salon

I studied factory farms for years. Visiting one was far worse than I imagined

I lectured about the public health dangers of industrial farming. But what I saw went beyond my fears

By **DR. AYSHA AKHTAR** **PUBLISHED APRIL 20, 2019 2:00PM (EDT)**

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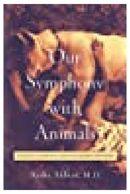
I was giving a talk at a conference in Oklahoma about the public health dangers of industrial animal farming, or "factory farming" as it is commonly called. Each year, more than 64 billion animals are raised and killed for food globally. In the United States alone, 1 million animals are slaughtered every hour. Largely because of increased demand for cheap animal products, intensive animal operations have replaced most traditional farming practices world- wide. The transformation of animal agriculture is so dramatic that it has been dubbed the "livestock revolution." This unprecedented change in the human relationship with animals has led to not only more animal suffering than ever before in human history but also to devastating harms to human health.

At the conference, I presented data showing how animal agriculture (and the resultant high consumption of animal products) causes more greenhouse gas emissions than the entire transportation sector. It also pollutes our land and water and increases our risks of cancers, obesity, strokes, and infectious diseases like salmonella, E. coli, and bird flus. Throughout my presentation, a solemn-looking woman with short, auburn hair and glasses kept shaking her head in disagreement. When I ended my talk and opened the floor for questions, the woman went on the attack. She disputed everything I said. There are no environmental hazards, no infectious disease risks, no animal welfare problems.

“Have you ever visited one of these farms?” she demanded, with evident anger.

I told her I had not because these places are not open for the public’s viewing. But my data came from reputable studies published by institutions like the Johns Hopkins Bloomberg School of Public Health and the Food and Agriculture Organization of the United Nations. The evidence is so strong, the American Public Health Association called for a moratorium on factory farms.



The woman, Jean Sander, was dean of the Oklahoma State University’s Center for Veterinary Health Sciences. “You need to visit our farms,” she replied. “They are nothing like what you say.”

Three months later, I take Jean up on her offer. The farms are worse than anything I’ve read.

On a dismal morning in late November, I meet Dr. Sander at the parking lot of a Sonic fast food restaurant in Bristow, Oklahoma. After we greet each other and complain about the weather, I get into her car. We head out to visit an egg-laying farm about a half hour away. This farm is not the place Jean initially set up for my visit. She was originally going to take me to see a “broiler” farm, where chickens are produced for meat, which is contracted by Tyson Foods. The Tyson chicken facility is one of Oklahoma’s largest.

But a few days before my flight to Tulsa, the Tyson facility manager backed out. He informed Jean that an undercover investigation at a chicken facility in Tennessee recently caught the attention of news reporters. As a result, he was not letting any outsiders in his buildings. The undercover investigators videotaped farm employees beating sick chickens with spiked clubs. Like the Oklahoma facility, the one in Tennessee was also contracted by and supplied chickens to Tyson Foods.

It's a wonder that the Tyson manager was initially willing to let me in at all. When I told Jean during my earlier presentation that factory farms don't allow visitors from the public, I wasn't exaggerating. Over the past decade, states have enacted laws to protect animal agricultural farms from outside attention. "Ag-gag" laws, in particular, criminalize journalists and animal protection groups, and they prevent just about anyone from taking undercover videos documenting what occurs within. These investigations have revealed not only rampant animal cruelty but also violations that have led to some of the largest meat recalls in the United States.

The only reason I am being allowed in is because of Jean. Her affiliation with Oklahoma State University, one of the largest agricultural schools in the country, has placed Jean in a position to know many of the animal farm managers in Oklahoma. They view her as an ally. And thanks to my connection with Jean, they must have seen me as nonthreatening. Even so, it took months for Jean to find facilities that would open their doors to us.

Herbert Wendell walks up to us and shakes our hands with fervor. With his ruddy cheeks and cheerful welcome, he immediately reminds me of my father-in law. Herbert comes from a family of crop farmers and was the first to move into animal agriculture. In 1957, he bought one chicken that started his egg-laying business. Since then, the number of chickens has grown to about thirty thousand.

After a few minutes of greeting, Jean hands me a disposable coverall, pair of booties, and gloves. They are meant to keep us from inadvertently introducing infectious agents into the facility as part of a biocontainment plan—methods that clearly don't work, given how often bird and swine flu epidemics sweep across industrial farms in the United States. Jean and I cover ourselves. We then follow Herbert and his granddaughter inside the nearest of the two animal sheds and . . . oh my god!

The smell that hovered outside drops hard and tries to smother me. I immediately turn away from the others, hold onto my knees, and gag. My head heaves. I'm so nauseated I think I'm going to throw up. As a doctor, I've been around plenty of bad smells. Nothing comes close to this. The best way I can describe the smell is this: Don't clean a cat's litter box for a month. Then add to it the litter from ten other cats, whose litter you had not changed in a month. Then add a rotting egg. Then a decomposing body. And, just for good measure, add a healthy dose of sulfur. Now stick your head inside this giant litter box, and that will give you an inkling of the smell inside this facility. Just an inkling.

I hide my face so the others don't see me gag. I'm worried I'll offend Herbert if I vomit.

With great effort, I swallow the bile pooling at the back of my throat and straighten up. Slowly, my other senses kick in. Touch first. Flies land on my face. I swat ineffectually at my forehead, nose, ears. Next comes sound. Not the individual noises of calls, clucks, and squawks. But a roar. A singular shout.

Then sight. Through the dim lighting, I see rows and rows of wire cages stacked two stories high. Each holding five hens. Twenty-five thousand birds kept in this building alone. The hens are so jam packed that their heads stick out above, along the sides, even below the cages. Their feet stand on wire grids. They have nowhere to go. They can't even stretch their wings.

Jean tells me that the standard of practice used to be to allow 54 square inches per bird in a cage. Now they're moving to 60 to 65 square inches per bird as an animal welfare gesture. Sixty-five square inches is about two-thirds the dimension of a single sheet of letter-sized paper. A hen is forced to live her entire life in the space of my laptop screen, but this is considered, by the agricultural industry, as progress.

As we walk down the rows, I breathe through my mouth to somewhat ease the stench. The birds scurry and climb on top of one another to hide near the back of the cages. They're terrified of us. I'm scared too. Scared that they will crush one another, which Herbert tells me, has happened. Up closer, I see raw, red exposed areas on most of the birds, where their feathers rubbed off against the wires entrapping them. I can't imagine how painful that must be.

“I’m sorry,” I whisper to them. “I’m so sorry.”

Since birds crowded like this commonly go mad and peck one another to death, these birds were debeaked, a practice whereby workers grab baby chicks in one hand and thrust their beaks between hot, steaming blades. Workers cut off anywhere from one-third to two-thirds of chicks’ beaks while they’re fully conscious. The industry calls this “trimming their beaks.” But slicing chickens’ beaks off with a heated blade or a scissor device, as is frequently done, is not like trimming your nails. Birds’ beaks are sensitive, highly innervated and able to feel pain and other sensations. It would be like having your toes cut off without anesthesia. Not only do chickens rely on their beaks for many functions, having their beaks severed causes them immense, acute, and, often, lifelong pain.

As we walk about, Herbert describes how the facility functions. Conveyer belts run along the span of the building, automatically collecting the eggs that fall under the chickens. Trenches alongside the cages hold feed pellets. It’s all mechanized. No human hand need ever touch a bird until the time of her death. This, then, is a chicken’s life. To huddle in a cage cowering on top of another for one and a half years until someone kills you.

Jean reminds me this is a small facility. Average-size farms house 100,000 birds. The largest may contain 200,000. I am so overwhelmed by the smell of filth and fear, I can’t fathom what those larger factories must be like.

“We keep the top and bottom rows of cages stacked,” Herbert says, breaking into my thoughts, “so that all of their droppings fall through the cages onto the floor below.” For the first time, I peer below the cages at the floor. It’s alive.

Maggots. Hundreds, thousands of maggots squirming about the ground. I jump and lift my legs. Squashed maggots are stuck on the bottom of my bootie-covered sneakers. As I hop on each leg to inspect my feet, I slip.

And down I go.

When I look back at this moment, the image that comes to mind is a scene in the movie *Poltergeist* (the original, of course), when the earth beneath the haunted family’s house erupts and releases the screaming skeletons and gaping skulls buried beneath. In the downpour of a raging storm, the mother desperately tries to rescue her children trapped inside the house. As she runs into their backyard screaming for help, her foot slips along the edge of a large, muddy pit. She slides into a pool of death.

My fall isn’t as dramatic, but if this place isn’t haunted by anguished souls, what is?

DR. AYSHA AKHTAR

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Food and Drug Administration. She is a Lieutenant Commander in the U.S. Public Health Service, in which she deploys to assist with national public health emergencies. She is also a fellow of the Oxford Centre for Animal Ethics and is a consultant editor for *The Journal of Animal Ethics*. She is the author of "Animals and Public Health" and lives in Maryland.

MORE FROM DR. AYSHA AKHTAR

The Problem with Factory Farming

Farm Animals Need Our Help

In polling, 94% of Americans agree (/shopwithyourheart/business-and-farmer-resources/aspca-surveys)that animals raised for food deserve to live free from abuse and cruelty. Yet the majority of the nearly 10 billion land-based animals, plus countless more aquatic animals, farmed for food each year in the U.S. live in unacceptable conditions that do not align with consumers' stated values.

Factory Farms

"Factory farm" is a term commonly used to describe an industrial facility that raises large numbers of farm animals such as pigs, chickens or cows in intensive confinement where their movements are extremely inhibited. Animals are kept in cages or crates, or are crowded together in pens. These types of farms are sometimes referred to as concentrated or confined animal feeding operations (CAFOs).

View the major sources of animal suffering on factory farms

- Cages and overcrowding.

- Physical alterations like teeth-clipping or tail-docking, performed without anesthetic
- Indoor confinement with poor air quality and unnatural light patterns
- Inability to engage in important natural behaviors, like laying eggs in nests or roosting at night
- Breeding for fast growth or high yields of meat, milk and eggs that compromises animal health and welfare
- Illnesses and injuries left unnoticed or untreated, often due to an unmanageable ratio of animals to workers
- Reliance on antibiotics to compensate for stressful and unsanitary conditions
- Rough or abusive handling by workers, often due to a lack of training, frustration at poor working conditions, unreasonable demands by superiors or poor design of facilities

It doesn't have to be this way. There are alternative farming systems that treat these sentient animals with compassion and respect.

Learn More about Animals on Factory Farms:
Chickens (/protecting-farm-animals/animals-factory-farms#Chickens) | Pigs (/protecting-farm-animals/animals-factory-farms#Pigs) | Cattle (/protecting-farm-animals/animals-factory-farms#Cattle) | Turkeys (/protecting-farm-animals/animals-factory-farms#Turkeys) | Aquatic Animals (https://www.aspca.org/protecting-farm-animals/animals-factory-farms#Fish)

Food Labels

Packages of meat, eggs and dairy often bear terms that appear to indicate meaningful animal welfare standards, but only a fraction of them do. This confusion prevents consumers from voting with their wallets for better treatment of farm animals and negatively impacts the farmers who truly are raising animals using higher-welfare methods.

View the most commonly misunderstood labels

FDA reports another rise in antibiotic sales for livestock

Filed Under: **Antimicrobial Stewardship** (/infectious-disease-topics/antimicrobial-stewardship)

Chris Dall | News Reporter | CIDRAP News (/ongoing-programs/news-publishing/news-publishing-staff) | Dec 16, 2020

United Soybean Board / Flickr c

For the second straight year, the Food and Drug Administration (FDA) is reporting an increase in the amount of medically important antibiotics sold for use in food-producing animals in the United States.

According to the FDA's summary report (https://www.fda.gov/media/144427/download) for 2019, domestic sales and distribution of medically important antibiotics for food animals rose 3% from 2018 through 2019, following a 9% increase from 2017 through 2018. "Medically important antibiotics" refers to antibiotics that are also used in human medicine.

The increases follow 3 years of declining sales of antibiotics for use in livestock. And the FDA notes that, since 2015, when US sales of medically important antibiotics for livestock peaked, there has been an overall 36% decline.

The FDA says the decline shows that efforts to support more appropriate use of antibiotics in food-animal production, including rules implemented in 2017 that banned the use of medically important antibiotics for growth promotion and required veterinary oversight for using antibiotics in water and feed, are having an impact. They also argue that some rebound in antibiotic sales was to be expected once producers adjusted to the new rules.

But advocates for more appropriate antibiotic use in food-producing animals say rising sales numbers over the past 2 years indicate the agency needs to do more to protect medically important antibiotics, which are becoming less effective as antibiotic resistance rises.

"It is appalling to see medically important antibiotic sales rise for the second year in a row," David Wallinga, MD, senior health advisor at the Natural Resources Defense Council (NRDC), said in a statement (https://www.nrdc.org/media/2020/201215-1). "Clearly, not enough is being done to protect the nation from a future pandemic. The next administration must act with the urgency that this public health threat demands."

Poultry industry leads the way

Antibiotics sales and distribution figure don't necessarily reflect how antibiotics are actually used on farms, but since the FDA doesn't collect such data, they provide the best estimate currently available.

The data show that, of the more than 6.1 million kilograms of medically important antibiotics sold to US farmers in 2019, an estimated 41% were intended for use in cattle, 42% in swine, 10% in turkeys, and 3% in chickens. While the amount of antibiotics sold for use in chickens fell by 13% compared with 2018 and antibiotic sales for turkeys declined by 4%, sales of antibiotics for swine rose by 9%. The increase for cattle was less than 1%.

The most frequently sold class of medically important antibiotics in 2019 for use in livestock were tetracyclines, which accounted for 67% of all sales. Penicillins accounted for 12% of sales, and macrolides for 8%. Sales of tetracyclines and macrolides rose by 4% and 3% in 2019, respectively, while sales of penicillins fell 2%.

The vast majority of antibiotics sold were for use in animal feed (65%) and water (29%). Sales of antibiotics for use in both feed and water increased by 4% over 2018.

The continuing decline in chicken antibiotic sales—a 62% reduction since 2016—likely reflects an ongoing consumer-driven movement that has transformed how poultry producers raise chickens. Over the past few years, several major fast-food chains and large poultry producers have committed to phasing out medically important antibiotics in poultry production in reaction to consumer demand for antibiotic-free chicken.

That movement has been slower to take hold in the beef and pork industries. Although antibiotic sales for cattle have fallen by 30% since 2016, an NRDC report (https://www.cidrap.umn.edu/news-perspective/2020/06/report-slams-beef-industry-overuse-antibiotics) this summer found that, on a weight-adjusted basis, US cattle producers still use antibiotics three to six times more intensively than many of their European counterparts.

Veterinary and public health consultant Gail Hansen, DVM, MPH, noted that even though the US swine population increased by 3% to 4%, the 9% increase in antibiotic sales indicate that swine antibiotic sales are "heading in the wrong direction."

"I think this shows that the chicken industry continues to improve their antibiotic stewardship, while the beef and pork industries continue to lag behind," said Matt Wellington, public health campaigns director for US Public Interest Research Groups (US PIRG). "That's the story that this tells."

Antibiotic use in animals has become an increasingly significant concern with the emergence of antibiotic resistance as a major public health threat. A recent analysis (https://www.nrdc.org/experts/david-wallinga-md/most-human-antibiotics-still-going-us-meat-production) by NRDC, conducted with the Center for Disease Dynamics, Economics & Policy, estimated that 65% of medically important antibiotics sold in the United States are being used in food-producing species, compared with 35% in humans.

The FDA points out that this is because there are many more animals in the country than humans. But concerns about overuse have resulted in the agency imposing some restrictions on how meat producers can use medically important antibiotics. Critics say the agency hasn't gone far enough.

While US meat producers are no longer allowed to use antibiotics to promote animal growth, they can still use them to prevent bacterial diseases in flocks and herds, a practice the World Health Organization has called on countries to end in order to prevent the emergence of antibiotic resistance. The FDA, however, still allows for preventive use of antibiotics in food-producing animals, and considers the practice appropriate and necessary for maintaining the health of herds and flocks.

Wellington and others say much of this preventive antibiotic use, particularly in beef and pork production, is to compensate for poor nutrition and unsanitary and stressful living conditions that contribute to disease.

"Producers, rather than changing those practices and mitigating the disease risk naturally, use antibiotics preventatively, so we know that that's a significant driver of antibiotic use," Wellington said. "It contributes to this slow-burning pandemic...of antibiotic resistance."

Targets and duration limits

Hansen and Wallinga say the report is another indication that the FDA needs to start setting goals for reduced antibiotic use in meat production.

