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The use of antibiotics on small dairy farms in rural Peru

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Abstract

Very little is known about the use of antibiotics on small dairy farms in lower/middle-income countries. The use of these drugs can have profound impacts on animal health, farmer income and public health. A survey of 156 farmers was conducted in Cajamarca, a major dairy-producing center in the highlands of Peru characterized by small farms (<15 cows) to assess patterns and determinants of antibiotic use and farmers' knowledge of antibiotics. The reported incidence of disease on these farms was relatively low (0.571 episodes of disease per cow-year), but more than 83% of the reported episodes were treated with antibiotics. The most commonly used antibiotics were oxytetracycline, penicillin and trimethoprim-sulfamethoxazole drugs; antiparasitic drugs were also used to treat what were likely bacterial infections. An increased incidence of treated disease was significantly associated with smaller farm size, lower farmer income, the previous use of the Californian Mastitis test on the farm and antibiotic knowledge. Farmers' knowledge of antibiotics was assessed with a series of questions on antibiotics, resulting in a "knowledge score". Increased knowledge was significantly associated with the use of antibiotics for preventative reasons, the purchase of antibiotics from feed-stores, the experience of complications in animals after having administered antibiotics, the number of workers on the farm and the educational level of the farmer. Overall, antibiotics appeared to be used infrequently, most likely because therapeutic interventions were sought only when the animal had reached an advanced stage of clinical disease. Few farmers were able to define an antibiotic, but many farmers understood that the use of antibiotics carried inherent risks to their animals and potentially to the consumers of dairy products from treated animals. The results of this study are useful for understanding the patterns of antibiotic use and associated management, demographic and knowledge factors of farmers on small dairy farms in rural Peru.

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Keywords

Antibiotic use; Dairy Farms; Lower-Middle Income Countries

1. Introduction

Small farms constitute the majority of farms in the developing world (FAO, 2010), and in many low/middle income (LMI) countries, they are still predominate suppliers of animal products to their domestic markets. Dairy production is a rapidly expanding sector of animal agriculture in the developing world because of population growth, increases in per capita income, urbanization and the westernization of diets (Cox and Zhu, 2005; Knips, 2005). However, few countries where dairy production is growing have adequate systems to ensure food animal product safety and quality. One of the areas where this is most evident is the use of antibiotics in animal agriculture. Very little is known about antibiotic use on small farms in LMI countries.

In the dairy industry, antibiotics are primarily used for therapeutic and prophylactic purposes (Oliver et al., 2011). These uses have demonstrated benefits, including improved animal health, higher production levels and the reduction of foodborne pathogens (Mathew et al., 2007); however, they can also result in a number of problems, including the emergence of antibiotic-resistant bacteria, human and animal illness, economic loss for farmers and dairy processors and environmental contamination (Barton, 2000; Gilchrist et al., 2007; Gustafson and Bowen, 1997). The inappropriate use of antibiotics, defined by the World Health Organization as overprescription, underprescription, inappropriate dosing, an incorrect duration of treatment or the incorrect choice of drug for the relevant organism, can exacerbate these problems.

Knowledge of patterns of antibiotic use is fundamental to understanding farming practices and animal health on small farms; furthermore, a basic knowledge of how drugs are used can provide some measures of drug misuse, the magnitude of the risk of disease and an the need to introduce other disease control methods. This knowledge is also necessary for designing, implementing and evaluating regional and local interventions directed at optimizing the use of veterinary drugs and improving farming practices.

Very few attempts have been made to document antibiotic usage on smallholder dairy farms in either the developed or the developing worlds. The studies that have evaluated antibiotic use on farms have either only examined a small number of farms (Luna-Tortos et al., 2006; Roderick et al., 2000) or enrolled farms through mailed questionnaires, resulting in low response rates and potential selection bias (Dunlop et al., 1998; Sawant et al., 2005; Zwald et al., 2004). The aim of this study was therefore to comprehensively assess patterns of antibiotic use on small dairy farms in Cajamarca, a major dairy-producing center in the northern highlands of Peru. Cajamarca is characterized mostly by small peri-urban and rural farms (<15 cows/farm) with 30,000 registered milk producers (Garcia and Gomez, 2006) producing an estimated 307,187 kg of milk per day (Gerz and Boucher, 2006). The farms encountered in Cajamarca are typical of small dairy farms in many other LMI countries, especially in Latin America.

2. Materials and Methods

2.1 Participants

This cross-sectional study was conducted in the countryside surrounding the city of Cajamarca, the capital of the region of Cajamarca. A list of randomly selected farmers was generated from among the farmers who work with the non-profit organization Foncreagro using simple random sampling. Foncreagro is a non-profit organization that works with small farms to develop agricultural projects related to improved farming practices and sustainable development. Foncreagro works with approximately 6000 farmers in two provinces and five districts of the region of Cajamarca. All farmers who agreed to participate provided verbal consent, and approval for this study was granted by the Institutional Review Boards of the University of Pennsylvania and the Universidad Peruana Cayetano-Heredia in Lima.

