestock keepers who got information about antibiotics from private extension or fellow farmers were 3% less likely to fall in the never-use category. Implying that information access increased probability of falling in the use categories. The marginal effects further revel that information from extension agents increased the probability of bellowing to occasional use by about 5% while getting information from fellow farmers increased probability by about 6%. However, the same information sources reduced the probability of belonging in the higher category of frequent use by 2% and 3% for extension and fellow farmer information sources respectively.

Frequency of antibiotics use was found to be driven by the type of livestock kept and the system in which livestock are produced. The results in Table 3 indicate that owning poultry or piggery increased the frequency of antibiotic use which is the reverse of the factors influencing the decision to use. This implies that once the decision has been made to use antibiotics, households keeping poultry or piggery were more likely to frequently use antibiotics. Marginal effects show that households keeping poultry or piggery was associated with a 3% (for both) higher likelihood of falling in the category of frequent use.

In addition, household keeping exotic animals were more likely to frequently use antibiotics compared to those keeping only indigenous animals. Household keeping exotic animals were associated with a 4% greater possibility of having used antibiotics frequently compared to households that were not keeping any exotic animals. Higher tropical livestock units (higher number of animals) were also associated with increased frequency of antibiotics use but the marginal effects reveal very small (less than 1%) but positive probabilities of increasing antibiotics use following an increase in tropical livestock units by one. Increasing the diversity of livestock kept significantly had mixed results on the frequency of antibiotics use holding all other factors constant. Increasing the diversity of livestock kept by one species marginally effected the probability of falling in the never use category, increased, and decreased the probabilities of falling in the occasional and frequent use by 2%.

Table 4: Zero-inflated Probit model estimates for the factors influencing the intensity of antibiotics use in livestock production in Uganda

	Parameter estimates			**Marginal effects**					
	Zero-inflated ordered Probit model			**Never**		**Occasionally**		**Frequently**	
Variable	**Coef.**	**std. err.**	**P>t**	dy/dx	std. err.	dy/dx	std. err.	dy/dx	std. err.
Socioeconomic and demographic factors									
Respondent is aged 35 years or below	-0.070	0.155	0.653	0.000	0.000	0.005	0.012	-0.005	0.012
Household head is male	-0.098	0.128	0.444	-0.031	0.011	0.033	0.014	-0.002	0.010
Household's main economic activity is agriculture	0.053	0.134	0.691	0.000	0.000	-0.004	0.010	0.004	0.010
Household's members belong to a farmer group	0.113	0.119	0.343	0.000	0.000	-0.009	0.009	0.009	0.009
Household head completed at least secondary school	0.029	0.102	0.777	-0.021	0.009	0.016	0.011	0.006	0.008
Production system and environment factors									
Household kept cattle and pack animals	-0.017	0.130	0.895	-0.012	0.009	0.012	0.013	0.001	0.010
Household kept pigs	0.392	0.139	**0.005**	-0.008	0.008	-0.023	0.013	0.031	0.010
Household kept poultry	0.398	0.134	**0.003**	-0.012	0.010	-0.020	0.013	0.032	0.010
Total tropical livestock units of both local and exotic animals owned	0.012	0.007	**0.094**	-0.008	0.002	0.006	0.002	0.002	0.001
Number of livestock types kept by the household	-0.232	0.093	**0.013**	0.000	0.000	0.018	0.007	-0.018	0.007
Proportion of land under crop	0.377	0.165	**0.022**	0.000	0.000	-0.028	0.012	0.028	0.012
Household has at least one exotic livestock species	0.483	0.133	**0.000**	-0.022	0.012	-0.018	0.013	0.040	0.010
Region									
Eastern (base)									
Western	-0.499	0.166	**0.003**	0.060	0.011	-0.012	0.015	-0.048	0.013