"It is past time for the US to set target goals to reduce antibiotic use in food animals, as has been done in several other countries," Hansen said.

One of those countries is the United Kingdom, where recently released targets (https://www.ruma.org.uk/wp-content/uploads/2020/11/SO-469-RUMA-REPORT-021220.pdf) for responsible antibiotic use in farm animals called for a 30% decrease in antibiotic use in pigs, a 15% reduction in dairy herds, and a 25% reduction in calf-rearing units by 2024. The UK's Responsible Use of Medicines in Agriculture Alliance, which developed the targets, says the original targets it set in 2017 have helped UK farmers significantly reduce the amount of antibiotics they use in their animals.

Wallinga is calling on the FDA to set a national goal of reducing medically important antibiotic use in US livestock production by 50% by the end of 2023, relative to a 2009 baseline.

Wellington says another way for the FDA to cut antibiotic use significantly in food animals would be to impose duration limits on their use. He noted that roughly one third of all medically important antibiotics used in livestock have no duration limit, which means farmers can use those antibiotics indefinitely at sub-therapeutic doses.

The FDA said in its 5-year action plan (https://www.cidrap.umn.edu/news-perspective/2018/07/fda-previews-veterinary-stewardship-plan) , released in 2018, that establishing appropriate duration limits would be one of its priorities, but it has not yet addressed the issue.

"That's the first thing I'd want to see the FDA do, is actually deliver on that goal and set duration limits for all medically important antibiotics," Wellington said.

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2019

Summary Report

On

Antimicrobials Sold or Distributed for Use in Food-Producing Animals

December 2020

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Executive Summary

Each year, every sponsor of an approved or conditionally approved animal drug application containing an antimicrobial active ingredient must report to the Food and Drug Administration (FDA) the amount of each such ingredient in these drug products sold or distributed for use in food-producing animals. FDA summarizes this information and makes it available to the public in annual summary reports. This reporting requirement was enacted by Congress in 2008 to assist FDA in its continuing analysis of the interactions (including antimicrobial resistance), efficacy, and safety of antimicrobials approved for use in both humans and food-producing animals.

This summary report presents the sales and distribution data for actively marketed antimicrobial drugs approved for use in food-producing animals by drug class, medical importance,[1] route of administration, indication, and dispensing status, as well as species-specific estimates, of sales and distribution from 2010 through 2019.

Key observations from the report include:

- Domestic sales and distribution of medically important antimicrobials approved for use in food-producing animals (Table 2b):
    - increased by 3% from 2018 through 2019.
    - decreased by 36% from 2015 (the year of peak sales) through 2019.
    - decreased by 25% from 2010 through 2019.
    - Tetracyclines, which represent the largest volume of these domestic sales (4,117,031 kg in 2019), increased by 4% from 2018 through 2019.
- The domestic sales and distribution of medically important antimicrobials approved for use in food-producing animals for 2019 included:
    - An estimated 41% was intended for use in cattle, an estimated 42% intended for use in swine, an estimated 10% intended for use in turkeys, an estimated 3% intended for use in chickens, and an estimated 4% intended for use in other species/unknown (Table 4a).
    - Tetracyclines accounted for 67%, penicillins for 12%, macrolides for 8%, sulfas for 5%, aminoglycosides for 5%, lincosamides for 2%, cephalosporins for less than 1%, and fluoroquinolones for less than 1% (Table 2a).
    - An estimated 81% of cephalosporins, 65% of sulfas, 45% of aminoglycocides, and 42% of tetracyclines were intended for use in cattle. An estimated 85% of lincosamides and 40% of macrolides were intended for use in swine. An estimated 66% of penicillins were intended for use in turkeys (Table 5a).

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[1] "Medically important antimicrobials" are those antimicrobials that have been determined to be medically important to human medicine.

I. Background

Section 105 of the Animal Drug User Fee Amendments of 2008 (ADUFA) (P.L. 110-316; 122 Stat. 3509) amended section 512 of the Federal Food, Drug, and Cosmetic Act ("the Act") [21 U.S.C. 360b] to require that sponsors of approved and conditionally approved applications for new animal drugs containing an antimicrobial active ingredient submit an annual report to the Food and Drug Administration (FDA) on the amount of each such ingredient in the drug that is sold or distributed for use in food-producing animals, including information on any distributor-labeled product. This legislation was enacted to assist FDA in its continuing analysis of the interactions (including antimicrobial resistance), efficacy, and safety of antimicrobials approved for use in both humans and food-producing animals (see H. Rpt. 110-804).

On May 11, 2016, FDA issued a final rule codifying annual reporting requirements under section 105 of ADUFA and adding a new reporting provision to obtain estimates of sales by major food-producing species (the 2016 final rule). The 2016 final rule is available at https://www.gpo.gov/fdsys/pkg/FR-2016-05-11/pdf/2016-11082.pdf. Sponsors must comply with the reporting requirements in the final rule when submitting their reports covering the period of calendar year 2016 and thereafter. Under 21 CFR 514.87, each report submitted to the FDA must include the following information: (1) A listing of each antimicrobial active ingredient contained in the product; (2) A description of each product sold or distributed by unit, including the container size, strength, and dosage form of such product units; (3) For each such product, a listing of the target animal species, indications, and production classes that are specified on the approved label; (4) For each such product, the number of units sold or distributed in the United States (i.e., domestic sales) for each month of the reporting year; and (5) For each such product, the number of units sold or distributed outside the United States (i.e., quantities exported) for each month of the reporting year. Each report must also provide a species-specific estimate of the percentage of each product that was sold or distributed domestically in the reporting year for use in any of the following animal species categories, but only for such species that appear on the approved label: Cattle, swine, chickens, turkeys. The total of the species-specific percentages reported for each product must account for 100 percent of its sales and distribution; therefore, a fifth category of "other species/unknown" must also be reported. Each year's report must be submitted to FDA no later than March 31 using Form FDA 3744, "Antimicrobial Animal Drug Distribution Report," the use of which is now mandatory as per the final rule. The form is available at https://www.fda.gov/about-fda/reports-manuals-forms/forms. These reports are separate from periodic drug experience reports that are required under 21 CFR 514.80(b)(4).

Under section 512(l)(3)(E) of the Act [21 U.S.C. 360b(l)(3)(E)], as codified at 21 CFR 514.87(f), FDA is directed to make annual summaries of the information reported by animal drug sponsors for each calendar year publicly available by December 31 of the following year. These annual reports must include a summary of sales and distribution data and information by antimicrobial drug class and may include additional summary data and information as determined by FDA.

Scope of Reporting

This summary report includes sales and distribution data of all antimicrobial drugs that are specifically approved for antibacterial uses or are known to have antibacterial properties, consistent with the requirements of Section 105 of ADUFA. However, as described elsewhere in this report, FDA has identified certain antimicrobial active ingredients as "medically important" based on their utility for treating disease in humans. Certain other antimicrobial drugs are not considered medically important. Ionophores, for example, lack utility in human medicine and their use in animals, primarily as coccidiostats, does not pose cross-resistance concerns; thus, they do not have the same human health risks as medically important antimicrobials.

Antifungal and antiviral drugs are not included in this report because, with the exception of formalin and hydrogen peroxide water immersion products, there are currently no approved drug applications actively marketed for these purposes in food-producing animals. Antiprotozoal drugs without antibacterial properties (e.g., amprolium) are also not included.

Many antimicrobial animal drugs are approved and labeled for use in multiple species. Under section 512(l)(3)(B)(iii) of the Act [21 U.S.C. 360b(l)(3)(B)(iii)], each report submitted to the FDA must specify "a listing of the target animals… that are specified on the approved label of the product." As stated above, the 2016 final rule includes an additional reporting requirement for species-specific sales estimates as a percentage of total domestic sales and distribution for each product, starting with calendar year 2016; therefore, this summary report includes summaries of sales and distribution estimates by certain major food-producing animal species – cattle, swine, chickens, and turkeys – but only if the species appears on the approved label for the product reported.

The total of the estimated species-specific percentages reported for each product must account for 100 percent of its sales and distribution; therefore, a fifth category of "Other Species/Unknown" must also be reported. The fifth category includes a single combined estimate of product sales and distribution for (1) other species listed on the approved label, including nonfood-producing animal species (e.g., dogs and horses) and minor food-producing species (e.g., fish and quail); (2) other species not listed on the approved label; and (3) unknown uses. For hypothetical scenarios that illustrate reporting of species-specific estimates, see the proposed rule published in the Federal Register of May 20, 2015 (80 FR 28863 at 28866).

Protecting Confidential Information

This report is designed to provide useful information to the public while, at the same time, meeting the requirement of section 512(l)(3)(E) of the Act [21 U.S.C. 360b(l)(3)(E)] to report summary data in a manner consistent with protecting both national security and confidential business information. In accordance with statutory requirements designed to protect confidential business information, and under 21 CFR 514.87(f), annual sales and distribution data are summarized by antimicrobial drug class, and only those antimicrobial drug classes and other categories with three or more distinct sponsors of approved and actively marketed animal drug products are independently reported. Antimicrobial drug classes with fewer than three distinct sponsors are reported collectively as "Not Independently Reported" (NIR).

The number of distinct sponsors in a particular antimicrobial class or other category is determined by two criteria: (1) the sponsor must be named in 21 CFR 510.600 as the holder of an approved application for an animal drug product in that particular class or category on the last day of the annual reporting period; and (2) the sponsor must have actively sold or distributed such animal drug product at some point during that annual reporting period. This same principle is utilized with the representation of any category included in this report. For example, for presentation of species-specific sales and distribution estimates, species categories (e.g., cattle) with fewer than three distinct sponsors are combined with the "Other Species/Unknown" category and reported collectively as "Not Independently Reported" (NIR).

Occasionally instances arise in which two or more individual pieces of summary data, when viewed together, can be utilized to derive other data that would reveal confidential business information (sometimes referred to as "the mosaic effect"). FDA believes the broad requirement to protect confidential business information means that we cannot independently report summary data that can be used together with summary data presented elsewhere in the report or data already in the public domain to indirectly derive confidential business information. In these instances, to protect the confidential business information that could be revealed by including such summary data, these categories will be reported collectively as “Other.”

Use of the Summary Information

The totals in this summary report represent sales and distribution data for antimicrobial drugs approved for use in food-producing animals. However, in reviewing this report it is important to keep in mind that there are certain inherent limitations on how the data provided in this report may appropriately be interpreted and used. For example, the sales and distribution data submitted by animal drug sponsors and summarized in this report are not indicative of how these antimicrobial drugs were actually used in animals (e.g., for what indications). With the exception of medicated feeds and certain drugs that are specifically prohibited from extralabel use (listed in FDA’s regulations at 21 CFR 530.41), veterinarians can legally use approved animal drugs for species and therapeutic indications for which the drugs were not approved. Further, because the majority of antimicrobial drugs used in animal feed are approved for multiple indications, simply knowing that the route of administration for a drug is, for example, by oral means through animal feed cannot, by itself, be used to determine the indication for which the drug was used.

As discussed in **Description of Tables and Figures**, some of the antimicrobials included in this summary report are approved for use in both food- and nonfood-producing animals. In addition many of the applications are approved and labeled for use in multiple species, for multiple indications, and with multiple dosage regimens. These points should be carefully considered when interpreting or comparing the data presented in this summary report.

It is also important to note that animal drug sales data represent a summary of the volume of product sold or distributed through various outlets by the manufacturer intended for sale to the end user, not the volume of product ultimately purchased by the end user for administration to animals. For example, veterinarians and animal producers may purchase drugs, but never actually administer them to animals, or they may administer the drugs in later years.

Regarding the collection and reporting of species-specific data, the percentages provided by the sponsors are estimates of product sales and distribution. The data are not intended to be a substitute for actual usage data and should be used in conjunction with on-farm species-specific data on antimicrobial use. Also, there is a variety of factors that confound direct comparison of species-specific sales estimates, including differences in population size, weight, lifespan, and drug metabolism. For these reasons, caution should be applied when making direct comparisons between species-specific sales estimates.

Additionally, it should be noted that the potency of specific antimicrobials can vary substantially, which may impact the volume of drug needed to complete a course of therapy. This factor should be considered when comparing sales data for different antimicrobials.

Comparison of the information in this summary report with information published elsewhere regarding sales and distribution of antimicrobial drugs for use in humans poses many challenges. A number of differences in the circumstances in which antimicrobial drugs are used in human and veterinary medicine must be carefully considered, including:

- The number of humans in the U.S. population (approx. 328 million[2]) compared to the much larger number of animals in each of the many animal species (e.g., approx. 9.3 billion chickens slaughtered annually[3]).
- The differences in physical characteristics of humans compared to various animal species (e.g., physiology and weight: average adult human weight, 184 lb.[4] versus adult cattle live weight, 1,347 lb.[5]).
- Duration and dosage of antibacterial drug administration may also vary by indication and, in general, between the various animal species and humans due to differences in physiology.
- As noted above, the available animal sales and distribution data are not reported to the FDA by each use indication and, thus, do not allow the FDA to distinguish between or among the different types of uses. The data, therefore, do not allow a direct comparison of the amounts of antimicrobials sold for certain animal uses with those sold for certain human uses.
- Veterinarians commonly utilize human antimicrobial drugs in their companion animal patients; therefore, amounts presented for certain human antimicrobial drugs may represent some unknown portion sold for use in companion animals.

It is, therefore, difficult to draw conclusions from any direct comparisons between the quantity of antimicrobial drugs sold for use in humans and the animal drug sales and distribution data (and species-specific estimates) for use in animals.

Description of Tables and Figures

The information presented in the following tables is based on 2019 annual sales and distribution data. Please note that the number of marketed products and associated sponsors may vary from year to year; thus, the categories presented in the tables may also vary from year to year to meet the requirements for protecting confidential business information. Any yearly variations in categories presented may make it difficult to directly compare certain tabular data between reported years. Furthermore, FDA occasionally receives updates or corrections to previously submitted 512(l)(3) data from animal drug sponsors at various times after the March 31 deadline. Therefore, minor variations in tabular data may occur over time depending on when these summary data are generated. The data included in the 2019 annual summary report differ in some cases from previously published reports. These differences may be attributed to updated sales and distribution information provided by sponsors for previous reporting years. Percent total, percent grand total, and percent change columns in the tables may sum to more than one hundred percent due to the rounding of kilogram totals. In general, the tables are formatted so that Table Xa corresponds to current-year data and Table Xb corresponds to multi-year trends, and that Figure Xa or Xb is associated with the corresponding Table Xa or Xb. Please note that the data for the multi-year trends is limited to ten years (2010 through 2019) for reasons of data representation, and which is adequate for time trend evaluation. For data before 2010, please refer to previously published reports.

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[2] U.S. Census Bureau, "Quick Facts: United States," available at https://www.census.gov/quickfacts/fact/table/US/PST045216.

[3] U.S. Department of Agriculture, National Agricultural Statistics Service, "Poultry Slaughter: 2019 Summary," February 2020, available at https://www.nass.usda.gov/Publications/Todays_Reports/reports/pslaan20.pdf.

[4] U.S. Centers for Disease Control and Prevention, National Center for Health Statistics, "Body Measurements," available at https://www.cdc.gov/nchs/fastats/body-measurements.htm.

[5] U.S. Department of Agriculture, National Agricultural Statistics Service, "Livestock Slaughter: 2019 Summary," April 2019, available at https://downloads.usda.library.cornell.edu/usda-esmis/files/r207tp32d/34850245n/5712mr72x/lsan0420.pdf.