2.2 Questionnaire

The questionnaire developed for this study was adapted from questionnaires used by Zwald et al. (2004), Sawant et al. (2005), Raymond et al. (2006) and Jimenez-Velasco (2002). The questionnaire was divided into four sections: 1) information on the farms and animals, 2) disease incidence, antibiotic use and knowledge of antibiotics, 3) farm management and 4) demographic and economic information pertaining to the farmer. A copy of the questionnaire is included in the with indicators of the test-retest reliability of the survey in the sampled population for a subset of questions. Questionnaires were piloted on a convenience sample of ten dairy farms in two villages outside of Cajamarca and optimized before they were administered to the full sample of farms. All questionnaires were administered in Spanish by a Peruvian veterinary student and a veterinary student from the United States. After the questionnaire was administered, the California Mastitis Test (CMT) was performed on all lactating cows on the farm and an average CMT score was generated for each farm. The California Mastitis Test (CMT) measures the somatic cell count in milk, which reflects the degree of inflammation present in the udder. Ali and Shook (1980) showed that a log transformation of SCC to a somatic cell score of the type used in the CMT achieves nearly normal distribution, and a CMT score of zero (corresponding to 200,000 cells/ml) is a generally accepted cut off with high sensitivity and specificity for intra-mammary infection (Doohoo and Leslie, 1991).

2.3 Disease incidence and drugs used

Farmers were asked about disease incidence and drug use on their farm in various ways. First, they were asked if they had used antibiotics to treat any diseases in the past year, and if so, to name the drugs used. Next, they were shown pictures of antibiotics available on the local market and asked if they had used any of those drugs in the past year. Finally, they were asked about specific categories of disease (mastitis, peri-parturient infections, respiratory infections, diarrhea, skin/foot infections and others (mostly non-specific symptoms such as febrile or off-feed)) in the past year. Farmers who reported that their cows experienced one or more episodes of disease were asked how many episodes they had observed, if they had treated any of the episodes, and, if so, with which antibiotic (using the illustrations to guide their choices).

2.4 Knowledge score

A knowledge score was generated to assess farmers' understanding of what antibiotics are and the risks associated with their use. First, farmers were asked if they knew what an antibiotic was and to define the term in their own words. Farmers were also asked if they knew what drug withdrawal times were and to define them in their own words. For each of these questions, zero points were awarded for not knowing and one point was awarded for knowing and providing an appropriate definition. Subsequently, farmers were presented with three questions: "Do you think that the use of antibiotics could produce allergic reactions in animals", "Do you think that using the same product more than once can create resistance" and "Do you think milk from treated cows is good for human consumption"; farmers could answer "Yes", "Don't know" or "No". Correct answers, "Don't know" and incorrect answers were assigned scores of 2, 1 and 0 points, respectively. A "knowledge" score consisting of the sum of the points obtained for these five questions was generated. The score thus ranges from 0 to 8 points; a score of 3 could indicate no knowledge, a score of less than 3 indicates incorrect knowledge and a score of more than 3 indicates some knowledge.

2.5 Milking hygiene score

The milking hygiene score was similarly composed of points attributed to answers for the following questions: "Do you clean the udder before milking?" (Never=0 points, Sometimes=1, Always=2); "What do you clean the udder with?" (Water=0, Water and soap=1, Disinfectant=2); "Do you clean your hands before milking?" (Never=0, Sometimes=1, Always=2); "Do you clean your hands between milking different cows?" (Never=0, Sometimes=1, Always=2); and "Do you seal the teats with iodine after milking?" (Never=0, Sometimes=1, Always=2).

2.6 Statistical analysis

Data from questionnaires were examined for normality (using a skewness/kirtosis test) and missing values and described in terms of means, standard deviations and ranges or medians and interquartile ranges for continuous variables and frequencies for categorical variables. Drugs used for various indications were compiled for each farm, and the rates of each treatment (number of antibiotic treatments/cow-year) were calculated. Incidences of treatment per cow-year were determined for each farm with a Poisson model with the number of cows (dry and lactating) on the farm as an offset and no covariates. Associations between the treatments rates and demographic, management and knowledge-related factors were assessed with a negative binomial regression model, where cow-years was included as an offset for each farm. This model allows for an assessment of extra-variability (that is, variability beyond what would be expected in a Poisson distribution) to serve as a test of model fit (Horton et al., 2007). A p-value entry threshold of 0.2 was used for initial variable selection along with a backwards elimination strategy to develop multivariable models and assess confounding. Risk factors with a p-value of <0.05 and any confounders that altered other associations by 15% or more were retained in final models. An additional analysis using linear regression was conducted to determine factors associated with farmers' antibiotic-knowledge score. The selection of variables proceeded as described above. A subsample of 13 farmers were administered the survey twice two weeks apart to assess the test-retest reliability of the survey. Intraclass correlation coefficients and kappa coefficients were calculated to determine the reliability of continuous and categorical parameters, respectively. All analyses were conducted in Stata, v.11 (StataCorp. College Station, TX).