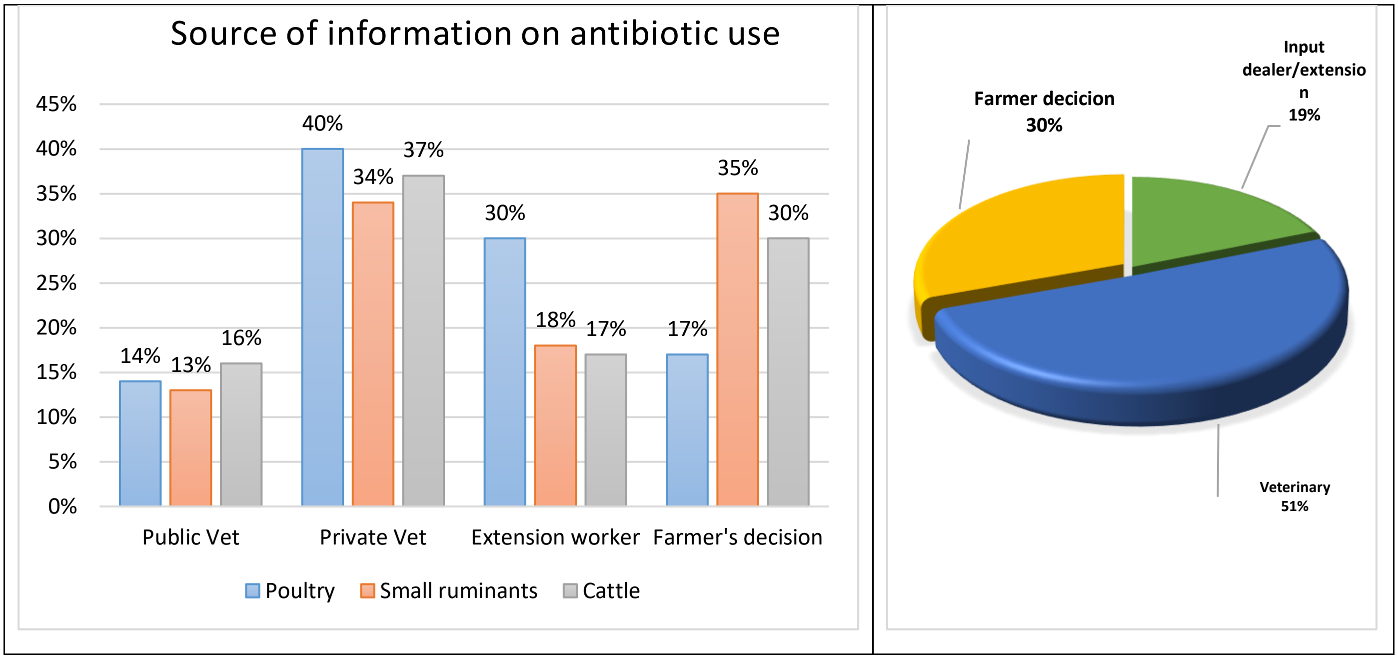
Variable	Parameter estimates			Marginal effects					
	Zero-inflated ordered Probit model			Never		Occasionally		Frequently	
	Coef.	std. err.	P>t	dy/dx	std. err.	dy/dx	std. err.	dy/dx	std. err.
Central	-0.533	0.180	**0.003**	0.053	0.013	-0.004	0.017	-0.049	0.014
Northern	-0.019	0.118	0.875	0.012	0.011	-0.008	0.013	-0.003	0.009
Perceptions towards antibiotics use									
Household believes antibiotics will not become less effective even with continuous use	**0.303**	0.104	**0.004**	-0.695	0.050	0.557	0.046	0.138	0.020
Institutional factors									
Information about antibiotics comes from private/public extension	-0.308	0.164	**0.060**	-0.028	0.017	0.047	0.018	-0.019	0.013
Information about antibiotics comes from farmer to farmer	-0.510	0.138	**0.000**	-0.028	0.011	0.062	0.015	-0.034	0.010
Distance to nearest input shop is greater than 5 kms	-0.173	0.106	0.100	0.012	0.008	0.003	0.010	-0.015	0.008
Farmer sought information from veterinary officer	-0.172	0.127	0.176	-0.777	0.055	0.661	0.050	0.116	0.017
Farmer did not seek advice from any source--self-administration	-0.195	0.166	0.240	-0.768	0.055	0.656	0.051	0.113	0.018
Household accessed loan for agricultural purposes	-0.204	0.153	0.183	-0.027	0.014	0.038	0.017	-0.011	0.011
Constant	-1.189	0.262	0.000						

