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Small-Scale Food Animal Production and Antimicrobial Resistance: Mountain, Molehill, or Something in-between?

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Summary: Small-scale food animal production is widely practiced around the globe, yet it is often overlooked in terms of the environmental health risks. Evidence suggests that small-scale food animal producers often employ the use of antimicrobials to improve the survival and growth of their animals, and that this practice leads to the development of antimicrobial resistance (AMR) that can potentially spread to humans. The nature of human–animal interactions in small-scale food animal production systems, generally practiced in and around the home, likely augments spillover events of AMR into the community on a scale that is currently unrecognized and deserves greater attention. https://doi.org/10.1289/EHP2116

Introduction

Small-scale food animal production is increasingly practiced throughout the world (Moges et al. 2010; Okeno et al. 2012; Robinson et al. 2014). Evidence suggests that small-scale food animal production can provide households with a means to reduce poverty, reduce food insecurity, and improve gender equity, especially in low- and middle-income countries (LMICs) (Herrero et al. 2014; Iannotti et al. 2014; Kafle 2014; Kristjanson et al. 2014; Leroy and Frongillo 2007; Miller et al. 2014). It is estimated that more than 80% of the chicken population worldwide occurs in small-scale production systems, producing up to 90% of the total poultry products in many LMICs (Mack et al. 2005). Of growing concern, however, is that small-scale food animals are often reported to receive antimicrobials to enhance their survival and growth. Although current information is insufficient to estimate the scale of unregulated antimicrobial use in the sector, this use appears to be common and creates a tension between development programs and public health.

To date, studies linking antimicrobial resistance (AMR) in humans with antimicrobial use in food animals has largely focused on commercial-scale production systems (Silbergeld et al. 2008). In these settings where animals are intensively raised, studies have shown that the intestinal microbiota of food animals can be a source of AMR in workers and humans living near the operations (Rinsky et al. 2013; Seiffert et al. 2013; Smith 2015). Small-scale systems can differ from commercial confinement operations in ways that may affect the transmission of AMR from animals to humans. In large commercial-scale production, the primary risk is likely associated with direct exposure of workers to animal feces, as well as consumer exposures to contaminated meat and poultry products that can be widely disseminated (Gieraltowski et al. 2016; Nordstrom et al. 2013; Wardyn et al. 2015). In small-scale systems that typically raise animals at lower density within the household environment, we suggest that the primary transmission pathways are environmental exposures that include direct contact with live animals and their wastes, especially among young children. For example, studies of young children in rural Zimbabwe and Bangladesh identified the ingestion of animal feces as an important route of childhood exposures to animal feces (Ngure et al. 2013). These environmental exposures increase the potential for spillover events; that is, they create situations where zoonotic microbiota, including drug-resistant bacteria and AMR genes, may spread to humans.

Here we report existing evidence on the use of antimicrobials in small-scale food animal production, which we hypothesize represents an important yet underappreciated reservoir of AMR. Additionally, because of the nature of human–animal interactions in these systems—often occurring in and around the home—the potential for spillover of AMR into the community may occur at a greater scale than is currently recognized (Figure 1).

Antimicrobial Use in Small-Scale Food Animals

In LMICs, antimicrobials are often available over the counter in animal agriculture shops (Katakweba et al. 2012). The practice of using antimicrobials in small-scale food animal production—whether for growth promotion, disease prevention, or disease treatment—has been documented in a diverse set of studies within LMICs (Andoh et al. 2016; Braykov et al. 2016; Katakweba et al. 2012; Lowenstein et al. 2016; Nguyen et al. 2015; Nonga et al. 2010; Roess et al. 2013) (Table 1). In rural Ecuador, for example, small-scale poultry farmers report that they regularly administer antimicrobials, including drugs from six different antimicrobial classes (Braykov et al. 2016). In southwestern Nigeria, a study of veterinary pharmacy shops found that tetracyclines, fluoroquinolones, and beta-lactams/aminoglycosides constituted the majority of antimicrobials used among small- to medium-scale food animal operations (Adesokan et al. 2015). In other studies of small- to medium-scale food animal operations, in Tanzania and Ghana, for example, researchers have documented the regular use of antimicrobials (Andoh et al. 2016; Nonga et al. 2010). Nguyen et al. (2015) have highlighted significant variability in the antimicrobial classes used in small food animal operations and have emphasized the potential for multidrug resistance to develop and be amplified. There is little information, however, regarding the doses or duration of antimicrobial use, further restricting the ability to assess the risks of AMR development within these operations. It is likely that households engaged in small-scale food animal production lack access to the necessary veterinary technical assistance required to