3. Results

3.1 Participants

A total of 168 farmers from 48 villages were invited to participate in the study (Table 1); 12 farmers declined to participate, resulting in a participation rate of 92.9%. Two farmers (one man and one women) tended to work on each farm, and 92 (59.0%) of the participants interviewed were women. The mean age of the farmers was 45 years, and more than half of them were analphabetic. The farms had a median size of seven cattle, including three lactating cows producing a median production of 5.63 L of milk per day each. For more than 90% of the farmers, the sale of milk was their sole of source of income, and farmers earned approximately 300 Peruvian Nuevo Soles ($115 according to the 2013 exchange rate) on a monthly basis. More than half (57.1%) of the farmers sold their milk to dairy processing companies (Nestlé or Gloria), while 35.3% and 7.7% of farmers sold their milk to cheese-makers and on the open market, respectively. The median CMT score on farms was 0.5 on a scale of 0–3 (0=negative, 1=weak positive, 2=distinct positive, 3=strong positive), which corresponds to a somatic cell count of approximately 300,000.

3.2 Disease incidence

Reported disease incidence was low, with an average incidence of 0.571 episodes of disease per cow-year, the majority (83.5%) of which were treated with antibiotics. Clinical mastitis occurred most frequently, followed by diarrhea, respiratory infections and peri-parturient infections (Table 2).

3.3 Antibiotic Use

Data were gathered on 216 reported treatments (Table 3). The most commonly used antibiotic was oxytetracycline, used in 107 of 216 (49.5%) reported treatments. Penicillin with or without streptomycin was used in 23 of 216 treatments (10.6%). Trimethoprim/sulfamethoxazole was used in 15 of 216 (6.5%) treatments. Cloxacilin intra-mammary injections were used in 25 of 59 (42.4%) reported cases of mastitis and in one case of metritis. Antiparasitic drugs, including fenbendazole, albendazole, levamisole and triclabendazole, were often used to treat diarrhea and infrequently used to treat respiratory disease.

Antibiotics were mostly used for therapeutic purposes; however, 27.2% of the farmers reported using antibiotics (either oxytetracycline or cloxacilin) for prophylactic purposes post-calving and/or for drying off.

3.4 Knowledge of antibiotics

When asked “Do you know what an antibiotic is?”, 35 of 156 (22.4%) farmers answered “Yes”. When asked to define the drug in their own words, answers ranged from “a medicine”, to “something for infections”, to “for fever or mastitis”; only one farmer knew that antibiotics specifically killed bacteria. Fifty-one of 156 (33.1%) farmers knew what drug withdrawal times were, and the majority defined this term as “when you are not supposed to send milk to the truck”.

The mean scores for the three questions pertaining to risk (risk of an allergic reaction, risk of producing resistance and risk for consumers) were 1.4, 1.5 and 1.7, respectively, of a maximal two points.

The mean knowledge score was 5.2 (SD=1.7) of a maximal 8 points, suggesting that, while farmers might not have been clear on the nature of antibiotics, they tended to understand that their use carried an inherent risk to their animals and potentially to the consumer.

The knowledge score was significantly associated with a number of factors (Table 4). Farmers who bought antibiotics from a feed-store themselves, farmers who used antibiotics for preventative reasons, farmers who administered more drugs when treatment failure occurred, farmers who observed complications in their animals after administering antibiotics, more highly educated farmers and farmers from farms with more workers had higher antibiotic-knowledge scores.

3.5 Acquisition of antibiotics

Antibiotics can be obtained from three sources in Cajamarca: a veterinarian, a feed-store or travelling drug distributors. Fifty-five (35.3%), 35 (22.4%) and eight (5.1%) farmers reported obtaining their drugs from a veterinarian only, a feed-store only and a distributor only, respectively; 47 (30.1%) farmers reported getting their drugs from a veterinarian and from the feed-store.

The farmers who reported buying drugs themselves at the feed-store were subsequently asked which factor was most important when buying antibiotics; 66 (80.5%) farmers reported that the recommendation of the veterinarian or feed-store vendor was the most important factor; 27 (32.9%) cited the quality of the product or the drug manufacturer as the determining factor, while eight (9.8%) stated that previous experience with the drug directed their choice. Seven farmers (8.5%) stated that the price of the drug drove their decision, acknowledging that the cheapest drug was often not the most effective choice.