What is the main source of information about antibiotics used by the farmers?

3.2.1 Antibiotics users' sources of information

The source of information was (public vet, private vet, extension worker or fellow farmer) was a significant driver in the decision to use antibiotics and the frequency of use (Tables 2 and 3). This subsection builds on the previous ones to establish the main sources of information and the drivers of the choice of information channel. Figure 2 (left) shows the main sources of information disaggregated by livestock type. In the survey, livestock keeping households that reported to have used antibiotics in livestock production processes were asked the main source of advice on antibiotic use by livestock types; that is Cattle & pack animals, small ruminants, and pigs (shoats) and poultry. Results revealed that the common sources of information on antibiotics use were from either a public or private veterinary practitioner (51%) and/or an extension service provider (19%) (extension services or input dealer).

Figure 2: Source of information on antibiotic use



Source: microdata from the 2018 AAS (UBOS)

What influences the choice of source of information on antibiotics use?

3.2.2 Antibiotics users' sources of information

This study used a bivariate Probit (BVP) model to determine the drivers of choice of information channel. The two pairwise correlation coefficients across the residuals of BVP model were statistically significant. This proves that the choices are correlated and estimating them using the simple binary Probit model would not yield consistent results. General model fit statistics (Akaike crit. (AIC) =1446.65 with a Chi-square =457.104) were also significant at 1% level of significance supports rejection of the null hypothesis that the estimated model is not significantly different from an empty model.

As shown in Table 4, the results of the bivariate model indicated that the factors that significantly influenced a household's choice to seek information on antibiotic use from a veterinary practitioner included; number of antibiotic used in shoats or cattle at 5% and 1% respectively, frequency of antibiotic use in poultry at 1%, the perception a Household has on the loss of effectiveness of antibiotics if frequently used at 5%, Using antibiotics for preventive and curative purposes at 1%, Households in central (1%), Eastern (1%) and Northern regions at 5%, Distance to input shop at 10%, intensive feeding for poultry at 1% and having ever vaccinated shoats at 1%.

Table 5: Bivariate Probit model estimates for the factors that influence livestock keeper's information source choice about use of antibiotics