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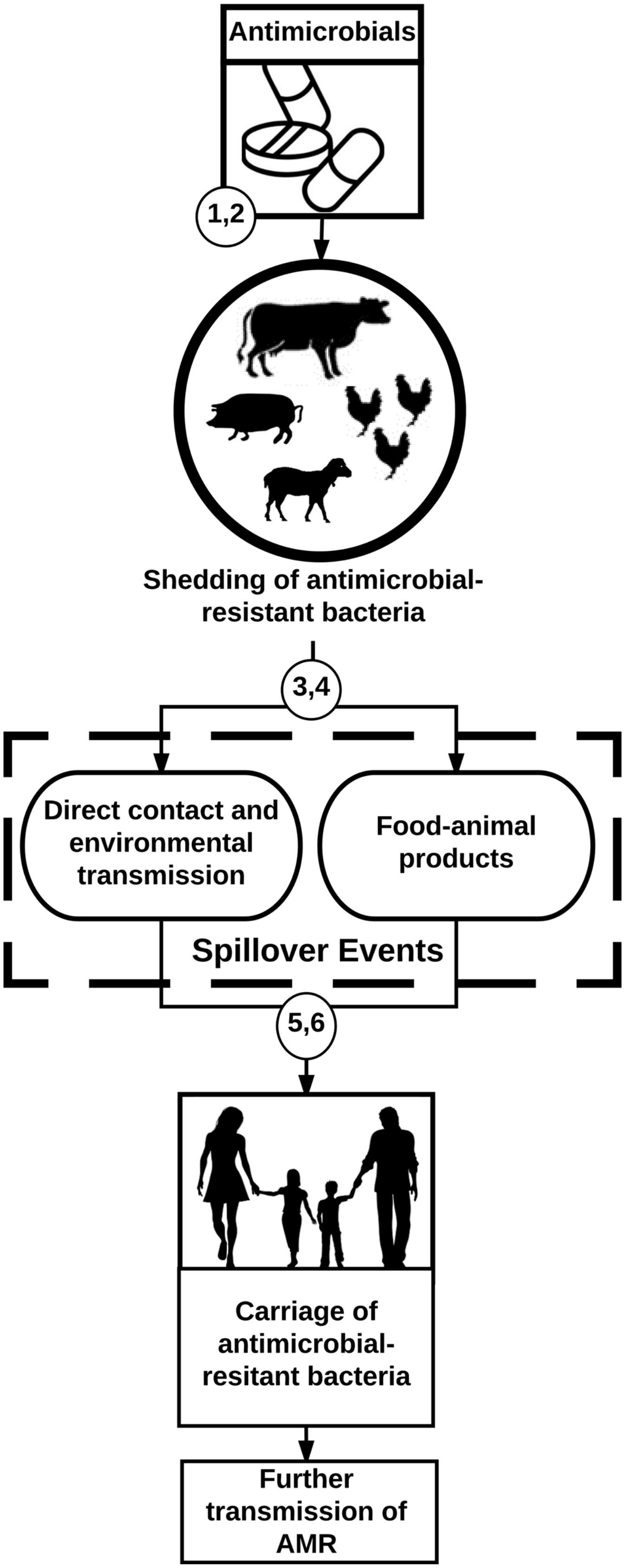

Figure 1. Conceptual illustration of AMR spillover from small-scale food animals to humans (Lowenstein et al. 2016; Roess et al. 2013; Braykov et al. 2016; Andoh et al. 2016; Pehrsson et al. 2016; Moser et al. 2017).

appropriately determine antibiotic selection, dose, and duration. Future interventions that aim to reduce the misuse of antimicrobials in small-scale livestock may need to target veterinary pharmacy shops, an approach that has been used in human medicine to reduce misuse of drugs available over the counter (Chalker et al. 2005).

Driving Factors for Antimicrobial Use in Small-Scale Food Animal Production

In Ghana, the stated drivers for using antimicrobials in poultry production—mainly prevention and treatment of diseases—did not vary significantly between small-scale and commercial-scale operations (Andoh et al. 2016). Nearly half of producers interviewed in a study in Ecuador perceived the use of antibiotics as an important strategy for helping animals grow faster and preventing disease, especially when the animals are young (Lowenstein et al. 2016). According to Lowenstein et al. (2016), one producer noted that the use of antimicrobials in animal feed is especially important when animals are raised indoors, "The [feed we use] has antibiotics, vitamins. Because of that the animals grow faster. We use medicines more because we raise them inside, because otherwise they die. The animals that are in the fields do not get sick." A few study respondents claimed that their animals rarely get sick and credited antimicrobials with animal health (Lowenstein et al. 2016). At the same time, there is evidence that many producers have a limited understanding of AMR. None of the small-scale food animal producers mentioned above knew of specific health risks for themselves or their children related to drug-resistant infections, although many shared the perception that eating animals that had been raised with too many antibiotics could be harmful to health (Lowenstein et al. 2016). Research suggests that the fundamental driver for antimicrobial use in this sector is likely rooted in the intensification of food animal production that is increasing globally (Jones et al. 2013; Wiethoelter et al. 2015).