3.6 Administration of antibiotics

Sixty-five (41.7%) farmers reported that they never treated their animals themselves and instead let the veterinarian or technician administer all treatments, while 91 (58.3%) farmers stated that they administered treatments to their animals themselves. Of the farmers who reported treating themselves, 73 (80.2%) reported always following the dosage recommended by the prescriber; of the 18 (19.9%) farmers who said they did not follow the recommended dosage, 15 (83.3%) and three (16.7%) farmers reported not doing so because the animal appeared better after the first dose and because the drug caused secondary effects, respectively.

Forty-five (29.0%) farmers reported having observed complications when antibiotics were administered to their animals, including weakness, vocalization, salivating, going off feed, inflammation at the site of injection, diarrhea, falling down and running around. Twenty-six (17.5%) farmers stated that they had never experienced treatment failure (i.e., treatments always cured the animal); of the farmers who had experienced treatment failure at some point (i.e., the animal did not improve after an initial treatment), 22 (16.9%) reported that they had increased the dose, 84 (64.6%) reported that they had administered a different drug, and 27 (20.8%) reported that they had sold the cow.

3.7 Milking hygiene score

The mean (SD) milking hygiene score was 8.78 (1.7) out of a maximal 13 points. One-hundred forty farmers (89.7%) reported always cleaning the udder (65.3% with water, 33.3% with water and soap and 1.4% with disinfectant), and 150 farmers (96.2%) reported always cleaning their hands before milking.

3.8 Factors associated with antibiotic treatments

In the regression, the incidence rate of treated episodes of disease was associated with a number of factors. Larger farms, defined as having more than seven cattle (the median number of cattle on farms in the sample), had fewer treatments per cow-year than smaller farms (incidence rate ratio (IRR)=0.72, 95% CI=0.54–0.97, p=0.016). Farmer income was negatively associated with treatment incidence: for every increase in 100 soles ($38.5) of income, the rate of treatments per cow-year decreased by 4.0% (IRR=0.96, 95% CI=0.934–0.998, p=0.015). The previous use of the California Mastitis Test on the farm (by either the farmer him/herself or by a veterinarian) was associated with a 59% increase in the incidence of treatments (IRR=1.59, 95% CI=1.24–2.04, p<0.0001). Finally, the knowledge score was also associated with treatment: for every one-point increase in knowledge score, an increase in the incidence rate of treatment of 8.2% was observed (IRR=1.08, 95% CI=1.01–1.17, p=0.033).

4. Discussion

Understanding antibiotic use on small farms in a region such as Cajamarca is important for a number of reasons. Small farms constitute the majority of providers in most of the developing world, and the use of antibiotics on these farms has implications for animal health, public health and farmer income (and therefore profitability and sustainability). We found that antibiotics were used relatively infrequently on surveyed farms (0.477 treated episodes of disease per cow-year) but that they were used more than 83% of the time when disease occurred.

The low incidence of disease was surprising, especially given that most of the animals are exclusively raised on low-quality pasture, frequently infested with parasites and provided with little preventive care (vaccination, concentrates, vitamins, etc.). A possible reason for this low reported incidence is that farmers may only notice (and remember) and seek veterinary care or treatment when the animal has reached an advanced stage of disease. Infections in chronically under-nourished animals may not initially appear dramatic to the farmer, and self-limiting diseases may not be noticed. Farmers may only decide to treat their animals when the animal has reached a clinical stage that can no longer be ignored. Training farmers to provide preventative care and recognize early signs of disease can be very useful in preventing animals from reaching the late stages of disease when treatments are less likely to be effective.

An increased incidence of treated disease was significantly associated with smaller-sized farms and lower incomes. This may seem counter-intuitive, as one would expect larger farms with more animals to be more likely to experience disease. However, farmers from larger farms and farmers with higher incomes had significantly higher levels of education (p=0.002 for trend) and therefore may have adopted better management practices that improved the general health of their animals. For example, education was significantly associated with the milking hygiene score (p=0.01 for trend), which represents one aspect of management that can significantly contribute to reducing the incidence of mastitis. Morrison et al. (1991) reported that the incidence of certain reproductive diseases was higher on small farms than on medium-sized farms in Columbia; Hill et al. (2009) also reported that the within-herd prevalence of disease in the United States decreased with increasing herd size and attributed this finding to differential management strategies adopted within different-sized herds. It is unclear why exposure to the CMT was associated with increased incidence of disease. It is possible that farms that experience higher rates of disease seek treatment from veterinarians who employ the CMT on their farm – in other words, disease may have preceded exposure to the CMT. Similarly, the association between increased incidence of disease and increased antibiotic knowledge score is likely due to the fact that farmers who experience disease and treatment more often are more knowledgeable about antibiotics (Table 4).