II. Data on all marketed antimicrobial drug

Table 1

Antimicrobial drug classes and active ingredients approved for use in food-producing animals[1]
Actively marketed in 2019

Aminocoumarins (NMI)[2]
Novobiocin

Aminoglycosides (MI)[3]
Dihydrostreptomycin
Gentamicin
Neomycin
Spectinomycin

Amphenicols (MI)[3]
Florfenicol

Cephalosporins (MI)[3]
Ceftiofur
Cephapirin

Diaminopyrimidines (MI)[3]
Ormetoprim

Fluoroquinolones (MI)[3]
Danofloxacin
Enrofloxacin

Glycolipids (NMI)[2]
Bambermycins

Ionophores (NMI)[2]
Laidlomycin
Lasalocid
Monensin
Narasin
Salinomycin

Lincosamides (MI)[3]
Lincomycin[1]
Pirlimycin

Macrolides (MI)[3]
Gamithromycin
Tildipirosin
Tilmicosin
Tulathromycin
Tylosin
Tylvalosin

Orthosomycins (NMI)[2]
Avilamycin

Penicillins (MI)[3]
Amoxicillin
Ampicillin[1]
Cloxacillin
Penicillin[1]

Pleuromutilins (NMI)[2]
Tiamulin

Polymyxins (MI)[3]
Polymyxin B[1]

Polypeptides (NMI)[2]
Bacitracin

Quinoxalines (NMI)[2]
Carbadox

Streptogramins (MI)[3]
Virginiamycin

Sulfonamides (Sulfas) (MI)[3]
Sulfadimethoxine
Sulfamethazine
Sulfaquinoxaline

Tetracyclines (MI)[3]
Chlortetracycline[1]
Oxytetracycline[1]
Tetracycline

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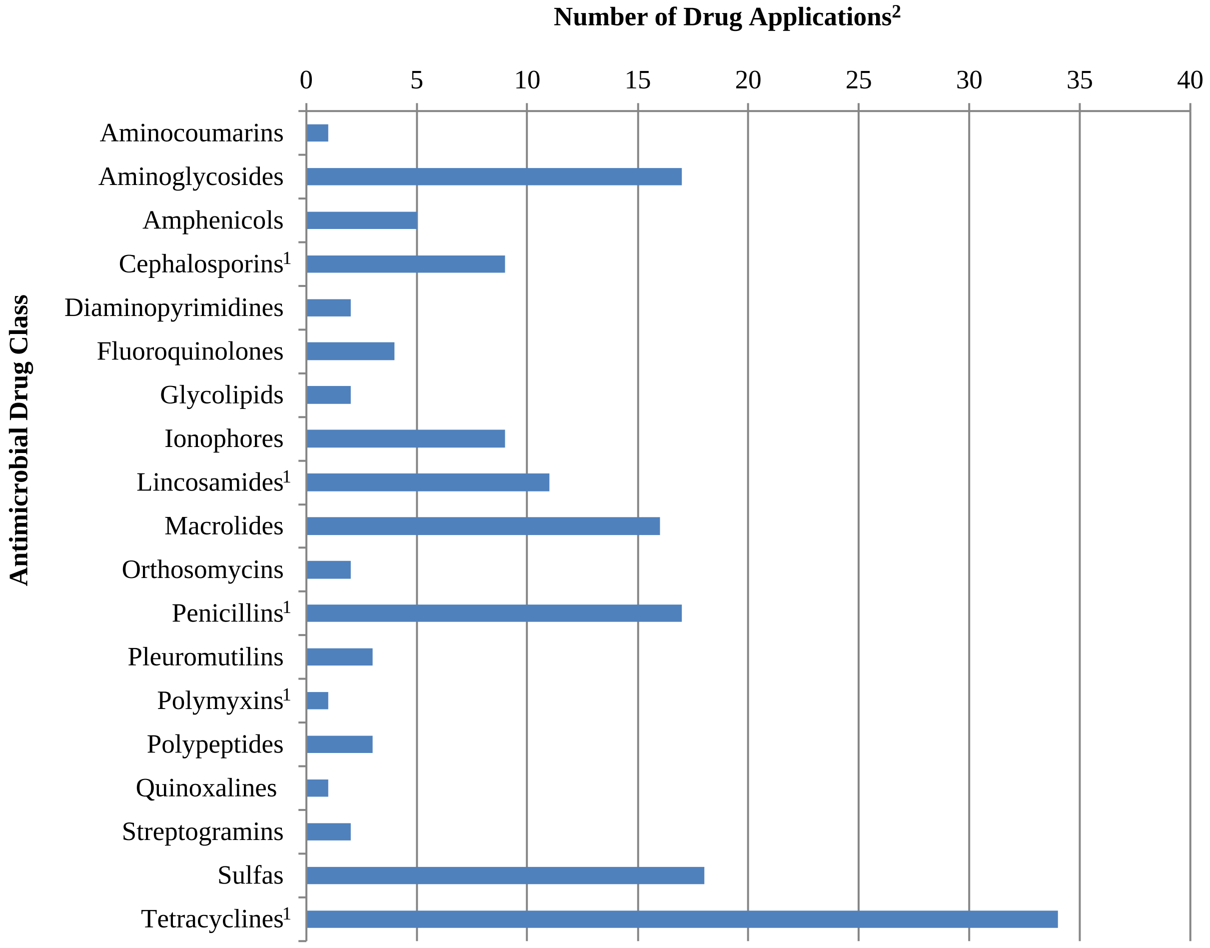
[1] Includes antimicrobial drug applications that are approved and labeled for use in both food-producing animals (e.g., cattle and swine) and nonfood-producing animals (e.g., dogs and horses).

[2] NMI = Not Medically Important. Refers to any antimicrobial class not listed in Appendix A of FDA's Guidance for Industry #152.

[3] MI = Medically Important. Guidance for Industry #213 states that all antimicrobial drugs and their associated classes listed in Appendix A of FDA's Guidance for Industry #152 are considered "medically important" in human medical therapy.

Figure 1a

Antimicrobial drug classes approved for use in food-producing animals[1]
Actively marketed in 2019
Domestic sales and distribution data
Number of drug applications[2]



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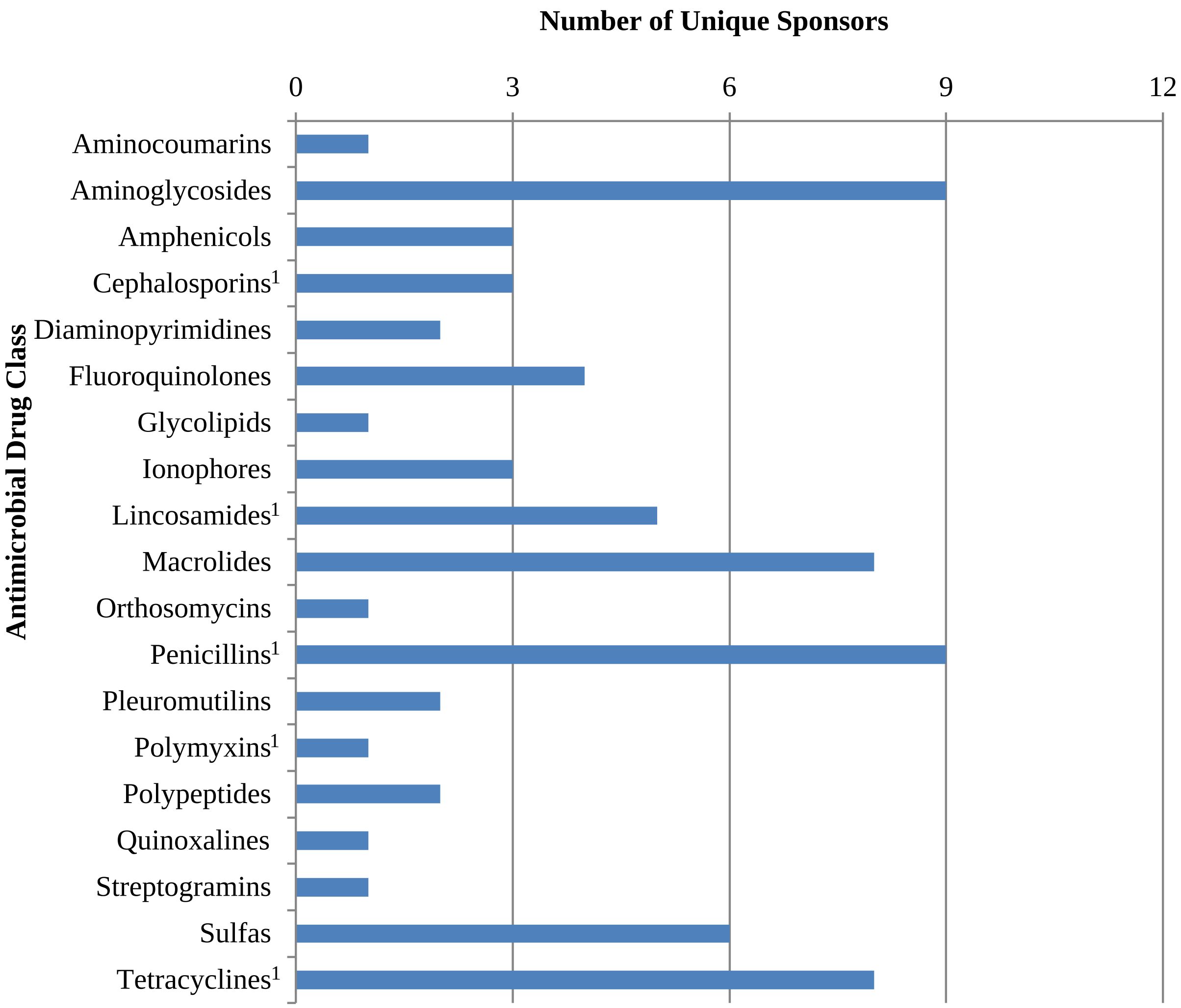
[1] Includes antimicrobial drug applications that are approved and labeled for use in both food-producing animals (e.g., cattle and swine) and nonfood-producing animals (e.g., dogs and horses).

[2] Some drug applications contain multiple active ingredients; therefore, drug applications containing more than one antimicrobial active ingredient may be represented more than once.

Figure 1b

Antimicrobial drug classes approved for use in food-producing animals[1]
Actively marketed in 2019
Domestic sales and distribution data
Number of unique sponsors



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[1] Includes antimicrobial drug applications that are approved and labeled for use in both food-producing animals (e.g., cattle and swine) and nonfood-producing animals (e.g., dogs and horses).

Table 2a

Antimicrobial drugs approved for use in food-producing animals[1]
Actively marketed in 2019
Domestic sales and distribution data
Reported by medical importance and drug class

	Drug Class	Annual Totals (kg)[2]	% Subtotal	% Grand Total
Medically Important[3]	*Aminoglycosides*	307,988	5%	3%
	Amphenicols	53,212	1%	<1%
	Cephalosporins[1]	29,830	<1%	<1%
	Fluoroquinolones	24,556	<1%	<1%
	Lincosamides[1]	134,962	2%	1%
	Macrolides	488,082	8%	4%
	Penicillins[1]	716,525	12%	6%
	Sulfas	304,327	5%	3%
	Tetracyclines[1]	4,117,031	67%	36%
	NIR[1,4]	12,746	<1%	<1%
	Subtotal	***6,189,260***	***100%***	***54%***
Not Medically Important[5]	*Ionophores*	4,270,122	81%	37%
	NIR[6]	1,008,976	19%	9%
	Subtotal	***5,279,098***	***100%***	***46%***
	Grand Total	***11,468,357***		***100%***

[1] Includes antimicrobial drug applications that are approved and labeled for use in both food-producing animals (e.g., cattle and swine) and nonfood-producing animals (e.g., dogs and horses).

[2] kg = kilogram of active ingredient. Antimicrobial class includes drugs of different molecular weights, with some drugs labeled in different salt forms. Antimicrobials that are labeled in International Units (IU) (e.g., Penicillins) were converted to kg.

[3] Guidance for Industry #213 states that all antimicrobial drugs and their associated classes listed in Appendix A of FDA's Guidance for Industry #152 are considered "medically important" in human medical therapy.

[4] NIR = Not Independently Reported. Antimicrobial classes for which there were fewer than three distinct sponsors actively marketing products domestically are not independently reported. These classes include the following: Diaminopyrimidines, Polymyxins, and Streptogramins.

[5] Not Medically Important refers to any antimicrobial class not listed in Appendix A of FDA's Guidance for Industry #152.

[6] NIR = Not Independently Reported. Antimicrobial classes for which there were fewer than three distinct sponsors are not independently reported. These classes include the following: Aminocoumarins, Glycolipids, Orthosomycins, Pleuromutilins, Polypeptides, and Quinoxalines.

Table 2b

Antimicrobial drugs approved for use in food-producing animals[1]
Actively marketed 2010-2019
Domestic sales and distribution data
Reported by medical importance and drug class

	Drug Class	2010 Annual Totals (kg)[2]	2011 Annual Totals (kg)[2]	2012 Annual Totals (kg)[2]	2013 Annual Totals (kg)[2]	2014 Annual Totals (kg)[2]	2015 Annual Totals (kg)[2]	2016 Annual Totals (kg)[2]	2017 Annual Totals (kg)[2]	2018 Annual Totals (kg)[2]	2019 Annual Totals (kg)[2]	% Change 2010 - 2019	% Change 2018 - 2019
Medically Important[3]	*Aminoglycosides*[1]	211,790	214,895	277,854	267,734	304,160	344,120	319,009	259,184	289,455	307,988	45%	6%
	Cephalosporins[1]	24,588	26,611	27,654	28,337	31,722	32,254	31,010	29,369	31,448	29,830	21%	-5%
	Fluoroquinolones	*	*	*	15,099	17,220	20,063	18,502	22,904	23,350	24,556	**	5%
	Lincosamides[1]	154,653	190,101	218,140	236,450	233,681	182,543	142,458	152,497	125,514	134,962	-13%	8%
	Macrolides[1]	553,229	582,836	616,274	563,251	621,769	627,757	554,714	468,794	473,038	488,082	-12%	3%
	Penicillins[1]	884,419	885,304	965,196	828,721	885,975	936,669	842,863	690,889	731,863	716,525	-19%	-2%
	Sulfas[1]	517,128	383,105	493,514	383,469	452,224	380,186	369,826	274,112	278,562	304,327	-41%	9%
	Tetracyclines[1]	5,602,281	5,652,855	5,954,361	6,514,779	6,604,199	6,881,530	5,861,188	3,535,701	3,974,179	4,117,031	-27%	4%
	NIR[1,4]	281,221	319,991	344,428	355,452	328,389	297,822	216,771	125,761	104,888	65,958	-77%	-37%
	Subtotal	***8,239,309***	***8,255,697***	***8,897,420***	***9,193,293***	***9,479,339***	***9,702,943***	***8,356,340***	***5,559,212***	***6,032,298***	***6,189,260***	-25%	***3%***
Not Medically Important[5]	*Ionophores*	3,820,004	4,122,397	4,573,795	4,434,657	4,718,650	4,740,615	4,651,491	4,394,850	4,562,260	4,270,122	12%	-6%
	NIR[6]	1,237,784	1,190,943	1,151,532	1,157,095	1,163,571	1,134,382	1,018,305	979,306	968,524	1,008,976	-18%	4%
	Subtotal	***5,057,788***	***5,313,340***	***5,725,327***	***5,591,752***	***5,882,221***	***5,874,997***	***5,669,796***	***5,374,156***	***5,530,784***	***5,279,098***	4%	***-5%***
	Grand Total	***13,287,097***	***13,569,037***	***14,622,747***	***14,785,045***	***15,361,560***	***15,577,940***	***14,026,136***	***10,933,367***	***11,563,081***	***11,468,357***	-14%	***-1%***

[1] Includes antimicrobial drug applications that are approved and labeled for use in both food-producing animals (e.g., cattle and swine) and nonfood-producing animals (e.g., dogs and horses).

[2] kg = kilogram of active ingredient. Antimicrobial class includes drugs of different molecular weights, with some drugs labeled in different salt forms. Antimicrobials that are labeled in International Units (IU) (e.g., Penicillins) were converted to kg.

[*] Not reported because there were fewer than three distinct sponsors actively marketing products domestically in 2009 through 2012.

[**] There were fewer than three distinct sponsors actively marketing products domestically in 2009 through 2012. Therefore, percentage change cannot be calculated.

[3] Guidance for Industry #213 states that all antimicrobial drugs and their associated classes listed in Appendix A of FDA's Guidance for Industry #152 are considered "medically important" in human medical therapy.