Source of Information for Antibiotic use	Veterinary Practitioner				Extension Services			
Variable	**Coef**	**P-Value**	**St.Err.**	**dydx**	**Coef**	**P-Value**	**St.Err.**	**dydx**
Antibiotic use								
Antibiotic use frequency	0.009	0.700	0.023	0.009	-0.012	0.786	0.046	-0.035
Number of Antibiotic used (shoats)	-0.192**	0.011	0.075	-0.278	0.236**	0.010	0.092	0.280
Number of Antibiotic used (cattle)	0.275***	0.000	0.046	0.225	-0.04	0.458	0.054	-0.153
Number of Antibiotic used (poultry)	-0.055	0.755	0.178	0.127	0.598***	0.001	0.187	0.544
Frequency of antibiotic use cattle	0.014	0.509	0.021	0.016	0.013	0.775	0.046	0.037
Frequency of antibiotic use Poultry	0.248***	0.002	0.082	0.258	-0.167	0.108	0.104	-0.103
Frequency of antibiotic use Shoats	-0.018	0.257	0.016	-0.017	-0.004	0.935	0.043	0.012
HH perception of frequent use of Antibiotics	0.004**	0.018	0.002	0.002	0	0.795	0.002	0.002
Antibiotics used for preventive purposes	0.974***	0.000	0.126	1.122	0.499***	0.002	0.159	0.591
Antibiotics used for Curative Purposes	0.927***	0.000	0.119	0.770	0.591***	0.000	0.147	0.672
Geographical region								
Central_region	0.628***	0.003	0.214	0.690	-0.064	0.803	0.258	-0.218
Eastern_region	0.49***	0.003	0.163	0.456	-0.123	0.545	0.203	-0.143
Northern_region	0.341**	0.038	0.164	0.040	-0.335*	0.098	0.203	-0.222
Household Characteristics								
Distance to input shop	0.078*	0.083	0.045	0.067	-0.002	0.976	0.059	-0.009
Distance to local produce market	-0.025	0.506	0.037	-0.014	0.01	0.836	0.047	-0.001
HH Head can read and write	0.152	0.131	0.1	0.278	-0.292**	0.029	0.133	-0.396
HH head is employed	-0.01	0.890	0.07	0.003	-0.005	0.953	0.09	-0.055
Male headed HH head	-0.118	0.370	0.131	-0.095	0.037	0.816	0.16	-0.154
Production Characteristics								
Total Tropical Livestock unit (TLU)	0.025	0.130	0.017	0.015	-0.022	0.323	0.022	-0.005
HH only grazes its Cattle	0.086	0.464	0.118	0.060	-0.398***	0.006	0.144	-0.408
HH grazes and feeds its cattle	0.06	0.679	0.145	0.065	-0.475**	0.024	0.21	-0.452
HH only feeds its shoats	-0.086	0.625	0.176	-0.080	-0.72**	0.021	0.312	-0.731
Grazing/scavenging with feeding Poultry	0.007	0.959	0.13	0.022	-0.183	0.301	0.177	-0.297
Only feeding for poultry	0.538***	0.002	0.172	0.477	-0.846**	0.013	0.342	-1.047
Ever vaccinated poultry	-0.002	0.302	0.002	-0.001	-0.003	0.174	0.002	-0.001
Ever Curatively treatment for poultry	-0.089	0.674	0.212	-0.257	-0.169	0.510	0.256	-0.317
Ever vaccinated shoats	-0.003***	0.007	0.001	-0.005	0.003*	0.089	0.002	0.004
Constant	-1.359***	0.000	0.308		-1.034***	0.006	0.379	
athrho	-0.012		0.046		-0.993***	0.000	0.124	
Mean dependent var			**0.107**	SD dependent var				**0.309**
Number of obs			**995**	Chi-square				**457.104**
Prob > chi2			**0.0000**	Akaike crit. (AIC)				**1446.65**
**** p<.01, ** p<.05, * p<.1*								

Similarly, number of antibiotics used in shoats at 5% and poultry 1%, using antibiotics for preventive and curative purposes both at 1%, Households in the Northern region at 10%, a Household head's capacity to read and write at 5%, Households who grazes only and those who grazes with some feeding for their cattle at 1% and 5% respectively, Households that feed their shoats at 5%, intensive feeding for poultry and having ever vaccinated shoats at 10% significantly influenced households seeking antibiotic use information from extension service provider.

The average marginal effects indicated that household that used a high number of different antibiotic types in shoats had a 27.8% lower chance of seeking antibiotic use information from a veterinary practitioner than those who used fewer antibiotics. According to this study, households that use various antibiotics in the production of shoats are less likely to be seeking for information on antibiotic use from a right source. This is quite a different case for cattle since the households that used a high number of different antibiotics in cattle had a 22.5% higher chance of seeking for information on antibiotic use from veterinary practitioners. This implies that households that used various antibiotics in cattle production sought information on their use from a veterinary practitioner. Additionally, the practice of veterinarians advising households to use various antibiotics in production of cattle could imply that the antibiotics on market are less effective in solely solving the set purpose and or that farmers don't adhere to the recommended use (ie with draw periods and right dosage) of antibiotics which leads to their ineffectiveness else the veterinary practitioners are contributing to antibiotic misuse in the country