A limited number of active ingredients was used on the farms (oxytetracycline, cloxacilin, penicillin and trimethoprim-sulfamethoxazole), and antiparasitic drugs were sometimes used to treat what likely would have been bacterial infections. Studies of small farms conducted in other LMI countries have indicated that a similarly small number of active ingredients are used to treat cattle. In a survey of 60 small farms in Costa Rica, Luna-Tortos et al. (2006) reported that penicillins, tetracyclines and aminoglycosides were the most commonly used drugs and that cephalosporins and fluoroquinolones were used infrequently (10 and 15% of treatments, respectively). In a survey of 155 farmers in Hyderabad, India, Sudershan and Bhat (1995) reported that oxytetracycline was the most commonly used antibiotic in cattle and buffalo and was used by 55% and 38% of urban and rural farmers, respectively. Three herds of cattle belonging to Maasai pastoralists in Kenya were followed for four years by Roderick et al. (2000) who reported that oxytetracycline was used at a rate of 0.20–1.00 treatments per animal-year. In Sudan, tetracyclines, penicillins, quinolones and sulfonamide-trimethoprim antibiotics were used in 25, 18, 32 and 4% of treatments (n=73), respectively (Eltayb et al., 2012). In contrast, a survey of large dairy and beef farms in Lima reported that 15 active ingredients were commonly used (Solimano-Maza et al., 2011), while a survey of 113 dairy herds in Pennsylvania reported that 24 different types of antibiotics were used (Sawant et al., 2005). Pol and Ruegg (2007) reported that conventional dairy farms in the United States used an average of 5.43 defined daily doses of antibiotics per cow-year, which is significantly more than was reported to be used on the farms of the present study.

The use of a limited number of drugs on small farms can enhance antibiotic resistance to these drugs (Shitandi and Sternesjö, 2004) and increase the likelihood of treatment failure. While it was unclear from these interviews why so few active ingredients were used, veterinarians interviewed on antibiotic use in Cajamarca in a previous study (Redding et al., 2013) mentioned that a limited number of active ingredients were available on the market and that farmers were often accustomed to using the same products repeatedly. Subsequent studies would need to be conducted to determine the degree of resistance to these antibiotics that exists on these farms. If the degree of resistance is high, animal health professionals could encourage the use of alternate active ingredients. The addition of new active ingredients to treatment regimens in Cajamarca would require the importation of new drugs, the promotion of these new ingredients by prescribers and the familiarization of farmers with these drugs. If, on the other hand, the degree of resistance in the field is low and if these treatments remain effective, then the use of a small number of active ingredients could actually be beneficial. It was interesting to note that no farmers claimed to have used drugs such as third or fourth generation cephalosporins (which are considered critically important antimicrobials by the WHO). Because a majority of dairy farmers in developed countries use these drugs on a regular basis for prophylactic purposes (e.g., drying off) (Sawant et al., 2005), there is concern that bacterial resistance to these products may be developing, resulting in the potential diminished efficacy of these drugs.

The use of antiparasitics drugs to treat what are probably bacterial or viral infections is of concern as well. Not only will these treatments likely be ineffective, but they will also exacerbate the already-significant problem of drug-resistant fascioliasis that exists in Cajamarca, where prevalence in cattle has been reported to be 78% (Claxton et al., 1998) and resistance to commonly used antiparasitic drugs can reach 87% (unpublished data). Indeed, 95% of producers in Cajamarca surveyed by Raunelli and Gonzalez (2009) administered an average of three antiparasitic treatments per year to their livestock; using antiparasitics even more frequently is likely to exacerbate the problem of resistance, which, in turn, will make parasitized animals even more predisposed to opportunistic infections.

Farmers appeared to have some knowledge of and familiarity with antibiotics. Although only 38% of farmers reported knowing what an antibiotic was, the majority of farmers thought that antibiotics could provoke an allergic reaction or generate resistance (i.e., that it was bad to use the same product repeatedly) and that milk with residues was bad for consumers (55.6, 58.6 and 75.0%, respectively). A study conducted in Chile reported that 60.4% of farmers (n=926) reported knowing what an antibiotic was and that 42.6% of these farmers specifically associated antibiotic with infectious disease (Chacón Saravia, 2011). Education, as expected, was positively associated with knowledge. Eltayb et al. (2012) also concluded that higher levels of education were significantly associated with higher levels of knowledge of antibiotic resistance and disease among farmers in Khartoum. Buying antibiotics from a feed-store was also associated with a higher knowledge score, most likely because a farmer who went to purchase antibiotics him/herself may have been more knowledgeable about animal health and confident in his/her ability to treat the disease. Similarly, a farmer who used antibiotics for preventative reasons most likely used antibiotics more often than a farmer who did not and therefore had more familiarity with these drugs. A farmer who had observed complications in his/her animals after drug administration was more likely to have a higher knowledge score, most likely because he/she was more likely to assign greater risk to antibiotic use. Finally, farmers from farms with more workers (family members) had higher knowledge scores, most likely due to the effect of pooled knowledge and greater interactions (and therefore communication) between farmers.