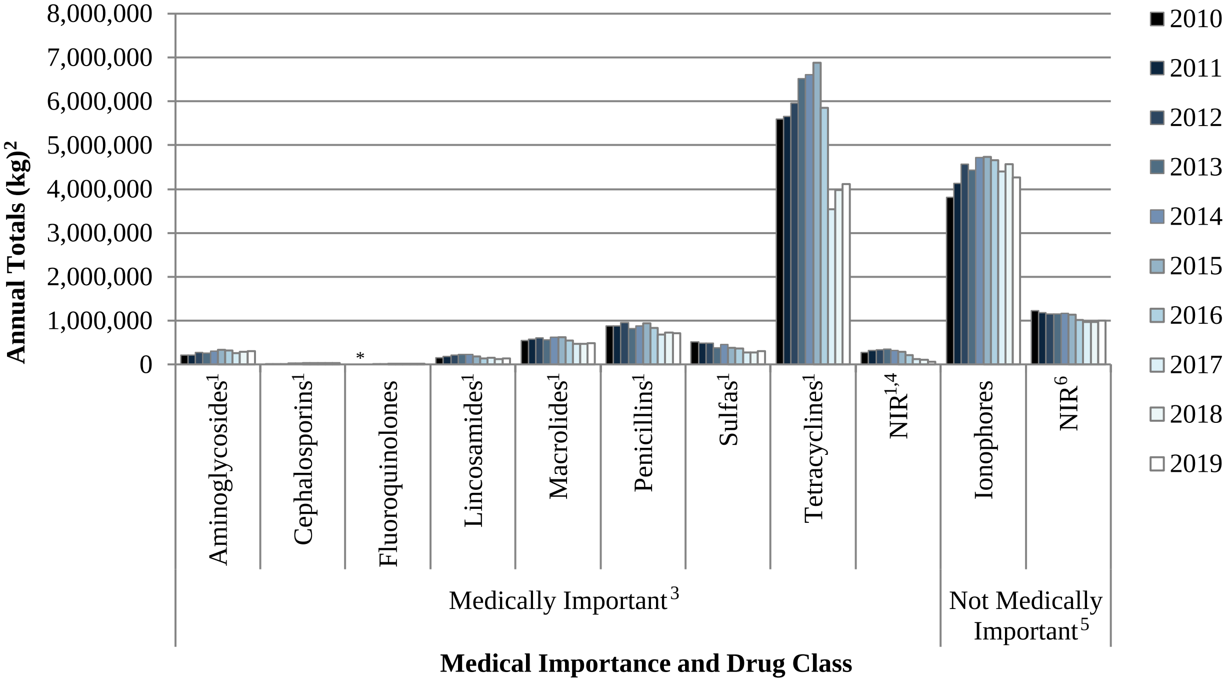
[4] NIR = Not Independently Reported. Antimicrobial classes for which there were fewer than three distinct sponsors actively marketing products domestically are not independently reported. These classes include the following: Amphenicols, Diaminopyrimidines, Fluoroquinolones (excluding 2013 through 2019), Polymyxins (excluding 2012 and 2013), and Streptogramins.

[5] Not Medically Important refers to any antimicrobial class not listed in Appendix A of FDA's Guidance for Industry #152.

[6] NIR = Not Independently Reported. Antimicrobial classes for which there were fewer than three distinct sponsors are not independently reported. These classes include the following: Aminocoumarins, Glycolipids, Orthosomycins (excluding 2010 through 2015), Pleuromutilins, Polypeptides, and Quinoxalines.

Figure 2b

Antimicrobial drugs approved for use in food-producing animals[1]
Actively marketed 2010-2019
Domestic sales and distribution data
Reported by medical importance and drug class



[1] Includes antimicrobial drug applications that are approved and labeled for use in both food-producing animals (e.g., cattle and swine) and nonfood-producing animals (e.g., dogs and horses).

[2] kg = kilogram of active ingredient. Antimicrobial class includes drugs of different molecular weights, with some drugs labeled in different salt forms. Antimicrobials that are labeled in International Units (IU) (e.g., Penicillins) were converted to kg.

[*] Not reported because there were fewer than three distinct sponsors actively marketing products domestically in 2009 through 2012.

[3] Guidance for Industry #213 states that all antimicrobial drugs and their associated classes listed in Appendix A of FDA's Guidance for Industry #152 are considered "medically important" in human medical therapy.

[4] NIR = Not Independently Reported. Antimicrobial classes for which there were fewer than three distinct sponsors actively marketing products domestically are not independently reported. These classes include the following: Amphenicols, Diaminopyrimidines, Fluoroquinolones (excluding 2013 through 2019), Polymyxins (excluding 2012 and 2013), and Streptogramins.

[5] Not Medically Important refers to any antimicrobial class not listed in Appendix A of FDA's Guidance for Industry #152.

[6] NIR = Not Independently Reported. Antimicrobial classes for which there were fewer than three distinct sponsors are not independently reported. These classes include the following: Aminocoumarins, Glycolipids, Orthosomycins (excluding 2010 through 2015), Pleuromutilins, Polypeptides, and Quinoxalines.

Table 3a

Antimicrobial drugs approved for use in food-producing animals[1]
Actively marketed in 2019
Domestic/export sales and distribution data

Domestic/Export	Annual Totals (kg)[2]	% Total
Domestic[1]	11,468,357	100%
Export[1,3]	5,355	<1%
Total	***11,473,712***	***100%***

[1] Includes antimicrobial drug applications that are approved and labeled for use in both food-producing animals (e.g., cattle and swine) and nonfood-producing animals (e.g., dogs and horses).

[2] kg = kilogram of active ingredient. Antimicrobial class includes drugs of different molecular weights, with some drugs labeled in different salt forms. Antimicrobials that are labeled in International Units (IU) (e.g., Penicillins) were converted to kg.

[3] Only includes exports of FDA-approved, US-labeled antimicrobial drugs approved for use in food-producing animals.

Table 3b

Antimicrobial drugs approved for use in food-producing animals[1]
Actively marketed in 2010-2019
Domestic/export sales and distribution data

Domestic/Export	2010 Estimated Annual Totals (kg)[2]	2011 Estimated Annual Totals (kg)[2]	2012 Estimated Annual Totals (kg)[2]	2013 Estimated Annual Totals (kg)[2]	2014 Estimated Annual Totals (kg)[2]	2015 Estimated Annual Totals (kg)[2]	2016 Estimated Annual Totals (kg)[2]	2017 Estimated Annual Totals (kg)[2]	2018 Estimated Annual Totals (kg)[2]	2019 Estimated Annual Totals (kg)[2]	% Change 2010 - 2019	% Change 2018 - 2019
Domestic[1]	13,287,097	13,569,037	14,622,747	14,785,045	15,361,560	15,577,940	14,026,136	10,933,367	11,563,081	11,468,357	-14%	-1%
Export[1,3]	219,072	202,335	139,173	74,374	30,682	20,861	6,818	10,038	8,134	5,355	-98%	-34%
Total	***13,506,168***	***13,771,373***	***14,761,919***	***14,859,419***	***15,392,242***	***15,598,801***	***14,032,953***	***10,943,406***	***11,571,216***	***11,473,712***	***-15%***	***-1%***

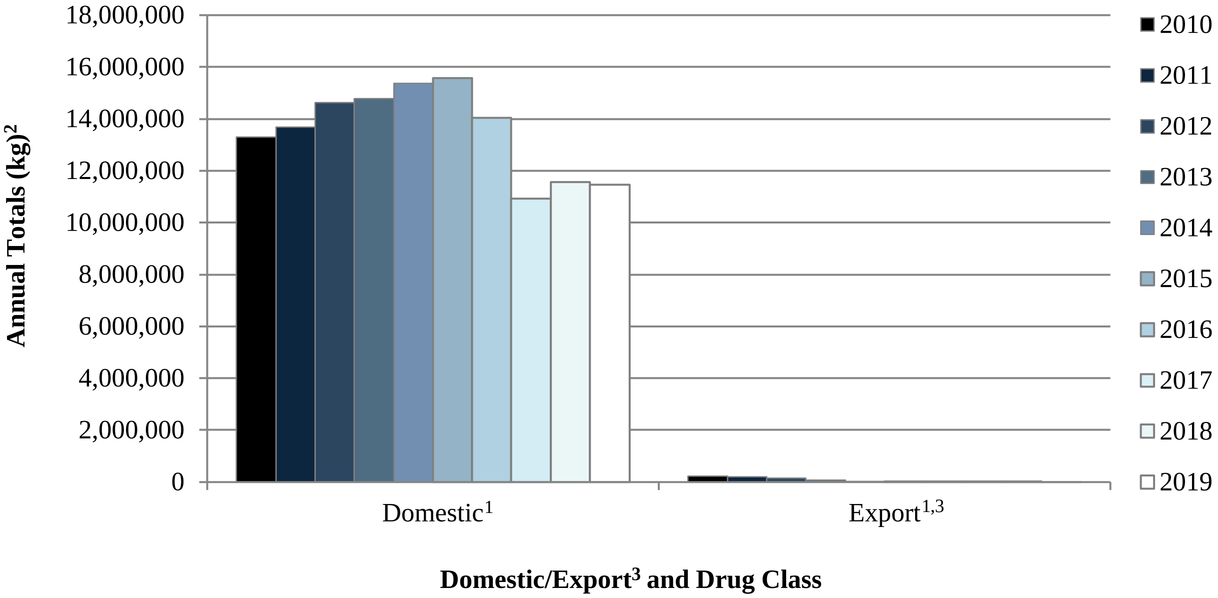
[1] Includes antimicrobial drug applications that are approved and labeled for use in both food-producing animals (e.g., cattle and swine) and nonfood-producing animals (e.g., dogs and horses).

[2] kg = kilogram of active ingredient. Antimicrobial class includes drugs of different molecular weights, with some drugs labeled in different salt forms. Antimicrobials that are labeled in International Units (IU) (e.g., Penicillins) were converted to kg.

[3] Only includes exports of FDA-approved, US-labeled antimicrobial drugs approved for use in food-producing animals.

Figure 3b

Antimicrobial drugs approved for use in food-producing animals[1]
Actively marketed 2010-2019
Domestic/export sales and distribution data



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[1] Includes antimicrobial drug applications that are approved and labeled for use in both food-producing animals (e.g., cattle and swine) and nonfood-producing animals (e.g., dogs and horses).

[2] kg = kilogram of active ingredient. Antimicrobial class includes drugs of different molecular weights, with some drugs labeled in different salt forms. Antimicrobials that are labeled in International Units (IU) (e.g., Penicillins) were converted to kg.

[3] Only includes exports of FDA-approved, US-labeled antimicrobial drugs approved for use in food-producing animals.

III. Data on medically important antimicrobial drugs

Table 4a

Medically important[1] antimicrobial drugs approved for use in food-producing animals[2]
Actively marketed in 2019
Domestic sales and distribution data
Reported by species-specific estimated sales

Species	Estimated Annual Totals (kg)[3]	% Total
Cattle	2,529,281	41%
Swine	2,582,399	42%
Chicken	192,964	3%
Turkey	644,921	10%
Other[4]	239,694	4%
Total	***6,189,260***	***100%***

[1] Guidance for Industry #213 states that all antimicrobial drugs and their associated classes listed in Appendix A of FDA's Guidance for Industry #152 are considered "medically important" in human medical therapy.

[2] Includes antimicrobial drug applications that are approved and labeled for use in both food-producing animals (e.g., cattle and swine) and nonfood-producing animals (e.g., dogs and horses).

[3] kg = kilogram of active ingredient. Antimicrobial class includes drugs of different molecular weights, with some drugs labeled in different salt forms. Antimicrobials that are labeled in International Units (IU) (e.g., Penicillins) were converted to kg.

[4] The Other category includes estimates of product sales intended for use in (1) species listed on the approved label other than cattle, swine, chickens, and turkeys, including nonfood-producing animal species (e.g., dogs and horses) and minor food-producing species (e.g., fish); (2) other species not listed on the approved label; and (3) unknown uses.

Table 4b

Medically important[1] antimicrobial drugs approved for use in food-producing animals[2]
Actively marketed in 2016-2019
Domestic sales and distribution data
Reported by species-specific estimated sales

Species	2016 Estimated Annual Totals (kg)[3]	2017 Estimated Annual Totals (kg)[3]	2018 Estimated Annual Totals (kg)[3]	2019 Estimated Annual Totals (kg)[3]	% Change 2016 - 2019	% Change 2018 - 2019
Cattle	3,605,543	2,333,839	2,517,386	2,529,281	-30%	<1%
Swine	3,133,262	2,022,932	2,374,277	2,582,399	-18%	9%
Chicken	508,800	268,047	221,774	192,964	-62%	-13%
Turkey	756,620	670,831	671,108	644,921	-15%	-4%
Other[4]	352,114	263,564	247,753	239,694	-32%	-3%
Total	***8,356,340***	***5,559,212***	***6,032,298***	***6,189,260***	***-26%***	***3%***

[1] Guidance for Industry #213 states that all antimicrobial drugs and their associated classes listed in Appendix A of FDA's Guidance for Industry #152 are considered "medically important" in human medical therapy.

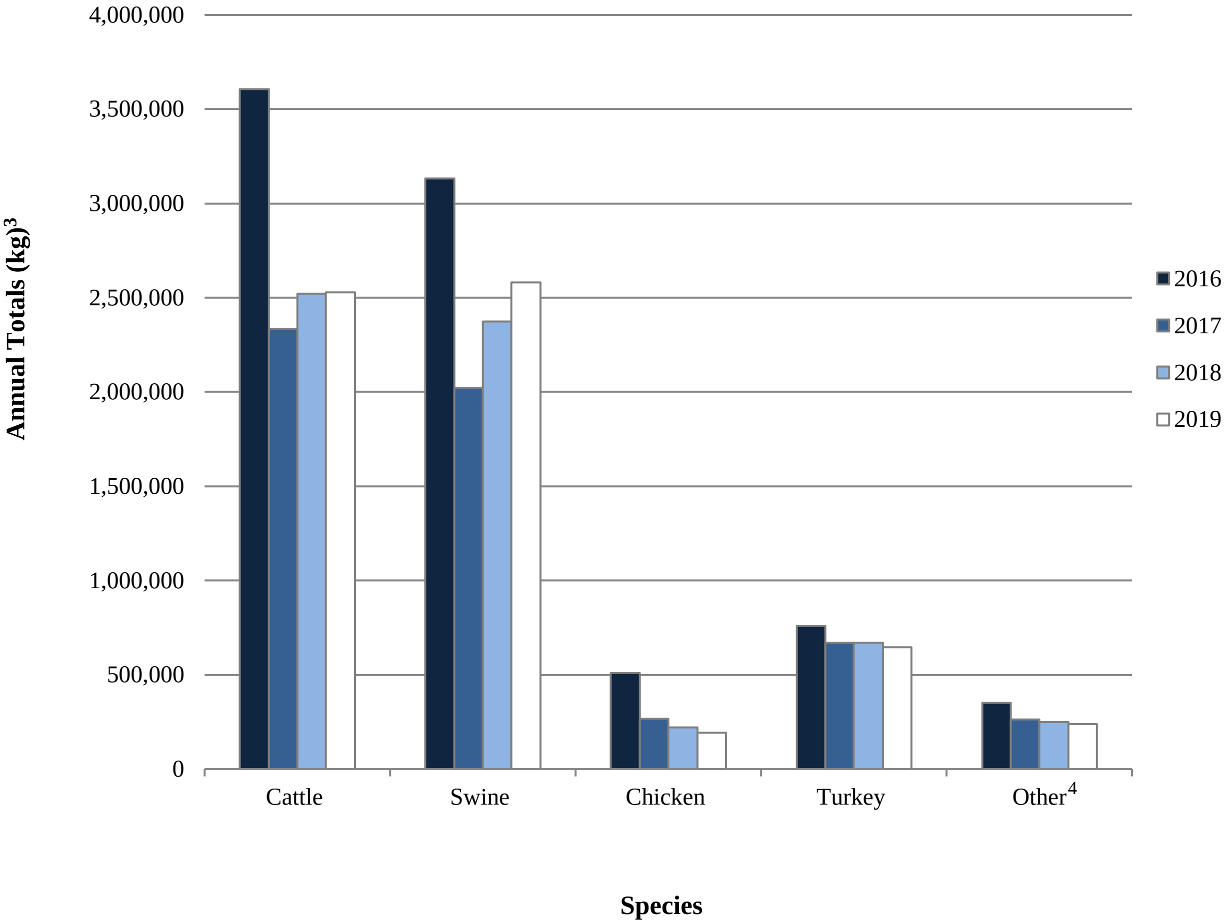
[2] Includes antimicrobial drug applications that are approved and labeled for use in both food-producing animals (e.g., cattle and swine) and nonfood-producing animals (e.g., dogs and horses).

[3] kg = kilogram of active ingredient. Antimicrobial class includes drugs of different molecular weights, with some drugs labeled in different salt forms. Antimicrobials that are labeled in International Units (IU) (e.g., Penicillins) were converted to kg.

[4] The Other category includes estimates of product sales intended for use in (1) species listed on the approved label other than cattle, swine, chickens, and turkeys, including nonfood-producing animal species (e.g., dogs and horses) and minor food-producing species (e.g., fish); (2) other species not listed on the approved label; and (3) unknown uses.

Figure 4b

Medically important[1] antimicrobial drugs approved for use in food-producing animals[2]
Actively marketed in 2016-2019
Domestic sales and distribution data
Reported by species-specific estimated sales



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[1] Guidance for Industry #213 states that all antimicrobial drugs and their associated classes listed in Appendix A of FDA's Guidance for Industry #152 are considered "medically important" in human medical therapy.

[2] Includes antimicrobial drug applications that are approved and labeled for use in both food-producing animals (e.g., cattle and swine) and nonfood-producing animals (e.g., dogs and horses).