Results also revealed that increased frequency of use of antibiotics in poultry keeping households increased the chance of a household seeking information from a veterinary practitioner by 25.8% as compared to poultry keeping households that used antibiotics less frequently. Additionally, Households whose perception on the loss of effectiveness of antibiotics if used more frequently was higher had a 0.2% more likely to seek advice on antibiotic use from veterinary practitioners when compared to those who had a different perception.

Also livestock keeping households that use antibiotic use for either preventive or curative purposes in livestock production were 112.2% and 77% respectively more likely to seek advice on antibiotic use from a veterinary practitioner. This is an indicator that for most farmers to treat their livestock using antibiotics, advice from a qualified veterinary practitioner is likely first sought. Interestingly, households in central region, Eastern region and northern region were 69%, 45.5% and 4.1% respectively more likely to seeking antibiotic use information form veterinary practitioners when compared to the households that keep livestock in Western region.

The marginal effects for the extension service as the main source of information for antibiotic use among livestock keeping households indicated that the increase in the number of antibiotic types used in production of shoats and poultry increased the chances of a household seeking information from an extension work by 28.0% and 54.4% respectively. Also using antibiotics for preventive and or curative purposes increased a household's chances of seeking antibiotic use information form an extension worker by 59.1 % and 67% respectively. On the contrary, chances of seeking information on antibiotic use from an extension worker decreased by 22.2% for households in the Northern region compared to the other regions. Households with a household head who could read and write (literate) were 39.6% less likely to seek antibiotic use information from extension compared to those who cannot read and write.

Households that either only grazed their cattle or grazes their cattle with some feeding and HH that only intensively fed their shoats were 40.9%, 45.2% and 73.1% respectively less likely to seek antibiotic use advice from extension source. Households that intensively fed their poultry were 104.6 % less likely to seek advice on antibiotic use from an extension source than those who never intensively fed their poultry. Households that ever vaccinated their shoats were 0.38% less likely to seek antibiotic use advise from an extension source compared to those who had not vaccinated their shoats.

3.3.1 Self-prescription of antibiotics

This study sought to explore the prevalence of administering antibiotics without professional advice among livestock keepers. Table 5 shows the prevalence of self-prescription of antibiotics among livestock keepers in Uganda disaggregated by livestock type, frequency of use, sex of household head, and region. The results indicate that about 77% of livestock keepers using antibiotics were involved in self-prescription at one point. This seems to affirm the findings of Ekakoro et. al. (2019) who found that farmers who consult at one point may use results from previous prescriptions (technically self-prescribing) on conditions that show similar symptoms in livestock health. Male household head would self-prescribe antibiotics more (1.26) compared to a female household head counterpart. The results also indicate that self-prescription habits were mostly among keepers of cattle, shoats and poultry. The results further show that most households involved in self-prescription were in the northern region. The northern region in Uganda is still largely rural and recovering from a a long-standing civil war. Arvidsson et al., 2020 found that rural areas normally have few veterinary service providers due to low profits involved. The absence of veterinary service providers could explain increased self-prescription given that the north is also experiencing significant growth in the rearing of pigs (Arvidsson et. al., 2022). This practice could be further supported by the fact that antibiotics are easily accessible from drug outlets and input dealers across the country with little to no regulation (Musoke et al., 2021). About nine in every ten antibiotics users engaged in self-prescription only occasionally used antibiotics in the last 12 months preceding data collection.