Overall, farmers in Cajamarca do not appear to be overusing antibiotics in their cattle. Antibiotic use was infrequent, and farmers' knowledge of antibiotics and the risks inherent in their use was adequate. The relatively high number of farmers (29%) who had observed complications/side-effects in their animals after administering antibiotics suggests that antibiotics may not have been administered correctly and that the farmer may not have received sufficient instructions on how to properly administer them. Indeed, 70.2% of the farmer who reported having observed complications also reported treating animals themselves.

Because we only asked farmers to enumerate episodes of treated disease, we were not able to assess whether appropriate drug doses were applied. While 80.4% of farmers reported always following the dosage recommended by the veterinarian or feed-store vendor, it is not clear whether the appropriate dosages were actually prescribed and followed. Indeed, in a previous work (Redding et al., 2013), veterinarians and feed-store vendors in Cajamarca cited underdosing as a serious problem and mentioned sometimes under-prescribing because of limited economic means of farmers.

Certain management factors that can influence the incidence of disease (such as the milking hygiene score) appeared adequate. The non-profit organization Foncreagro has conducted a number of training sessions on good milking hygiene, and milk companies often try to instruct their farmers on good milking hygiene, which may explain the relatively high hygiene scores. Other factors, however, appeared lacking; for example, only 17.9% of farmers reported vaccinating their animals, and 54.4% of farmers reported never giving their animals concentrates. Interventions to improve preventative care in animals could be of great importance to improving animal health.

Several limitations apply to this study. Recall bias among farmers may have resulted in the underreporting of drug treatments and the attenuation of associations between drug use and demographic/management factors. However, because the obtention of self-reported pharmacoepidemiological data can be enhanced by asking questions in a variety of ways (i.e., with visual prompts) (West et al., 1995), asking farmers to recall drug treatments in a variety of ways (directly, by association with disease entities and using pictures of antibiotics available on the market) likely mitigated issues of poor recall. In addition, answers related to the incidence of disease had high reliability (intraclass correlation coefficient of 0.80). It is also possible that social desirability may have influenced some of the answers provided by the farmers, especially those related to proper drug use (e.g., always following the dose prescribed) and management (e.g., milking hygiene). However, the purpose of the survey was explained to the farmers and it was made very clear that their participation and responses would have no impact on their interaction with Foncreagro or on the care administered to their animals. Because this was a cross-sectional study, it is also possible that some of our findings may be due to reverse causality. For example, the finding that farmers exposed to the CMT had higher rates of treated disease may be due to the fact that the CMT was used to diagnose the disease. Nevertheless, these associations are important to elucidate, as they point to the interconnected nature of farmer knowledge, farm management and disease incidence.

Finally, the results of the study may not be generalizable to other small dairy farms in other LMI countries. In particular, because these farmers were involved with Foncreagro, they may have received training and educational interventions that other farmers may not have received and therefore may have had improved knowledge and awareness of good farming practices. However, even if these farmers represent best-case scenarios, we were still able to glean an understanding of the patterns of and indications for antibiotic use that are likely generalizable to farms of this size and type in other countries.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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References

Ali AKA, Shook GE. Heritability and repeatability of somatic cell concentration in milk. J Dairy Sci. 1980; 63:100.

Barton MD. Antibiotic use in animal feed and its impact on human health. Nutr Res. 2000; 13:279–299.

Chacón Saravia, T. Boletín Veterinario Oficial. Uso y conocimiento sobre medicamentos veterinarios en establecimientos ganaderos de la Region de Aysén. Pecuaria, DdP, editor. Ministerio de Agricultura de Chile; 2011.

Claxton JR, Zambrano H, Ortiz P, Delgado E, Escurra E, Clarkson MJ. Strategic control of fasciolosis in the inter-Andean valley of Cajamarca, Peru. Vet Rec. 1998; 143:42–45. [PubMed: 9699251]

Cox, T.; Zhu, Y. Dairy: Assessing World Markets and Policy Reforms: Implications for Developing Countries. In: Aksoy, M.; Beghin, J., editors. Global Agricultural Trade and Developing Countries. The World Bank; Washington, DC: 2005. p. 161-176.

Doohoo IR, Leslie KE. Evaluation of changes in somatic cell counts as indicators of new intramammary infections. Prev Vet Med. 1991; 10:225–237.

Dunlop RH, McEwen SA, Meek AH, Black WD, Clarke RC, Friendship RM. Individual and group antimicrobial usage rates on 34 farrow-to-finish swine farms in Ontario, Canada. Prev Vet Med. 1998; 34:247–264. [PubMed: 9618740]

Eltayb A, Barakat S, Marrone G, Shaddad S, Stalsby Lundborg C. Antibiotic use and resistance in animal farming: a quantitative and qualitative study on knowledge and practices among farmers in Khartoum, Sudan. Zoonoses Publ Hlth. 2012; 59:330–338.

FAO. Status of and Prospects for Smallholder Milk Production – A Global Perspective. In: Hemme, T.; Otte, J., editors. In Pro-Poor Livestock Policy Initiative. Rome: 2010.