[3] kg = kilogram of active ingredient. Antimicrobial class includes drugs of different molecular weights, with some drugs labeled in different salt forms. Antimicrobials that are labeled in International Units (IU) (e.g., Penicillins) were converted to kg.

[4] The Other category includes estimates of product sales intended for use in (1) species listed on the approved label other than cattle, swine, chickens, and turkeys, including nonfood-producing animal species (e.g., dogs and horses) and minor food-producing species (e.g., fish); (2) other species not listed on the approved label; and (3) unknown uses.

Table 5a

Medically important[1] antimicrobial drugs approved for use in food-producing animals[2]
Actively marketed in 2019
Domestic sales and distribution data
Reported by drug class and species-specific estimated sales

Ingredient Class	Species	Estimated Annual Totals (kg)[3]	% Subtotal
Aminoglycosides	*Cattle*	139,445	45%
	Swine	101,270	33%
	Chicken	16,200	5%
	Turkey	25,125	8%
	Other[4]	25,949	8%
	Subtotal	***307,988***	***100%***
Amphenicols	*All Species*[5]	53,212	100%
	Subtotal	***53,212***	***100%***
Cephalosporins[2]	*Cattle*	24,158	81%
	NIR[6]	5,672	19%
	Subtotal	***29,830***	***100%***
Fluoroquinolones	*Cattle*	12,560	51%
	Swine	11,790	48%
	Other[4]	205	1%
	Subtotal	***24,556***	***100%***
Lincosamides[2]	*Swine*	114,398	85%
	Chicken	6,409	5%
	NIR[7]	14,156	10%
	Subtotal	***134,962***	***100%***
Macrolides	*Cattle*	286,438	59%
	Swine	195,441	40%
	Chicken	2,760	1%
	Turkey	1,944	<1%
	Other[4]	1,498	<1%
	Subtotal	***488,082***	***100%***
Penicillins[2]	*Cattle*	78,887	11%
	Turkey	471,660	66%
	NIR[8]	165,978	23%
	Subtotal	***716,525***	***100%***
Sulfas	*Cattle*	197,486	65%
	Swine	72,126	24%
	Chicken	5,903	2%
	Turkey	14,908	5%
	Other[4]	13,905	5%
	Subtotal	***304,327***	***100%***
Tetracyclines[2]	*Cattle*	1,741,883	42%
	Swine	2,062,275	50%
	Chicken	149,295	4%
	Turkey	131,034	3%
	Other[4]	32,545	1%
	Subtotal	***4,117,031***	***100%***
NIR[2,9]	*All Species*[10]	12,746	100%
	Subtotal	***12,746***	***100%***

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[1] Guidance for Industry #213 states that all antimicrobial drugs and their associated classes listed in Appendix A of FDA's Guidance for Industry #152 are considered "medically important" in human medical therapy.

[2] Includes antimicrobial drug applications that are approved and labeled for use in both food-producing animals (e.g., cattle and swine) and nonfood-producing animals (e.g., dogs and horses).

[3] kg = kilogram of active ingredient. Antimicrobial class includes drugs of different molecular weights, with some drugs labeled in different salt forms. Antimicrobials that are labeled in International Units (IU) (e.g., Penicillins) were converted to kg.

[4] The Other category includes estimates of product sales intended for use in (1) species listed on the approved label other than cattle, swine, chickens, and turkeys, including nonfood-producing animal species (e.g., dogs and horses) and minor food-producing species (e.g., fish); (2) other species not listed on the approved label; and (3) unknown uses.

[5] This category includes the following: Cattle, Swine, and Other.

[6] NIR = Not Independently Reported. Species-specific sales estimates for which there were fewer than three distinct sponsors are not independently reported. This category includes the following: Swine, Chicken, and Other.

[7] NIR = Not Independently Reported. Species-specific sales estimates for which there were fewer than three distinct sponsors are not independently reported. This category includes the following: Cattle, Turkey, and Other.

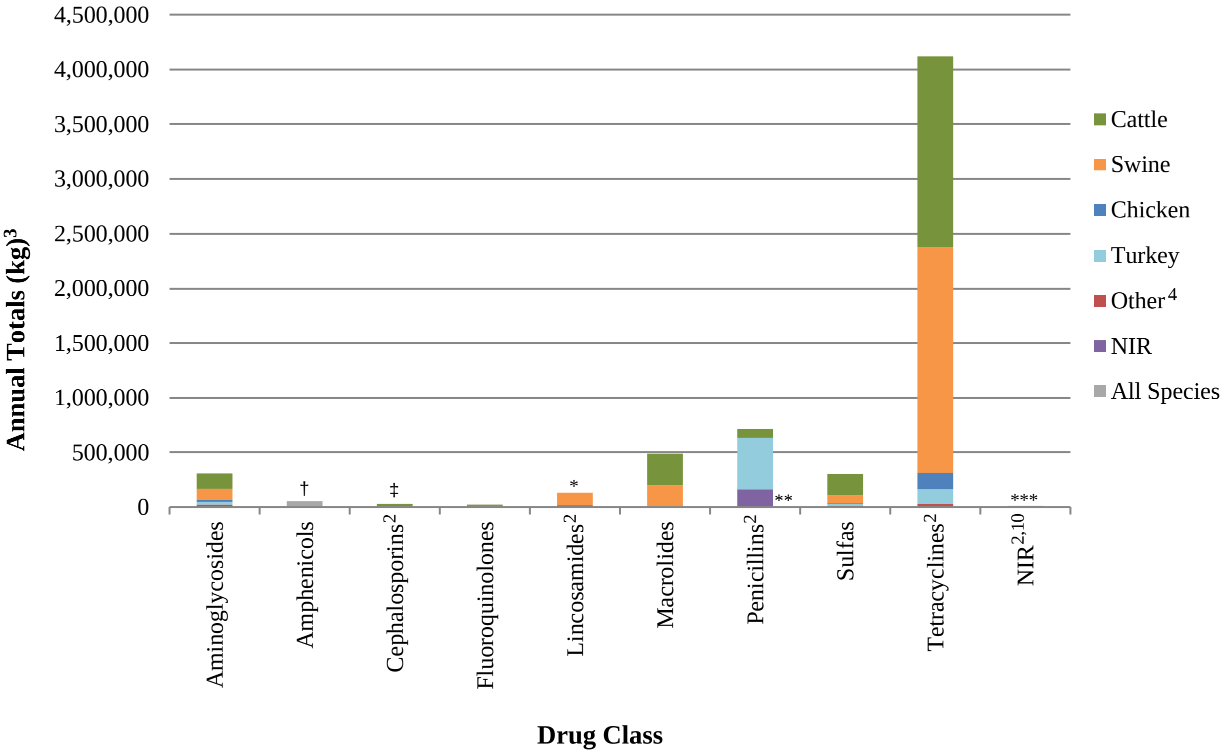
[8] This category includes the following: Swine and Other.

[9] NIR = Not Independently Reported. Antimicrobial classes for which there were fewer than three distinct sponsors actively marketing products domestically are not independently reported. These classes include the following: Diaminopyrimidines, Polymyxins, and Streptogramins.

[10] This category includes the following: Cattle, Swine, Chicken, and Other.

Figure 5a

Medically important[1] antimicrobial drugs approved for use in food-producing animals[2]
Actively marketed in 2019
Domestic sales and distribution data
Reported by drug class and species-specific estimated sales



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[1] Guidance for Industry #213 states that all antimicrobial drugs and their associated classes listed in Appendix A of FDA's Guidance for Industry #152 are considered "medically important" in human medical therapy.

[2] Includes antimicrobial drug applications that are approved and labeled for use in both food-producing animals (e.g., cattle and swine) and nonfood-producing animals (e.g., dogs and horses).

[3] kg = kilogram of active ingredient. Antimicrobial class includes drugs of different molecular weights, with some drugs labeled in different salt forms. Antimicrobials that are labeled in International Units (IU) (e.g., Penicillins) were converted to kg.

[4] The Other category includes estimates of product sales intended for use in (1) species listed on the approved label other than cattle, swine, chickens, and turkeys, including nonfood-producing animal species (e.g., dogs and horses) and minor food-producing species (e.g., fish); (2) other species not listed on the approved label; and (3) unknown uses.

[†] This category includes the following: Cattle, Swine, and Other.

[‡] NIR = Not Independently Reported. Species-specific sales estimates for which there were fewer than three distinct sponsors are not independently reported. This category includes the following: Swine, Chicken, and Other.

[*] NIR = Not Independently Reported. Species-specific sales estimates for which there were fewer than three distinct sponsors are not independently reported. This category includes the following: Cattle, Turkey, and Other.

[**] This category includes the following: Swine and Other.

[10] NIR = Not Independently Reported. Antimicrobial classes for which there were fewer than three distinct sponsors actively marketing products domestically are not independently reported. These classes include the following: Diaminopyrimidines, Polymyxins, and Streptogramins.

[***] This category includes the following: Cattle, Swine, Chicken, and Other.

Table 5b

Medically important[1] antimicrobial drugs approved for use in food-producing animals[2]
Actively marketed 2016-2019
Domestic sales and distribution data
Reported by drug class and species-specific estimated sales

Ingredient Class	**Species**	**2016 Estimated Annual Totals (kg)[3]**	**2017 Estimated Annual Totals (kg)[3]**	**2018 Estimated Annual Totals (kg)[3]**	**2019 Estimated Annual Totals (kg)[3]**	**% Change 2016 - 2019**	**% Change 2018 - 2019**
Aminoglycosides	*Cattle*	161,646	124,675	133,842	139,445	-14%	4%
	Swine	65,850	63,602	90,708	101,270	54%	12%
	Chicken	24,111	20,185	13,430	16,200	-33%	21%
	Turkey	22,198	24,042	24,321	25,125	13%	3%
	Other[4]	45,204	26,680	27,154	25,949	-43%	-4%
	Subtotal	***319,009***	***259,184***	***289,455***	***307,988***	***-3%***	***6%***
Amphenicols	*All Species*[5]	*	49,321	56,056	53,212	**	-5%
	Subtotal	*****	***49,321***	***56,056***	***53,212***	******	***-5%***
Cephalosporins[2]	*Cattle*	24,677	23,512	25,337	24,158	3%	-5%
	NIR[6]	6,333	5,857	6,111	5,672	-4%	-7%
	Subtotal	***31,010***	***29,369***	***31,448***	***29,830***	***1%***	***-5%***
Fluoroquinolones	*Cattle*	*	*	*	12,560	**	**
	Swine	*	*	*	11,790	**	**
	Other[4]	*	*	*	205	**	**
	All Species[7]	18,502	22,904	23,350	*	**	**
	Subtotal	***18,502***	***22,904***	***23,350***	***24,556***	***33%***	***5%***
Lincosamides[2]	*Swine*	118,916	128,642	104,527	114,398	-4%	9%
	Chicken	8,874	8,213	8,780	6,409	-28%	-27%
	NIR[8]	14,667	15,642	12,208	14,156	-3%	16%
	Subtotal	***142,458***	***152,497***	***125,514***	***134,962***	***-5%***	***8%***
Macrolides	*Cattle*	194,811	274,479	274,837	286,438	47%	4%
	Swine	337,295	189,503	192,175	195,441	-42%	2%
	Chicken	20,718	2,614	2,971	2,760	-87%	-7%
	Turkey	1,176	1,307	1,653	1,944	65%	18%
	Other[4]	714	891	1,403	1,498	110%	7%
	Subtotal	***554,714***	***468,794***	***473,038***	***488,082***	***-12%***	***3%***
Penicillins[2]	*Cattle*	99,935	96,936	96,591	78,887	-21%	-18%
	Swine	17,958	*	*	*	**	**
	Turkey	529,083	423,689	463,939	471,660	-11%	2%
	Other[4]	195,888	*	*	*	**	**
	NIR[9]	*	170,263	171,333	165,978	**	-3%
	Subtotal	***842,863***	***690,889***	***731,863***	***716,525***	***-15%***	***-2%***
Sulfas[2]	*Cattle*	234,955	196,902	187,603	197,486	-16%	5%
	Swine	40,215	31,024	45,581	72,126	79%	58%
	Chicken	21,115	7,319	*	5,903	-72%	**
	Turkey	41,127	28,817	30,446	14,908	-64%	-51%
	Other[4]	32,414	10,050	*	13,905	-57%	**
	NIR[10]	*	*	14,933	*	**	**
	Subtotal	***369,826***	***274,112***	***278,562***	***304,327***	***-18%***	***9%***
Tetracyclines[2]	*Cattle*	2,840,519	1,560,542	1,732,416	1,741,883	-39%	1%
	Swine	2,520,680	1,579,145	1,902,950	2,062,275	-18%	8%
	Chicken	285,513	153,621	140,561	149,295	-48%	6%
	Turkey	156,617	192,976	150,749	131,034	-16%	-13%
	Other[4]	57,859	49,416	47,502	32,545	-44%	-31%
	Subtotal	***5,861,188***	***3,535,701***	***3,974,179***	***4,117,031***	***-30%***	***4%***
NIR[2,11]	*All Species*[12]	216,771	76,440	48,832	12,746	-94%	-74%
	Subtotal	***216,771***	***76,440***	***48,832***	***12,746***	***-94%***	***-74%***

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[1] Guidance for Industry #213 states that all antimicrobial drugs and their associated classes listed in Appendix A of FDA's Guidance for Industry #152 are considered "medically important" in human medical therapy.

[2] Includes antimicrobial drug applications that are approved and labeled for use in both food-producing animals (e.g., cattle and swine) and nonfood-producing animals (e.g., dogs and horses).

[3] kg = kilogram of active ingredient. Antimicrobial class includes drugs of different molecular weights, with some drugs labeled in different salt forms. Antimicrobials that are labeled in International Units (IU) (e.g., Penicillins) were converted to kg.

[4] The Other category includes estimates of product sales intended for use in (1) species listed on the approved label other than cattle, swine, chickens, and turkeys, including nonfood-producing animal species (e.g., dogs and horses) and minor food-producing species (e.g., fish); (2) other species not listed on the approved label; and (3) unknown uses.

[5] This category includes the following: Cattle, Swine (excluding 2016), and Other.

* Species-specific sales estimates for which there were fewer than three distinct sponsors are not independently reported.

** Species-specific sales estimates for which there were fewer than three distinct sponsors are not independently reported. Therefore, percentage change cannot be calculated.

[6] NIR = Not Independently Reported. Species-specific sales estimates for which there were fewer than three distinct sponsors are not independently reported. This category includes the following: Swine, Chicken, and Other.

[7] This category includes the following: Cattle, Swine, and Other (excluding 2019).

[8] NIR = Not Independently Reported. Species-specific sales estimates for which there were fewer than three distinct sponsors are not independently reported. This category includes the following: Cattle, Turkey (excluding 2016 through 2018), and Other.

[9] This category includes the following: Swine and Other (excluding 2016).

[10] This category includes Chicken and Other for 2018.

[11] NIR = Not Independently Reported. Antimicrobial classes for which there were fewer than three distinct sponsors actively marketing products domestically are not independently reported. These classes include the following: Amphenicols, Diaminopyrimidines, Polymyxins, and Streptogramins.

[12] This category includes the following: Cattle, Swine, Chicken, Turkey (excluding 2017 through 2019), and Other.

Table 6a

Medically important[1] antimicrobial drugs approved for use in food-producing animals[2]
Actively marketed in 2019
Domestic sales and distribution data
Reported by route of administration

Route	Annual Totals (kg)[3]	% Total
Feed[2]	4,013,580	65%
Injection[2]	311,562	5%
Intramammary	16,155	<1%
Oral[2,4] *or Topical*[2,5]	72,486	1%
Water[6]	1,775,475	29%
Total	***6,189,260***	***100%***

[1] Guidance for Industry #213 states that all antimicrobial drugs and their associated classes listed in Appendix A of FDA's Guidance for Industry #152 are considered "medically important" in human medical therapy.

[2] Includes antimicrobial drug applications that are approved and labeled for use in both food-producing animals (e.g., cattle and swine) and nonfood-producing animals (e.g., dogs and horses).

[3] kg = kilogram of active ingredient. Antimicrobial class includes drugs of different molecular weights, with some drugs labeled in different salt forms. Antimicrobials that are labeled in International Units (IU) (e.g., Penicillins) were converted to kg.

[4] Orally administered, excluding administration by means of feed and water.

[5] The Oral or Topical category includes Topical products marketed by less than three distinct sponsors; therefore, Topical products cannot be independently reported (excluding 2012 and 2013).

[6] Water includes when the drug is administered either through drinking water, as a drench, through the immersion of fish, or as a syrup or dusting for honey bees.