Table 6: Prevalence of self-prescription of antibiotics among livestock keepers in Uganda

Variable	Self-prescription	
	Mean (%)	Linearized std. err.
Livestock kept by household		
Cattle	77.15	2.64
Donkeys	5.28	1.84

Shoats	83.67	2.15
Pigs	16.07	1.81
Poultry	52.04	3.53
Rabbits	1.46	0.59
Sex of household head	1.26	0.03
Region		
Central	3.12	0.86
Eastern	11.52	1.51
Northern	71.78	2.30
Western	13.59	1.61
Frequency of antibiotic use		
Occasionally	91.99	1.61
Regularly-once per month	7.01	1.57
Regularly- once per week	1.00	0.39

Source: microdata from the 2018 AAS

What factors determine whether one seeks professional advice or self-prescribes antibiotics to be used?

3.3.2 Factors that influence non-advice-seeking (self-prescription) behaviors by livestock keepers

A Probit model was used to determine the factors that influence non-advice-seeking (self-prescription) behaviors by livestock keepers. Results indicate that socioeconomic and demographic (household size, education and access to credit), production system (keeping poultry), and the purpose of use influenced the probability of administering antibiotics without seeking professional advice. For instance, the probability of a livestock keeper to self-prescribe antibiotics lowers by 2.5 percentage points with each additional year of secondary school education (P<0.005). Similarly, a livestock keeper who obtained extension advice is not likely to self-prescribe antibiotics (P<0.001) compared to one who did not. On the contrary, if a farmer used at least one type of antibiotic during the year, they were more likely to use antibiotics without seeking professional help (P<0.001). In addition, the probability of self-prescription increased significantly (P<0.001) among farmers who used antibiotics for growth purposes in their livestock. This is in tandem with a study by Musoke et al. (2021) that also showed that farmers tended to buy antibiotics (including those for human consumption) without prescription to promote growth in their animals.

Table 7: Factors that influence non-advice-seeking (self-prescription) behaviors by livestock keepers in Uganda

Information source- Self	dy/dx	std. err.	p-value
Household characteristics			
Household size	-0.005	0.002	0.016
Sex of household head	-0.009	0.018	0.629
Marital status	-0.001	0.018	0.953
Attained secondary education	-0.025	0.011	0.033
Belongs to farmer group	-0.024	0.014	0.084
Obtained agricultural related loan	-0.040	0.018	0.030
Farmer received training	0.029	0.019	0.128
Farmer got extension advice	-0.061	0.018	0.001
Livestock			
Cattle	0.014	0.011	0.208
Shoats	0.013	0.012	0.286
Pigs	-0.001	0.012	0.965
Poultry	-0.047	0.011	0.000
Total tropical livestock units of both local and exotic owned by the household	0.001	0.001	0.610
Used at least one type of antibiotic	0.119	0.022	0.000
If antibiotics are often given to animals, they will not become less effective	0.008	0.012	0.469
Purpose of antibiotic			
Farmer used antibiotics for curative treatment	0.123	0.020	0.000
Farmer used antibiotics to promote animal growth	0.112	0.023	0.000
Farmer used antibiotics as preventive measure against disease	0.078	0.020	0.000
Farmer used antibiotics for vaccination purposes	0.031	0.025	0.213
Geogaphical region			
Central region	-0.099	0.020	0.000
Eastern region	-0.045	0.014	0.002
Northern region	0.032	0.012	0.010
Constant	2.947	0.651	0.000

Source: microdata from the 2018 AAS

4.0 Summary and conclusion

The results of this study built on initial work by Mikecz et al., 2020 about antibiotics use in Uganda. The results also provided the first, as far as the literature available can provide, study on antibiotics use frequency at a country level. The results are nationally representative and come from rigorously collected and analyzed data. These results can be used to draw inferences at national and in some context at the scale of Sub-Saharan Africa. The results of this study in any case confirm the concerns of *UNAS et al 2015* that antibiotics use in Uganda was no longer limited to humans but had expanded to the livestock sector as well. This supports the efforts of the government of Uganda to streamline the use of antibiotics not only in humans but in livestock production too.