Garcia, O.; Gomez, C. The Economics of Milk Production in Cajamarca, Peru, with Particular Emphasis on Small-scale Producers. In: P-PLP, editor. A Living From Livestock, Initiative. FAO; 2006.

Gerz, A.; Boucher, F. Origin-based Products: Lessons for pro-poor market development. Royal Tropical Institute - CIRAD; 2006. Mantecoso cheese in Peru: Organizing to conquer the national market; p. 41-51.

Gilchrist MJ, Greko C, Wallinga DB, Beran GW, Riley DG, Thorne PS. The potential role of concentrated animal feeding operations in infectious disease epidemics and antibiotic resistance. Environ Health Persp. 2007; 115:313–316.

Gustafson RH, Bowen RE. Antibiotic use in animal agriculture. J Appl Microbiol. 1997; 83:531–541. [PubMed: 9418018]

Hill AE, Green AL, Wagner BA, Dargatz DA. Relationship between herd size and annual prevalence of and primary antimicrobial treatments for common diseases on dairy operations in the United States. Prev Vet Med. 2009; 88:264–277. [PubMed: 19147244]

Horton NJ, Kim E, Saitz R. A cautionary note regarding count models of alcohol consumption in randomized controlled trial. BMC Medical Research Methodology. 2007; 7:1–9. [PubMed: 17217545]

Jimenez-Velasco, G. Bachelor's thesis. Universidad Peruana Cayetano-Heredia; Lima, Peru: 2002. Estudio sobre la utilizacion de antibioticos en la produccion de bovines lecheros en la region de la Maica Universidad Peruana Cayetano-Heredia, Lima.

Knips, V. Developing Countries and the Global Dairy Sector Part I Global Overview. In: P-PLP, editor. PPLPI Working Papers, Initiative. Food and Agriculture Organization of the United Nations; 2005.

Luna-Tortos C, Correa M, Cedeno-Guerra H, Caballero M. Estudio sobre los patrones de uso de antibioticos y los factores de relevancia en el surgimiento de la resistencia bacteriana en fincas lecheras artesanales de Costa Rica. Ciencias Veterinarias. 2006; 24:151–165.

Mathew AG, Cissell R, Liamthong S. Antibiotic resistance in bacteria associated with food animals: a United States perspective of livestock production. Foodborne Pathog Dis. 2007; 4:115–133. [PubMed: 17600481]

Morrison RB, Navarrete M, Orjuela J, Otte E. Salud y productividad en bovinos de la costa norte de Colombia. FAO World Animal Review. 1991

Oliver SP, Murinda SE, Jayarao BM. Impact of antibiotic use in adult dairy cows on antimicrobial resistance of veterinary and human pathogens: a comprehensive review. Foodborne Pathog Dis. 2011; 8:337–355. [PubMed: 21133795]

Pol M, Ruegg PL. Treatment practices and quantification of antimicrobial drug usage in conventional and organic dairy farms in Wisconsin. J Dairy Sci. 2007; 90:249–261. [PubMed: 17183093]

Raunelli F, Gonzalez S. Strategic Control and Prevalence of Fasciola Hepatica in Cajamarca, Peru. A Pilot Study. Int J Appl Res Vet Med. 2009; 7:145–152.

Raymond MJ, Wohrle RD, Call DR. Assessment and promotion of judicious antibiotic use on dairy farms in Washington State. J Dairy Sci. 2006; 89:3228–3240. [PubMed: 16840641]

Redding LE, Barg FK, Smith GS, Galligan DT, Levy MZ, Hennessy S. The role of veterinarians and feed-store vendors in the prescription and use of antibiotics on small dairy farms in rural Peru. J Dairy Sci. 2013; 96:7349–7354. [PubMed: 24054290]

Roderick S, Stevenson P, Mwendia C, Okech G. The use of trypanocides and antibiotics by Maasai pastoralists. Trop Anim Health Prod. 2000; 32:361–374. [PubMed: 11147276]

Sawant AA, Sordillo LM, Jayarao BM. A survey on antibiotic usage in dairy herds in Pennsylvania. J Dairy Sci. 2005; 88:2991–2999. [PubMed: 16027213]

Shitandi A, Sternesjö A. Prevalence of Multidrug Resistant Staphylococcus aureus in Milk from Large- and Small-Scale Producers in Kenya. J Dairy Sci. 2004; 87:4145. [PubMed: 15545376]

Solimano-Maza G, Fernandez-Cuadros C, Evaristo-Romero R, Falcon-Perez R. Antibacterianos de empleo frecuente en ganado bovino destinado a la producción de leche y carne en Lima, Perú. Una Salud Revista Sapuvet de Salud Pública. 2011; 2:81.