Table 6b

Medically important[1] antimicrobial drugs approved for use in food-producing animals[2]
Actively marketed 2010-2019
Domestic sales and distribution data
Reported by route of administration

Route	2010 Annual Totals (kg)[3]	2011 Annual Totals (kg)[3]	2012 Annual Totals (kg)[3]	2013 Annual Totals (kg)[3]	2014 Annual Totals (kg)[3]	2015 Annual Totals (kg)[3]	2016 Annual Totals (kg)[3]	2017 Annual Totals (kg)[3]	2018 Annual Totals (kg)[3]	2019 Annual Totals (kg)[3]	% Change 2010 - 2019	% Change 2018 - 2019
Feed[2]	5,957,748	5,933,440	6,250,770	6,833,526	6,981,097	7,139,853	5,982,351	3,432,373	3,862,586	4,013,580	-33%	4%
Injection[2]	421,272	416,775	393,422	352,693	341,790	353,197	348,239	358,534	355,994	311,562	-26%	-12%
Intramammary	24,692	21,023	25,979	9,875	11,450	16,049	16,172	17,583	14,056	16,155	-35%	15%
Oral[2,4] *or Topical*[2,5]	109,839	126,775	113,409	97,952	104,082	121,288	90,464	95,311	88,609	72,486	-34%	-18%
Water[6]	1,715,757	1,757,686	2,113,840	1,899,248	2,040,920	2,072,557	1,919,115	1,655,410	1,711,053	1,775,475	3%	4%
Total	***8,229,309***	***8,255,697***	***8,897,420***	***9,193,293***	***9,479,339***	***9,702,943***	***8,356,340***	***5,559,212***	***6,032,298***	***6,189,260***	***-25%***	***3%***

[1] Guidance for Industry #213 states that all antimicrobial drugs and their associated classes listed in Appendix A of FDA's Guidance for Industry #152 are considered "medically important" in human medical therapy.

[2] Includes antimicrobial drug applications that are approved and labeled for use in both food-producing animals (e.g., cattle and swine) and nonfood-producing animals (e.g., dogs and horses).

[3] kg = kilogram of active ingredient. Antimicrobial class includes drugs of different molecular weights, with some drugs labeled in different salt forms. Antimicrobials that are labeled in International Units (IU) (e.g., Penicillins) were converted to kg.

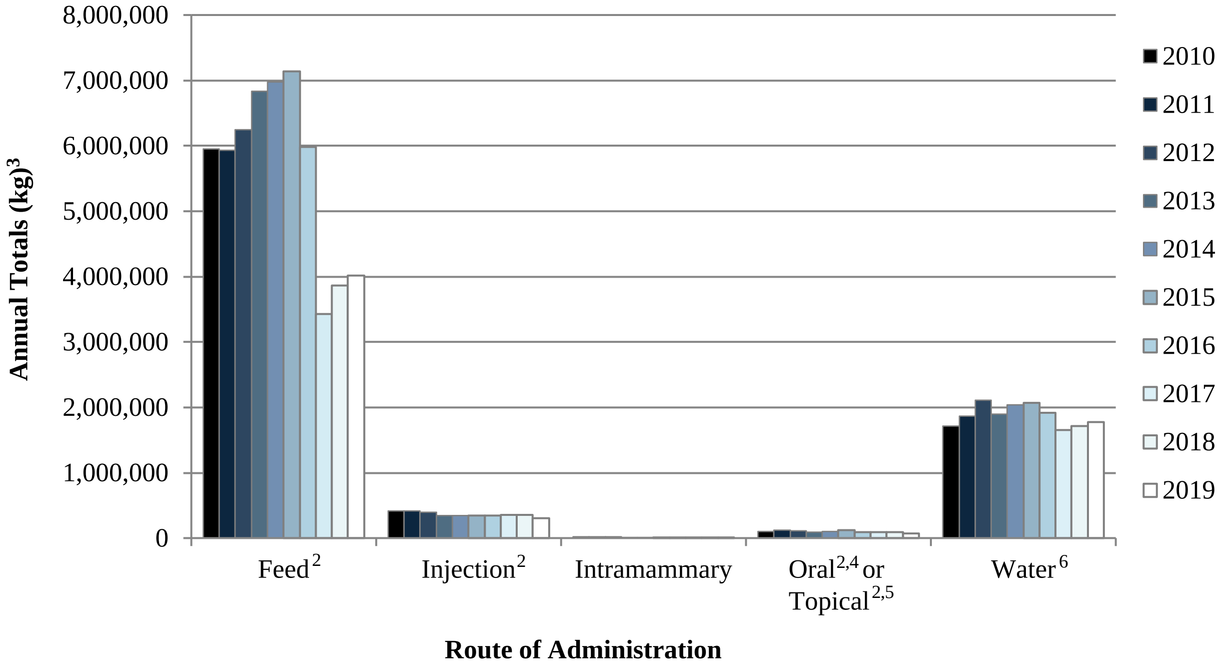
[4] Orally administered, excludes administration by means of feed and water.

[5] The Oral or Topical category includes Topical products marketed by less than three distinct sponsors; therefore, Topical products cannot be independently reported (excluding 2012 and 2013).

[6] Water includes when the drug is administered either through drinking water, as a drench, through the immersion of fish, or as a syrup or dusting for honey bees.

Figure 6b

Medically important[1] antimicrobial drugs approved for use in food-producing animals[2]
Actively marketed 2010-2019
Domestic sales and distribution data
Reported by route of administration



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[3] kg = kilogram of active ingredient. Antimicrobial class includes drugs of different molecular weights, with some drugs labeled in different salt forms. Antimicrobials that are labeled in International Units (IU) (e.g., Penicillins) were converted to kg.

[4] Orally administered, excluding administration by means of feed and water.

[5] The Oral or Topical category includes Topical products marketed by less than three distinct sponsors; therefore, Topical products cannot be independently reported (excluding 2012 and 2013).

[6] Water includes when the drug is administered either through drinking water, as a drench, through the immersion of fish, or as a syrup or dusting for honey bees.

Table 7a

Medically important[1] antimicrobial drugs approved for use in food-producing animals[2]
Actively marketed 2010-2019
Domestic sales and distribution data
Reported by indications

Indications	2010 Annual Totals (kg)[3]	2011 Annual Totals (kg)[3]	2012 Annual Totals (kg)[3]	2013 Annual Totals (kg)[3]	2014 Annual Totals (kg)[3]	2015 Annual Totals (kg)[3]	2016 Annual Totals (kg)[3]	2017 Annual Totals (kg)[3]	2018 Annual Totals (kg)[3]	2019 Annual Totals (kg)[3]	% Change 2010 - 2019	% Change 2018 - 2019
Production[4] or Production/Therapeutic[5] Indications[2,6]	5,828,079	5,770,871	6,073,485	6,664,835	6,790,996	6,917,639	5,770,655	0*	0*	0*	**	**
Therapeutic Indications Only[2,5]	2,401,230	2,484,827	2,823,935	2,528,458	2,688,343	2,785,304	2,585,685	5,559,212*	6,032,298	6,189,260	158%	3%
Total	***8,229,309***	***8,255,697***	***8,897,420***	***9,193,293***	***9,479,339***	***9,702,943***	***8,356,340***	***5,559,212***	***6,032,298***	***6,189,260***	***-25%***	***3%***

[1] Guidance for Industry #213 states that all antimicrobial drugs and their associated classes listed in Appendix A of FDA's Guidance for Industry #152 are considered "medically important" in human medical therapy.

[2] Includes antimicrobial drug applications that are approved and labeled for use in both food-producing animals (e.g., cattle and swine) and nonfood-producing animals (e.g., dogs and horses).

[3] kg = kilogram of active ingredient. Antimicrobial class includes drugs of different molecular weights, with some drugs labeled in different salt forms. Antimicrobials that are labeled in International Units (IU) (e.g., Penicillins) were converted to kg.

[4] The implementation of GFI #213 was completed in January 2017; all affected medically important products had production indications removed from their labeling at that time.

[5] Therapeutic Indications (e.g., treatment, control, or prevention of disease).

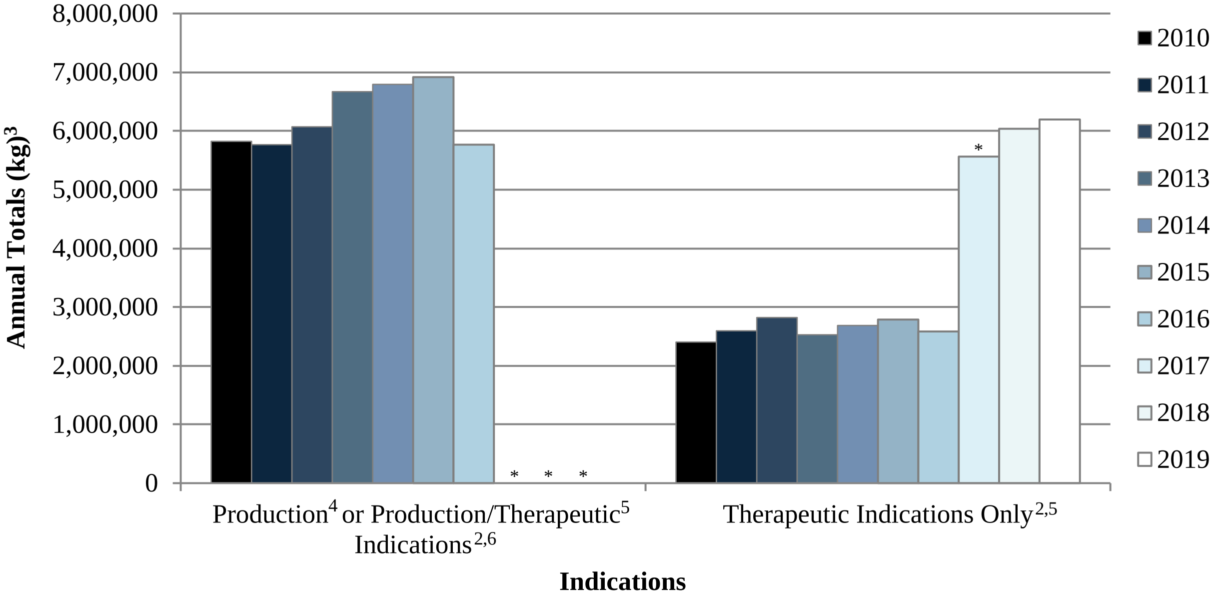
[6] There were fewer than three distinct sponsors marketing antimicrobial animal drugs with only production indications (i.e., with no therapeutic indications). To protect confidential business information these data cannot be independently reported and are, therefore, combined with the data for drugs with both production and therapeutic (production/therapeutic) indications.

[*] The quantities reported in 2017 through 2019 under the production indications category dropped to zero as a result of the implementation of GFI #213. Applications that were formerly in the Production category were voluntarily withdrawn. Applications that were formerly in the Production/Therapeutic Indications category had production claims eliminated and were moved to the Therapeutic Only Indications category.

[**] Cannot divide by zero.

Figure 7a

Medically important[1] antimicrobial drugs approved for use in food-producing animals[2]
Actively marketed 2010-2019
Domestic sales and distribution data
Reported by indications



[1] Includes antimicrobial drug applications that are approved and labeled for use in both food-producing animals (e.g., cattle and swine) and nonfood-producing animals (e.g., dogs and horses).

[2] Includes antimicrobial drug applications that are approved and labeled for use in both food-producing animals (e.g., cattle and swine) and nonfood-producing animals (e.g., dogs and horses).

[3] kg = kilogram of active ingredient. Antimicrobial class includes drugs of different molecular weights, with some drugs labeled in different salt forms. Antimicrobials that are labeled in International Units (IU) (e.g., Penicillins) were converted to kg.

[4] The implementation of GFI #213 was completed in January 2017; all affected medically important products had production indications removed from their labeling at that time.

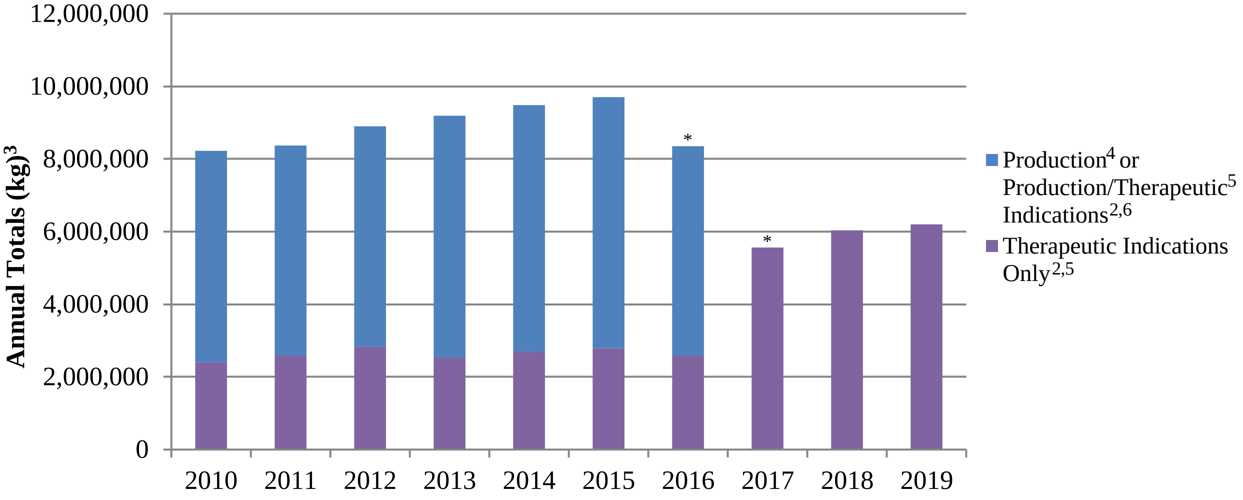
[5] Therapeutic Indications (e.g., treatment, control, or prevention of disease).

[6] There were fewer than three distinct sponsors (excluding 2013 through 2016 for the Not Medically Important category) marketing antimicrobial animal drugs with only production indications (i.e., with no therapeutic indications). To protect confidential business information these data cannot be independently reported and are, therefore, combined with the data for drugs with both production and therapeutic (production/therapeutic) indications.

[*] The quantity reported in 2017 under the production indications category dropped to zero as a result of the implementation of GFI #213. Applications that were formerly in the Production category were voluntarily withdrawn. Applications that were formerly in the Production/Therapeutic Indications category had production claims eliminated and were moved to the Therapeutic Only Indications category.

Figure 7b

Medically important[1] antimicrobial drugs approved for use in food-producing animals[2]
Actively marketed 2010-2019
Domestic sales and distribution data
Reported by indications (combined annual totals)



[1] Includes antimicrobial drug applications that are approved and labeled for use in both food-producing animals (e.g., cattle and swine) and nonfood-producing animals (e.g., dogs and horses).

[2] Includes antimicrobial drug applications that are approved and labeled for use in both food-producing animals (e.g., cattle and swine) and nonfood-producing animals (e.g., dogs and horses).

[3] kg = kilogram of active ingredient. Antimicrobial class includes drugs of different molecular weights, with some drugs labeled in different salt forms. Antimicrobials that are labeled in International Units (IU) (e.g., Penicillins) were converted to kg.

[4] The implementation of GFI #213 was completed in January 2017; all affected medically important products had production indications removed from their labeling at that time.

[5] Therapeutic Indications (e.g., treatment, control, or prevention of disease).

[6] There were fewer than three distinct sponsors (excluding 2013 through 2016 for the Not Medically Important category) marketing antimicrobial animal drugs with only production indications (i.e., with no therapeutic indications). To protect confidential business information these data cannot be independently reported and are, therefore, combined with the data for drugs with both production and therapeutic (production/therapeutic) indications.

[*] The quantity reported in 2017 under the production indications category dropped to zero as a result of the implementation of GFI 213. Applications that were formerly in the Production category were voluntarily withdrawn. Applications that were formerly in the Production/Therapeutic Indications category had production claims eliminated and were moved to the Therapeutic Only Indications category.

Table 8a

Medically important[1] antimicrobial drugs approved for use in food-producing animals[2]
Actively marketed in 2019
Domestic sales and distribution data
Reported by dispensing status

Dispensing Status	Annual Totals (kg)[3]	% Total
OTC[2,4,5]	223,753	4%
Rx[2,6]	1,918,965	31%
Rx[6]*/OTC*[2,4,7]	32,961	1%
VFD[8]	4,013,580	65%
Total	***6,189,260***	***100%***

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[1] Guidance for Industry #213 states that all antimicrobial drugs and their associated classes listed in Appendix A of FDA's Guidance for Industry #152 are considered "medically important" in human medical therapy.