This study revealed the extent of antibiotics use among Uganda livestock keepers and the frequency of use. The results show a considerable number of livestock users are using antibiotics but most occasionally use antibiotics. The study has further revealed that different factors ranging from socio-economic, demographic, production environment and systems, regional, perceptional, and institutional interact to shape livestock keeper's decision to use antibiotics and at what frequency these are used. In addition, the study has confirmed findings of previous studies (mostly qualitative) that livestock keepers' source of information is not static and keeps evolving. We found that livestock keepers access information related to antibiotics use from multiple sources. In addition, livestock keepers are likely to switch between seeking professional (vets) or paraprofessional (extension workers and experienced fellow farmers) advice before using antibiotics, but they could also use their own experience to decide whether to use antibiotics or not and how often to use them. This study concludes that the use of antibiotics among smallholder livestock keepers in Uganda is mostly occasional and there is still a window of opportunity to regulate use. This study further concludes that antibiotics use in Uganda, though not yet as high as in developed countries, has reached levels that require intervention to streamline its use if antimicrobial resistance is to be managed.

5.0 Recommendations from the study

To curb non-judicious antibiotic use to check the buildup of the antimicrobial resistance in livestock and human populations, this study recommends as follows.

- Design of programs to counter livestock keepers ‘perceptions towards continued use of antibiotics. This can be done through development key messages on the potential effects of continuous, improper and or non-medically prescribed use of antibiotics to animals, livestock and the environment in general because perceptions influenced.
- Programs campaigning for judicious use of antibiotics need to target more educated livestock keepers, keepers of exotic livestock and households in the northern and central regions. These were associated with higher likelihood of use and frequency of use.

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Appendix 1: BIC and AIC estimates

Appendix II: Ordered Probit model estimates

Table 8: Ordered Probit model estimates for the factors influencing the intensity of antibiotics use in livestock production in Uganda

	Ordered Probit model		
Variable	**Coef.**	**std. err.**	**P>t**
Respondent is aged 35 years or below	-0.031	0.102	0.759
Household head is male	0.171	0.067	**0.010**
Household kept cattle and pack animals	-0.172	0.095	**0.069**
Household kept pigs	-0.130	0.088	0.142

Variable	Ordered Probit model		
	Coef.	**std. err.**	**P>t**
Household kept poultry	-0.099	0.088	0.263
Total tropical livestock units of both local and exotic animals owned	0.020	0.007	**0.007**
Number of livestock types kept by the household	0.218	0.059	**0.000**
Proportion of land under crop	-0.103	0.110	0.348
region==Western Region	-0.658	0.088	**0.000**
region==Central Region	-0.470	0.102	**0.000**
region==Northern Region	-0.228	0.080	**0.004**
Household has at least one exotic livestock species	0.330	0.096	**0.001**
Household's main economic activity is agriculture	0.108	0.090	0.227
Household's members belong to a farmer group	0.043	0.089	0.627
Household head completed at least secondary school	0.129	0.073	**0.077**
Household believes antibiotics will not become less effective even with continuous use	1.021	0.087	**0.000**
Information about antibiotics comes from private/public extension	0.043	0.114	0.704
Information about antibiotics comes from farmer to farmer	0.021	0.086	0.806
Information about antibiotics comes from word of mouth/other peers	-0.238	0.100	**0.017**
Distance to nearest input shop is greater than 5 kms	-0.213	0.066	**0.001**
Farmer sought information from veterinary officer	2.160	0.107	**0.000**
Farmer did not seek advice from any source--self-administration	2.012	0.114	**0.000**
Household accessed loan for agricultural purposes	0.106	0.095	0.265
/cut1	0.890	0.196	
/cut2	3.430	0.241	
Number of observations		4407.000	
Design degrees of freedom		4393.000	
F(23, 4371)		48.510	
Prob > F		0.000	