Sudershan RV, Bhat RV. A survey on veterinary drug use and residues in milk in Hyderabad. Food Addit Contam. 1995; 12:645–650. [PubMed: 8522029]

Zwald AG, Ruegg PL, Kaneene JB, Warnick LD, Wells SJ, Fossler C, Halbert LW. Management practices and reported antimicrobial usage on conventional and organic dairy farms. J Dairy Sci. 2004; 87:191–201. [PubMed: 14765827]

Table 1

Characteristics of small farms and farmers (n=156) participating in a study on antibiotic use in Cajamarca, Peru.

Farm or Farmer characteristic	No. of respondents
Farmers interviewed - women, n(%)	92/156 (59)
Mean (SD, min, max) age (years)	45.0 (15.1, 17, 89)
Education level, n(%)	
None (analphabetic)	84/156 (53.6)
Some primary school	58/156 (37.2)
Some secondary school	14/156 (8.97)
Median (interquartile range) number of farmers on each farm	2 (1–3)
Men	1 (0–1)
Women	1 (1–2)
Median (interquartile range, min, max) number of animals on each farm	
Cattle (cows, calves/heifers and bulls)	7 (5–9, 1, 27)
Lactating cows	3 (2–4, 1, 14)
Dry cows	1 (0–2, 0, 7)
Median (interquartile range, min, max) amount of milk produced daily (L)	
On-farm total	16 (10–25, 3, 120)
Per cow	5.63 (4.58–8, 2, 18)
Median (interquartile range, min, max) monthly income from milk ($)	115 (67.3–173, 15.4, 1076)
Destination of milk, n(%)	
Nestlé	24/156 (15.4)
Gloria	65/156 (41.7)
Cheese-makers	55/156 (35.3)
Home consumption/open market	12/156 (7.69)
Median (interquartile range) mastitis score on a scale of 0 to 3	0.5 (0–1)

Table 2

Incidence of treated and untreated disease on small dairy farms in Cajamarca, Peru (n=156)

Type of disease	Number of episodes on all farms	Incidence rate (number of episodes/cow-year)	
		Rate	95% CI
Mastitis			
Total	126	0.182	0.152–0.216
Treated	102	0.147	0.121–0.178
Peri–parturtient infections			
Total	68	0.100	0.080–0.126
Treated	66	0.095	0.078–0.121
Respiratory infections			
Total	82	0.119	0.096–0.148
Treated	74	0.106	0.085–0.133
Diarrhea			
Total	76	0.101	0.080–0.127
Treated	70	0.082	0.063–0.106
Skin/Foot infections			
Total	11	0.016	0.009–0.029
Treated	8	0.011	0.006–0.023
All diseases			
Total	363	0.571	0.512–0.630
Treated	320	0.477	0.428–0.531

Table 3

Antibiotics used in reported treatments on small dairy farms in Cajamarca

Disease	Drug	Percent of reported treatments
Mastitis	Cloxacilin intra-mammary	42 (25/59)
	Penicillin±Streptomycin	27 (16/59)
	Oxytetracycline	22 (13/59)
	Cephalexin intra-mammary	6.8 (4/59)
	Other	1.7 (1/59)
Peri-parturient infections	Oxytetracycline	89 (42/47)
	Penicillin±Streptomycin	8.5 (4/47)
	Cloxacilin	2.1 (1/47)
Respiratory disease	Oxytetracycline	80 (45/56)
	Penicillin±Streptomycin	5.4 (3/56)
	Trimethoprim/sulfamethoxazole	5.4 (3/56)
	Tylosin+Gentamycin	3.6 (2/56)
	Antiparasitics	1.8 (1/56)
Diarrhea	Antiparasitics	54 (29/54)
	Trimethoprim/sulfamethoxazole	22 (12/54)
	Oxytetracycline	13 (7/54)
	Tylosin+Gentamycin	1.9 (1/54)

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Table 4

Identification of factors associated with the antibiotic knowledge score by linear regression analysis in a sample of 156 dairy farmers in Cajamarca, Peru

	Univariate analysis			Multivariate analysis		
	Coefficient	**p-value**	**95% CI**	**Coefficient**	**p-value**	**95% CI**
Farmer buys antibiotics from feed-store	0.98	<0.001	0.440–1.52	0.65	0.009	0.165–1.13
Antibiotics used for preventative reasons	0.79	0.014	0.166–1.42	0.67	0.019	0.110–1.22
In response to treatment failure, the farmer increases the dose	0.86	0.026	0.103–1.61	0.77	0.027	0.087–1.45
Farmer has observed complications in animals administered antibiotics	1.29	<0.001	0.726–1.86	0.65	0.019	0.106–1.19
Education (compared to none)						
Some primary	0.84	0.003	0.281–1.40	0.61	0.017	0.109–1.10
Some secondary	1.50	0.002	0.563–2.45	1.07	0.011	0.248–1.90
Number of workers on the farm	0.46	<0.001	0.216–0.716	0.29	0.01	0.073–0.517