[2] Includes antimicrobial drug applications that are approved and labeled for use in both food-producing animals (e.g., cattle and swine) and nonfood-producing animals (e.g., dogs and horses).

[3] kg = kilogram of active ingredient. Antimicrobial class includes drugs of different molecular weights, with some drugs labeled in different salt forms. Antimicrobials that are labeled in International Units (IU) (e.g., Penicillins) were converted to kg.

[4] OTC = Over-the-Counter. Approved animal drugs that are available without a prescription or veterinary feed directive.

[5] The implementation of GFI #213 was completed in January 2017; all affected medically important products transitioned from OTC to either Rx or VFD dispensing status at that time.

[6] Rx = Prescription. Approved animal drugs that require a prescription from a licensed veterinarian.

[7] Animal drugs that were approved with both a prescription and OTC dispensing status (Rx/OTC), with the approved drug being marketed with either a prescription label or an OTC label, depending upon the species and indication on the label.

[8] VFD = Veterinary Feed Directive. Approved animal drugs that are intended for use in or on animal feed and must be used under the professional supervision of a licensed veterinarian.

Table 8b

Medically important[1] antimicrobial drugs approved for use in food-producing animals[2]
Actively marketed 2010-2019
Domestic sales and distribution data
Reported by dispensing status

Dispensing Status	2010 Annual Totals (kg)[3]	2011 Annual Totals (kg)[3]	2012 Annual Totals (kg)[3]	2013 Annual Totals (kg)[3]	2014 Annual Totals (kg)[3]	2015 Annual Totals (kg)[3]	2016 Annual Totals (kg)[3]	2017 Annual Totals (kg)[3]	2018 Annual Totals (kg)[3]	2019 Annual Totals (kg)[3]	% Change 2010 - 2019	% Change 2018 - 2019
OTC[2,4,5]	8,050,340	8,029,437	8,642,153	8,964,750	9,219,892	9,422,402	8,000,326	271,280*	262,678	223,753	-97%	-15%
Rx[6]*/OTC*[2,4,7]	47,901	50,205	54,968	54,942	48,489	56,363	60,705	57,269	47,245	32,961	-31%	-30%
Rx[6] *or VFD*[2,8,9]	131,068	176,055	200,298	173,600	210,958	224,179	295,309	5,230,663*	5,722,375	5,932,545	4426%	4%
Total	***8,229,309***	***8,255,697***	***8,897,420***	***9,193,293***	***9,479,339***	***9,702,943***	***8,356,340***	***5,559,212***	***6,032,298***	***6,189,260***	***-25%***	***3%***

[1] Guidance for Industry #213 states that all antimicrobial drugs and their associated classes listed in Appendix A of FDA's Guidance for Industry #152 are considered "medically important" in human medical therapy.

[2] Includes antimicrobial drug applications that are approved and labeled for use in both food-producing animals (e.g., cattle and swine) and nonfood-producing animals (e.g., dogs and horses).

[3] kg = kilogram of active ingredient. Antimicrobial class includes drugs of different molecular weights, with some drugs labeled in different salt forms. Antimicrobials that are labeled in International Units (IU) (e.g., Penicillins) were converted to kg.

[4] OTC = Over-the-Counter. Approved animal drugs that are available without a prescription or veterinary feed directive.

[5] The implementation of GFI #213 was completed in January 2017; all affected medically important products transitioned from OTC to either Rx or VFD dispensing status at that time.

[*] The quantity reported in 2017 under the OTC category dropped sharply as a result of the implementation of GFI #213. Applications that were formerly in the OTC category moved to the Rx or VFD category.

[6] Rx = Prescription. Approved animal drugs that require a prescription from a licensed veterinarian.

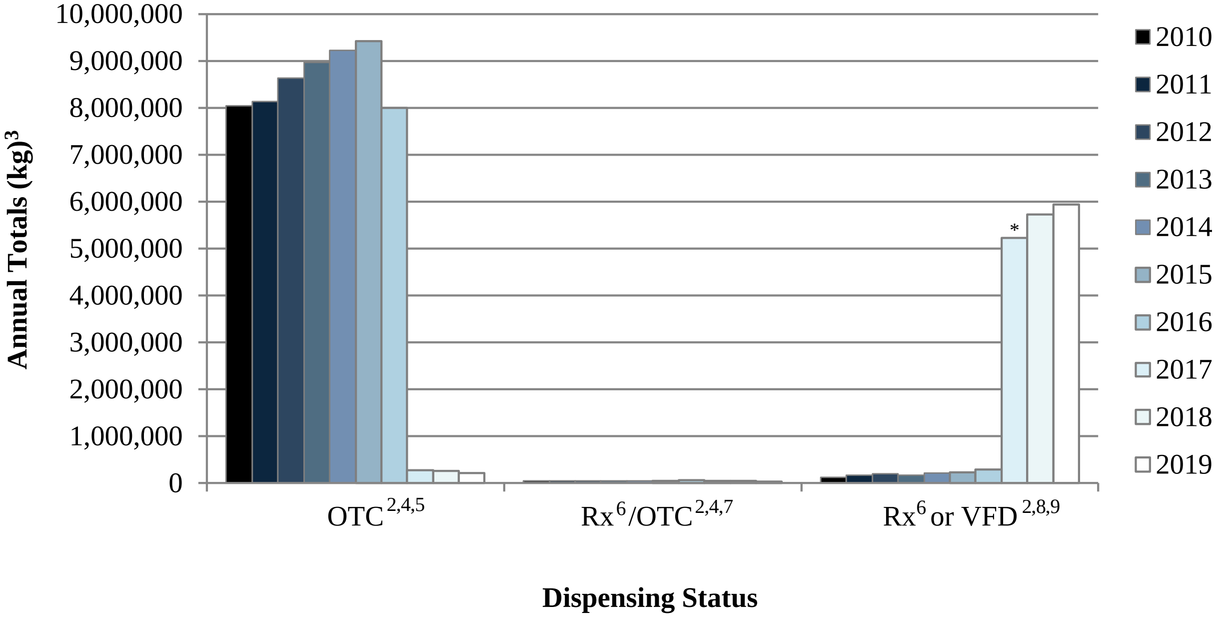
[7] Animal drugs that were approved with both a prescription and OTC dispensing status (Rx/OTC), with the approved drug being marketed with either a prescription label or an OTC label, depending upon the species and indication on the label.

[8] VFD = Veterinary Feed Directive. Approved animal drugs that are intended for use in or on animal feed and must be used under the professional supervision of a licensed veterinarian.

[9] The Rx or VFD category includes VFD products marketed by less than three distinct sponsors; therefore, VFD products cannot be independently reported (excluding 2013 through 2019).

Figure 8b

Medically important[1] antimicrobial drugs approved for use in food-producing animals[2]
Actively marketed 2010-2019
Domestic sales and distribution data
Reported by dispensing status



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[1] Guidance for Industry #213 states that all antimicrobial drugs and their associated classes listed in Appendix A of FDA's Guidance for Industry #152 are considered "medically important" in human medical therapy.

[2] Includes antimicrobial drug applications that are approved and labeled for use in both food-producing animals (e.g., cattle and swine) and nonfood-producing animals (e.g., dogs and horses).

[3] kg = kilogram of active ingredient. Antimicrobial class includes drugs of different molecular weights, with some drugs labeled in different salt forms. Antimicrobials that are labeled in International Units (IU) (e.g., Penicillins) were converted to kg.

[4] OTC = Over-the-Counter. Approved animal drugs that are available without a prescription or veterinary feed directive.

[5] The implementation of GFI #213 was completed in January 2017; all affected medically important products transitioned from OTC to either Rx or VFD dispensing status at that time.

[*] The quantity reported in 2017 under the OTC category dropped sharply as a result of the implementation of GFI #213. Applications that were formerly in the OTC category moved to the Rx or VFD category.

[6] Rx = Prescription. Approved animal drugs that require a prescription from a licensed veterinarian.

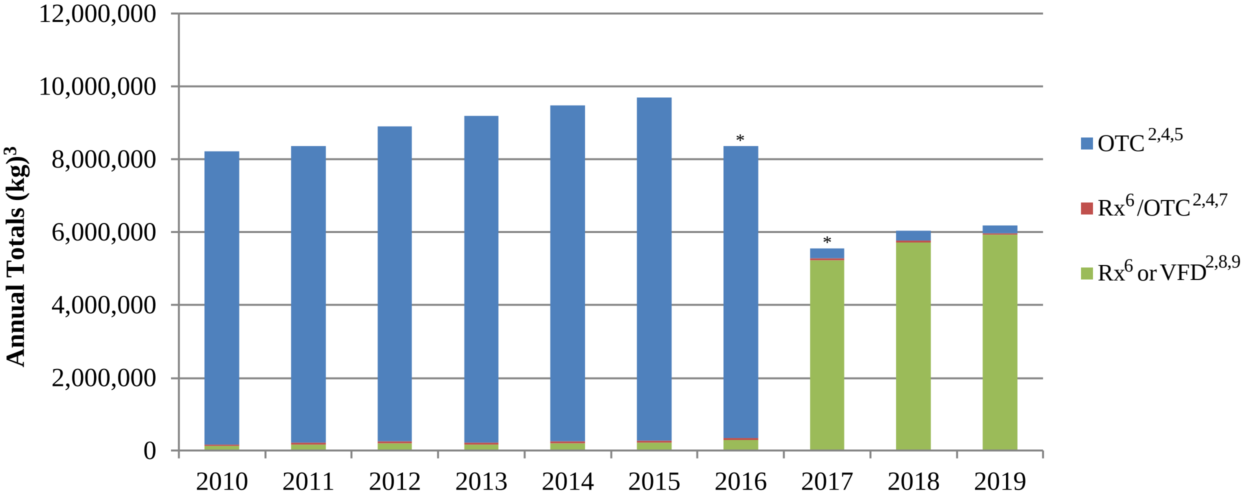
[7] Animal drugs that were approved with both a prescription and OTC dispensing status (Rx/OTC), with the approved drug being marketed with either a prescription label or an OTC label, depending upon the species and indication on the label.

[8] VFD = Veterinary Feed Directive. Approved animal drugs that are intended for use in or on animal feed and must be used under the professional supervision of a licensed veterinarian.

[9] The Rx or VFD category includes VFD products marketed by less than three distinct sponsors; therefore, VFD products cannot be independently reported (excluding 2013 through 2019).

Figure 8c

Medically important[1] antimicrobial drugs approved for use in food-producing animals[2]
Actively marketed 2010-2019
Domestic sales and distribution data
Reported by dispensing status (combined annual totals)



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[1] Guidance for Industry #213 states that all antimicrobial drugs and their associated classes listed in Appendix A of FDA's Guidance for Industry #152 are considered "medically important" in human medical therapy.

[2] Includes antimicrobial drug applications that are approved and labeled for use in both food-producing animals (e.g., cattle and swine) and nonfood-producing animals (e.g., dogs and horses).

[3] kg = kilogram of active ingredient. Antimicrobial class includes drugs of different molecular weights, with some drugs labeled in different salt forms. Antimicrobials that are labeled in International Units (IU) (e.g., Penicillins) were converted to kg.

[4] OTC = Over-the-Counter. Approved animal drugs that are available without a prescription or veterinary feed directive.

[5] The implementation of GFI #213 was completed in January 2017; all affected medically important products transitioned from OTC to either Rx or VFD dispensing status at that time.

[*] The quantity reported in 2017 under the OTC category dropped sharply as a result of the implementation of GFI 213. Applications that were formerly in the OTC category moved to the Rx or VFD category.

[6] Rx = Prescription. Approved animal drugs that require a prescription from a licensed veterinarian.

[7] Animal drugs that were approved with both a prescription and OTC dispensing status (Rx/OTC), with the approved drug being marketed with either a prescription label or an OTC label, depending upon the species and indication on the label.

[8] VFD = Veterinary Feed Directive. Approved animal drugs that are intended for use in or on animal feed and must be used under the professional supervision of a licensed veterinarian.

[9] The Rx or VFD category includes VFD products marketed by less than three distinct sponsors; therefore, VFD products cannot be independently reported (excluding 2013 through 2019).

Table 9a

Medically important[1] antimicrobial drugs approved for use in food-producing animals[2]
Actively marketed in 2019
Domestic sales and distribution data
Reported by route of administration and drug class

Route	Drug Class	Annual Total (kg)[3]	% Total
Feed	*Sulfas*	34,510	1%
	Tetracyclines[2]	3,443,546	56%
	Other Drugs[4]	535,524	9%
Water	*Aminoglycosides*	215,980	3%
	Lincosamides	70,444	1%
	Penicillins	607,741	10%
	Sulfas	197,631	3%
	Tetracyclines	598,052	10%
	Other Drug[5]	85,627	1%
Other Routes[6]	*Cephalosporins*[2]	29,830	<1%
	Sulfas	72,186	1%
	Tetracyclines[2]	75,433	1%
	Other Drugs[2,7]	222,755	4%
	Total	***6,189,260***	***100%***

[1] Guidance for Industry #213 states that all antimicrobial drugs and their associated classes listed in Appendix A of FDA's Guidance for Industry #152 are considered "medically important" in human medical therapy.

[2] Includes antimicrobial drug applications that are approved and labeled for use in both food-producing animals (e.g., cattle and swine) and nonfood-producing animals (e.g., dogs and horses).

[3] kg = kilogram of active ingredient. Antimicrobial class includes drugs of different molecular weights, with some drugs labeled in different salt forms. Antimicrobials that are labeled in International Units (IU) (e.g., Penicillins) were converted to kg.

[4] This category includes the following: Aminoglycosides, Amphenicols, Diaminopyrimidines, Lincosamides, Macrolides, and Streptogramins.

[5] This category includes the following: Amphenicols and Macrolides.

[6] This category includes the following: Injection, Intramammary, Oral (excluding administration by means of feed or water), and Topical.

[7] This category includes the following: Aminoglycosides, Amphenicols, Fluoroquinolones, Lincosamides, Macrolides, Penicillins, and Polymyxins.

Table 9b

Medically important[1] antimicrobial drugs approved for use in food-producing animals[2]
Actively marketed 2010-2019
Domestic sales and distribution data
Reported by route of administration and drug class

Route	Drug Class	2010 Annual Total (kg)[3]	2011 Annual Total (kg)[3]	2012 Annual Total (kg)[3]	2013 Annual Total (kg)[3]	2014 Annual Total (kg)[3]	2015 Annual Total (kg)[3]	2016 Annual Total (kg)[3]	2017 Annual Total (kg)[3]	2018 Annual Total (kg)[3]	2019 Annual Total (kg)[3]	% Change 2010 - 2019	% Change 2018 - 2019
Feed	*Sulfas*	109,983	105,400	90,972	90,723	103,243	98,831	77,217	21,871	28,838	34,510	-69%	20%
	Tetracyclines[2]	4,921,071	4,848,946	5,085,178	5,699,364	5,811,961	6,033,388	5,109,033	2,819,727	3,282,091	3,443,546	-30%	5%
	Other Drugs[4]	926,695	979,093	1,074,620	1,043,439	1,065,893	1,007,634	796,102	590,775	551,656	535,524	-42%	-3%
Water	*Aminoglycosides*	153,907	162,672	195,043	198,247	198,505	223,139	233,668	188,684	204,826	215,980	40%	5%
	Lincosamides	41,186	66,510	72,187	88,709	100,057	90,086	57,085	63,959	63,249	70,444	71%	11%
	Penicillins	630,946	650,220	753,510	672,131	740,929	793,018	700,779	559,589	599,409	607,741	-4%	1%
	Sulfas	289,529	145,972	283,909	192,995	239,582	154,529	199,201	152,432	158,257	197,631	-32%	25%
	Tetracyclines	582,660	710,403	782,959	719,529	712,026	762,411	663,602	625,568	609,430	598,052	3%	-2%
	Other Drugs[5]	17,529	21,909	26,233	27,637	49,822	49,374	64,780	65,179	75,881	85,627	388%	13%
Other Routes[6]	*Cephalosporins*[2]	24,588	26,611	27,654	28,337	31,722	32,254	31,010	29,369	31,448	29,830	21%	-5%
	Fluoroquinolones	*	*	*	15,099	17,220	20,063	18,502	22,904	23,350	24,556	**	5%
	Tetracyclines[2]	98,551	93,506	86,224	95,887	80,211	85,732	88,553	90,406	82,657	75,433	-23%	-9%
	Other Drugs[2,7]	432,665	444,456	418,933	321,196	328,168	352,485	316,809	328,749	321,205	270,385	-38%	-16%
	Total	***8,229,309***	***8,255,697***	***8,897,420***	***9,193,293***	***9,479,339***	***9,702,943***	***8,356,340***	***5,559,212***	***6,032,298***	***6,189,260***	***-25%***	***3%***

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[1] Guidance for Industry #213 states that all antimicrobial drugs and their associated classes listed in Appendix A of FDA's Guidance for Industry #152 are considered "medically important" in human medical therapy.