AMR in Small-Scale Food Animals

In a study of AMR comparing two types of small-scale poultry production systems, Braykov et al. (2016) found a higher prevalence of drug-resistant *Escherichia coli* (i.e., tetracycline and amoxicillin-clavulanic acid resistance) in household production chickens versus free-range chickens. In this study, production chickens were defined as a nonlocal breed that is designed to grow larger; these birds were generally raised in confinement and were raised to be sold, rather than for household consumption. The study highlighted that management practices for production-oriented chickens may result in more antimicrobial use to enhance their survival and growth (Braykov et al. 2016). Researchers in Ghana identified nearly a quarter of *Salmonella* isolates (24%) from poultry raised in small-scale settings that were resistant to four or more antimicrobials (Andoh et al. 2016). Further, a study of chicken fecal samples and milk samples from dairy cows in small- to medium-scale operations in Odisha, India, identified ESBL (extended-spectrum beta lactamase)-producing *E. coli* in 18 of 305 of the samples screened (5.9%) (Kar et al. 2015).

Spillover of AMR from Small-Scale Food Animals to Humans

Research has demonstrated spillover of zoonotic enteric pathogens into the household environment from small-scale food animals. Examples include atypical enteropathogenic *E. coli* (Vasco et al. 2016), *Campylobacter* spp. (El-Tras et al. 2015; Harvey et al. 2003; Vasco et al. 2016), and *Giardia* and *Cryptosporidium* (Berrilli et al. 2012). Transmission of zoonotic pathogens

Table 1. Examples of antimicrobial use by small-scale food animal producers.

Reference	Country	Setting	Animals studied	Scale of operations studied	Findings
Braykov et al. 2016	Ecuador	Rural	Chickens	Small to medium[a]	Farmers reported using penicillin plus streptomycin, tetracycline, sulfonamide, sulfamethazine plus trimethoprim, piperacillin, erythromycin, sulbactam, and/or enrofloxacin. Sixteen of 20 farmers reported supplementation with antibiotics beyond what is already available in feed.
Katakweba et al. 2012	Tanzania	Rural	Mixed	Small to large	The most commonly reported antibiotics used were tetracycline, sulphadimidines, and penicillin-streptomycin and these were present at the farms. Livestock keepers gathered advice on antimicrobial use from veterinarians, sales shop agents, extension agents, or in some cases received no consultation.
Nonga et al. 2010	Tanzania	Rural	Chickens	Small ($n=19$) to medium ($n=1$)[b]	All farmers reported using drugs to either treat or prevent occurrence of diseases in their birds. Two-thirds (65%) of the farmers reported treating their chickens themselves after getting advice from the sales shop agents. A range of 10 different antimicrobials were used among the 20 farms; sulfonamides were used on all farms.
Roess et al. 2013	Bangladesh	Rural	Chickens	Small	Most respondents reported to use antimicrobial drugs and could name them by using local terms or the brand name. The most commonly used antibiotic was oxytetracyline. Medicines used for household members were sometimes provided to animals, when their symptoms were similar to illnesses observed in humans.
Lowenstein et al. 2016	Ecuador	Peri-urban	Mixed	Small	In-depth interviews with small-scale food animal producers found that antibiotics were considered an important strategy for helping animals grow faster and preventing parasites, especially when the animals are young.
Ström et al. 2017	Thailand	Rural	Pigs	Small[c] ($n=25$) and medium ($n=27$)	All farms administered antimicrobials to their pigs. Small-scale farmers made decisions on when to administer antimicrobials and made purchases at local shops. Medium-scale farmers discussed antimicrobial treatment with a veterinarian. Medium-scale farms used a greater diversity of antimicrobials than small-scale farms.
Andoh et al. 2016	Ghana	Rural	Chickens	Medium[d]	All 75 poultry keepers reported providing antimicrobials to their poultry based on advice of veterinarians and shop sales agents. The most common drugs used included oxytetracycline, penicillin, tylosin, ciprofloxacin, erythromycin, enrofloxacin, streptomycin, doxycycline, trimethoprim-sulfadozine, and neomycin. None of the 75 poultry keepers complied with withdrawal periods indicated on product labels.
Rugumisa et al. 2016	Tanzania	Rural	Chickens	Small[e]	Chickens were generally provided feed and water that may contain antibiotics, including tetracycline, enrofloxacin, and sulfa-trimethoprim.
Nguyen et al. 2015	Vietnam	Rural	Chickens	Household chickens ($n=104$) to Small chicken farms ($n=104$)[f]	Household chickens and chickens from small farms were commonly fed antibiotics, including tetracyclines, macrolides, penicillins, and polymyxins.

[a]The range varied from high intensity (>500 chickens) to medium intensity (150–500 chickens) to low intensity (<150 chickens).
[b]The range varied from 30 to 4,820 chickens. Nineteen of the 20 farms studied had <500 chickens.
[c]Small farms had a maximum of 20 pigs, whereas medium-scale farms were defined as farms with 100–500 pigs.
[d]This study included chicken farms with ≤1,000 chickens ($n=15$), 1,001–2,000 chickens ($n=16$), 2,001–4,000 chickens ($n=17$), and >4,000 chickens ($n=26$).
[e]In this study, small was characterized as <200 chickens.
[f]Household chickens had 10–200 chickens and small chicken farms had 200–2,000 chickens.

underscores that proximity to domestic food animals could also potentially increase the risk of AMR transmission if food animals are carrying drug-resistant bacteria. There are a large number of studies on the spillover of AMR between industrial food animals and humans (de Been et al. 2014; Huijbers et al. 2014; Seiffert et al. 2013; Silbergeld et al. 2008; van Hoek et al. 2016). Very few studies, however, have been conducted with small-scale operations, which are common in LMICs, but also increasingly common in high-income countries (Tobin et al. 2015). In a small study of the resistome (i.e., all the resistance determinants present in the gut) of household members, in Peru and Panama, which included 263 fecal samples from 115 individuals in 27 houses and 209 environmental samples, researchers identified chicken feces as an important source of AMR genes and that, on average, human fecal and chicken coop soil resistomes shared 10 antibiotic resistance-encoding proteins (Pehrsson et al. 2016). A study in Ecuador found an elevated risk of carrying resistance determinants (e.g., integrons) among households raising production chickens, described above, compared with households without chicken production operations (Moser et al. 2017).

Conclusion

Antimicrobial resistance is a major global health threat that is linked to antimicrobial use in both clinical and community settings (Finley et al. 2013). The attributable fraction of AMR due to antimicrobial use within agricultural systems is unknown, and within that, how much is due to small-scale food animal production is even less clear. Small-scale food animal production is an important livelihood that has the potential to improve the economy of households and communities (Gates 2016). Given their importance and the potential growth of this livelihood, there is a critical need to better understand the fraction of AMR in humans that is due to antimicrobial use in food animal production, specifically across the range of systems—from backyard to larger-scale operations. On one hand, antimicrobial use in large-scale operations is quantitatively large and exposures to AMR, due to food distribution systems, are likely to be global (Thornton 2010). On the other hand, antimicrobial use in small-scale systems generally occurs within the household environment in LMIC settings; these settings often result in intimate human–animal exposures as well as poor water, sanitation, and hygiene conditions, both of which may enhance AMR spread (Wuijts et al. 2017). Understanding the impact of small-scale food animals on AMR transmission will require better characterizations of the quantity and classes of antimicrobials used in different scales of production systems and the prevalence of specific types of AMR. There is also a need to clarify how different food animal species and management practices are associated with the spillover of AMR from small-scale food animals to human microbiota (Landers et al. 2012). A variety of actions will be needed to change the behaviors of antimicrobial producers, sales agents, farmers, and consumers (Chalker et al. 2005; Ferreira and Staerk 2017; Rojo-Gimeno et al. 2016). Moving forward, a supportive environment will be needed that includes regulations controlling use, improved systems for monitoring use, and financial incentives in tandem with programs that aim to improve farmers' knowledge, attitudes, and practices (Lhermie et al. 2016).

Increasing the production of food animals can be an important contributor to food security and the resilience and productivity of people's livelihoods; yet, at the same time, there is an understanding that if food animals are not carefully managed, adverse consequences can ensue. Ensuring that food animal production systems fully benefit the poor and do not further drive the spread of AMR is of critical importance to public health.

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