[2] Includes antimicrobial drug applications that are approved and labeled for use in both food-producing animals (e.g., cattle and swine) and nonfood-producing animals (e.g., dogs and horses).

[3] kg = kilogram of active ingredient. Antimicrobial class includes drugs of different molecular weights, with some drugs labeled in different salt forms. Antimicrobials that are labeled in International Units (IU) (e.g., Penicillins) were converted to kg.

[4] This category includes the following: Aminoglycosides, Amphenicols, Diaminopyrimidines, Lincosamides, Macrolides, Penicillins (excluding 2017 through 2019), and Streptogramins.

[5] This category includes the following: Amphenicols (excluding 2013 and 2016) and Macrolides.

[*] Not reported because there were fewer than three distinct sponsors actively marketing products domestically 2010 through 2012.

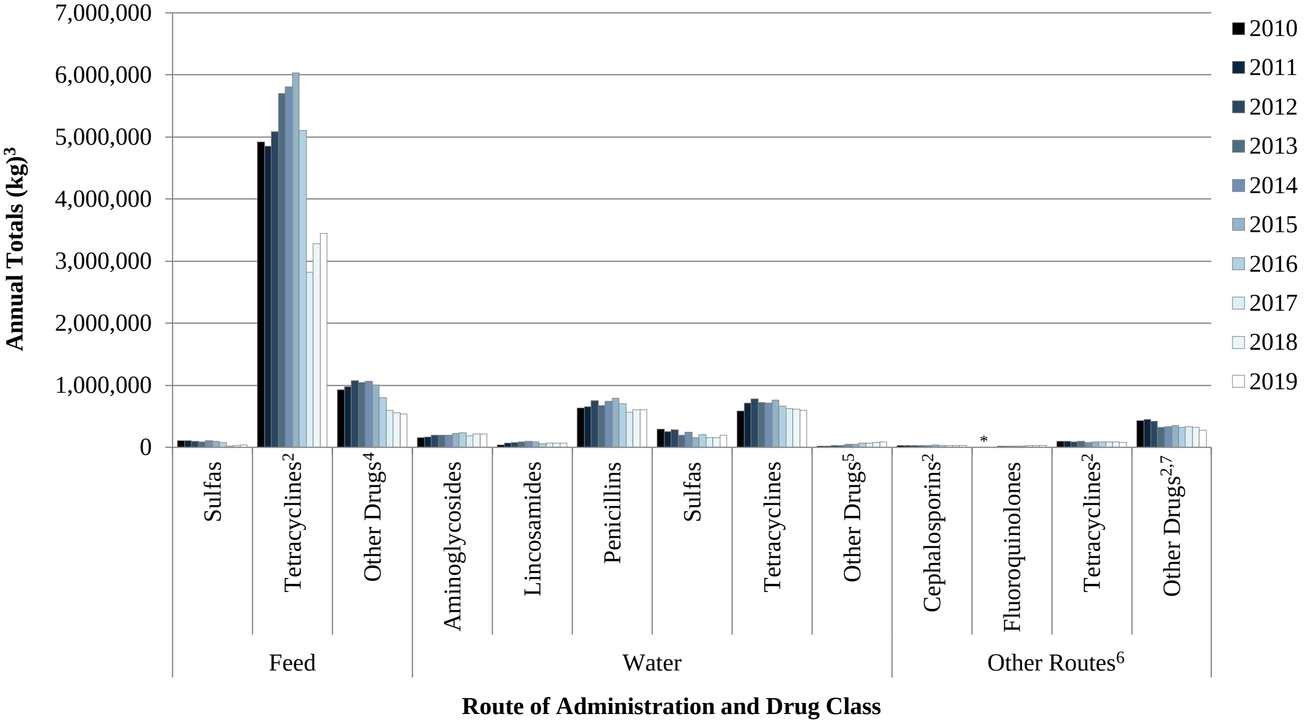
[**] Not reported because there were fewer than three distinct sponsors actively marketing products domestically 2010 through 2012. Therefore, percentage change cannot be calculated.

[6] This category includes the following: Injection, Intramammary, Oral (excluding administration by means of feed or water), and Topical (excluding 2012 and 2013).

[7] This category includes the following: Aminoglycosides, Amphenicols, Fluoroquinolones (excluding 2013 through 2019), Lincosamides, Macrolides, Penicillins, Polymyxins (excluding 2012 and 2013), and Sulfonamides.

Figure 9b

Medically important[1] antimicrobial drugs approved for use in food-producing animals[2]
Actively marketed 2010-2019
Domestic sales and distribution data
Reported by route of administration and drug class



[1] Guidance for Industry #213 states that all antimicrobial drugs and their associated classes listed in Appendix A of FDA's Guidance for Industry #152 are considered "medically important" in human medical therapy.

[2] Includes antimicrobial drug applications that are approved and labeled for use in both food-producing animals (e.g., cattle and swine) and nonfood-producing animals (e.g., dogs and horses).

[3] kg = kilogram of active ingredient. Antimicrobial class includes drugs of different molecular weights, with some drugs labeled in different salt forms. Antimicrobials that are labeled in International Units (IU) (e.g., Penicillins) were converted to kg.

[4] This category includes the following: Aminoglycosides, Amphenicols, Diaminopyrimidines, Lincosamides, Macrolides, Penicillins (excluding 2017 through 2019), and Streptogramins.

[5] This category includes the following: Amphenicols (excluding 2013 and 2016) and Macrolides.

[*] Not reported because there were fewer than three distinct sponsors actively marketing products domestically.

[6] This category includes the following: Injection, Intramammary, Oral (excluding administration by means of feed or water), and Topical (excluding 2012 and 2013).

[7] This category includes the following: Aminoglycosides, Amphenicols, Fluoroquinolones (excluding 2013 through 2019), Lincosamides, Macrolides, Penicillins, Polymyxins (excluding 2012 and 2013), and Sulfonamides.

IV. Data on antimicrobial drugs that are not medically important

Table 10a

Not medically important[1] antimicrobial drugs approved for use in food-producing animals
Actively marketed in 2019
Domestic sales and distribution data
Reported by species-specific estimated sales

Species	Estimated Annual Totals (kg)[2]	% Total
Cattle	3,246,667	62%
Swine	404,343	8%
Chicken	1,315,354	25%
Turkey	310,426	6%
Other[3]	2,308	<1%
Total	***5,279,098***	***100%***

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[1] Not Medically Important refers to any antimicrobial class not listed in Appendix A of FDA's Guidance for Industry #152.

[2] kg = kilogram of active ingredient. Antimicrobial class includes drugs of different molecular weights, with some drugs labeled in different salt forms. Antimicrobials that are labeled in International Units (IU) (e.g., Penicillins) were converted to kg.

[3] The Other category includes estimates of product sales intended for use in (1) species listed on the approved label other than cattle, swine, chickens, and turkeys, including nonfood-producing animal species (e.g., dogs and horses) and minor food-producing species (e.g., fish); (2) other species not listed on the approved label; and (3) unknown uses.

Table 10b

Not medically important[1] antimicrobial drugs approved for use in food-producing animals
Actively marketed 2016-2019
Domestic sales and distribution data
Reported by species-specific estimated sales

Species	2016 Estimated Annual Totals (kg)[2]	2017 Estimated Annual Totals (kg)[2]	2018 Estimated Annual Totals (kg)[2]	2019 Estimated Annual Totals (kg)[2]	% Change 2016 - 2019	% Change 2018 - 2019
Cattle	3,164,626	3,139,331	3,376,063	3,246,667	3%	-4%
Swine	425,568	395,994	414,170	404,343	-5%	-2%
Chicken	1,700,124	1,477,197	1,401,759	1,315,354	-23%	-6%
Turkey	379,478	358,774	335,826	310,426	-18%	-8%
Other[3]	0	2,860	2,965	2,308	*	-22%
Total	***5,669,796***	***5,374,156***	***5,530,784***	***5,279,098***	***-7%***	***-5%***

[1] Not Medically Important refers to any antimicrobial class not listed in Appendix A of FDA's Guidance for Industry #152.

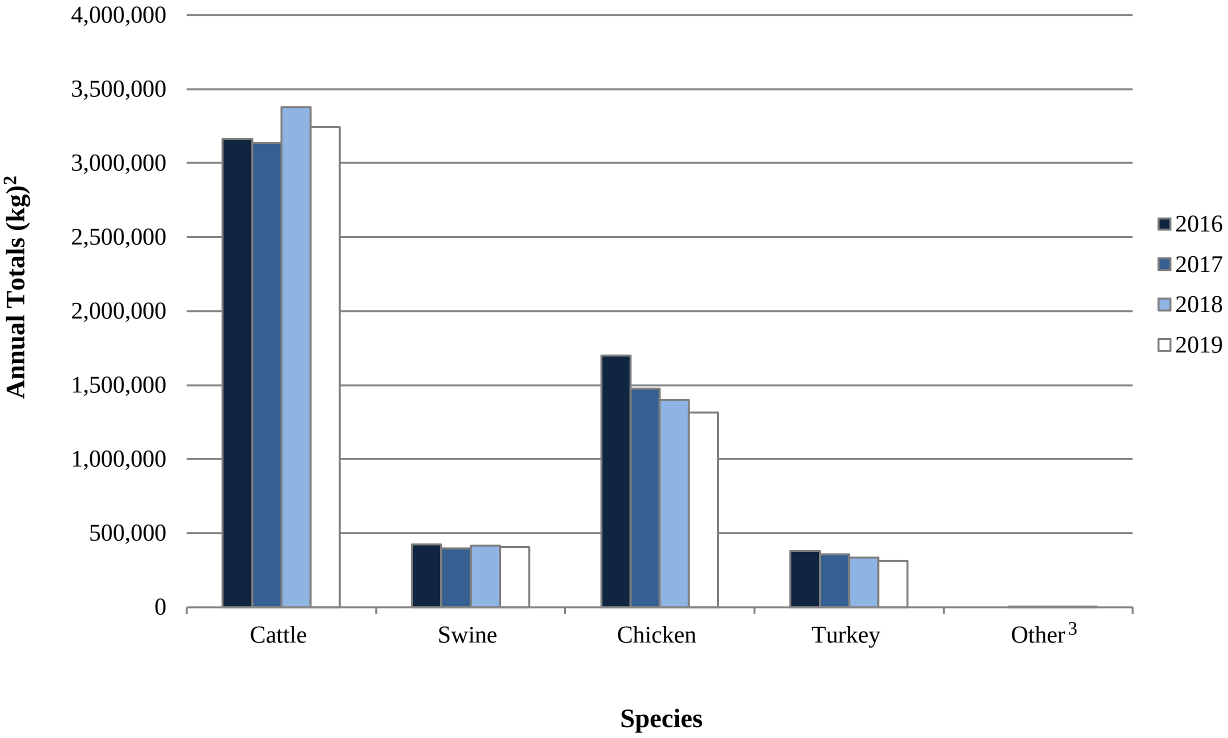
[2] kg = kilogram of active ingredient. Antimicrobial class includes drugs of different molecular weights, with some drugs labeled in different salt forms. Antimicrobials that are labeled in International Units (IU) (e.g., Penicillins) were converted to kg.

[3] The Other category includes estimates of product sales intended for use in (1) species listed on the approved label other than cattle, swine, chickens, and turkeys, including nonfood-producing animal species (e.g., dogs and horses) and minor food-producing species (e.g., fish); (2) other species not listed on the approved label; and (3) unknown uses.

* Cannot divide by zero.

Figure 10b

Not medically important[1] antimicrobial drugs approved for use in food-producing animals
Actively marketed in 2019
Domestic sales and distribution data
Reported by species-specific estimated sales



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[1] Not Medically Important refers to any antimicrobial class not listed in Appendix A of FDA's Guidance for Industry #152.

[2] kg = kilogram of active ingredient. Antimicrobial class includes drugs of different molecular weights, with some drugs labeled in different salt forms. Antimicrobials that are labeled in International Units (IU) (e.g., Penicillins) were converted to kg.

[3] The Other category includes estimates of product sales intended for use in (1) species listed on the approved label other than cattle, swine, chickens, and turkeys, including nonfood-producing animal species (e.g., dogs and horses) and minor food-producing species (e.g., fish); (2) other species not listed on the approved label; and (3) unknown uses.

Table 11a

Not medically important[1] antimicrobial drugs approved for use in food-producing animals
Actively marketed 2010-2019
Domestic sales and distribution data
Reported by route of administration

Route	2010 Annual Totals (kg)[2]	2011 Annual Totals (kg)[2]	2012 Annual Totals (kg)[2]	2013 Annual Totals (kg)[2]	2014 Annual Totals (kg)[2]	2015 Annual Totals (kg)[2]	2016 Annual Totals (kg)[2]	2017 Annual Totals (kg)[2]	2018 Annual Totals (kg)[2]	2019 Annual Totals (kg)[2]	% Change 2010 - 2019	% Change 2018 - 2019
All Routes[3]	5,057,788	5,313,340	5,725,327	5,591,752	5,882,221	5,874,997	5,669,796	5,374,156	5,530,784	5,279,098	4%	-5%

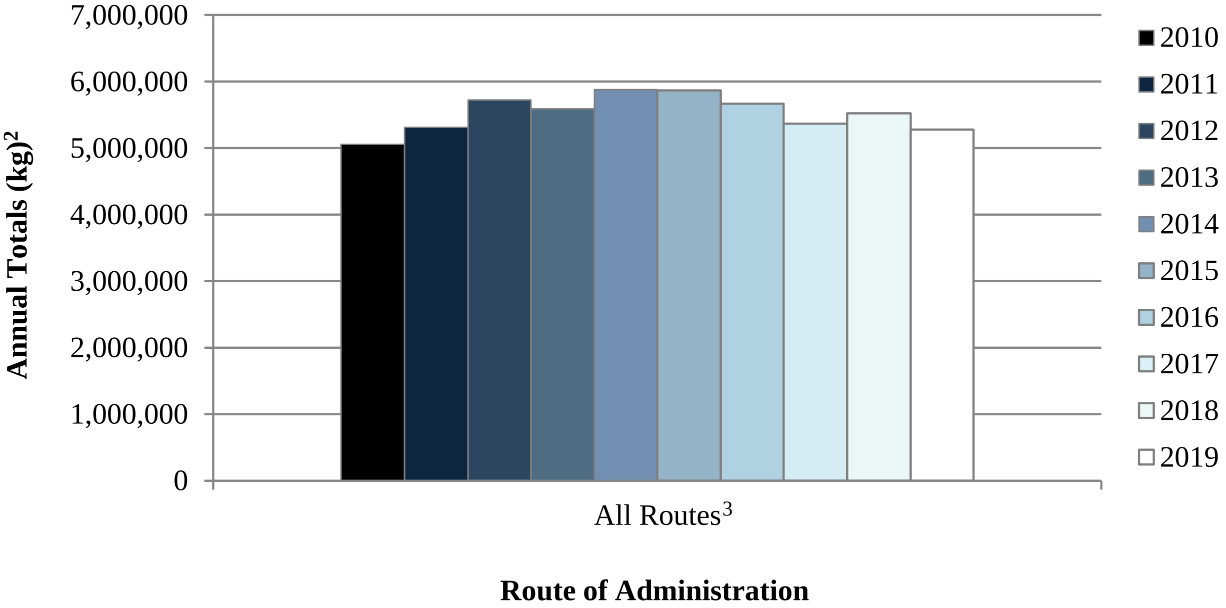
[1] Not Medically Important refers to any antimicrobial class not listed in Appendix A of FDA's Guidance for Industry #152.

[2] kg = kilogram of active ingredient. Antimicrobial class includes drugs of different molecular weights, with some drugs labeled in different salt forms. Antimicrobials that are labeled in International Units (IU) (e.g., Penicillins) were converted to kg.

[3] This category includes the following: Feed, Intramammary, and Water. To protect confidential business information, the routes of administration for the Not Medically Important antimicrobial drugs are not separately presented.

Figure 11a

Not medically important[1] antimicrobial drugs approved for use in food-producing animals
Actively marketed 2010-2019
Domestic sales and distribution data
Reported by route of administration



[1] Not Medically Important refers to any antimicrobial class not listed in Appendix A of FDA's Guidance for Industry #152.

[2] kg = kilogram of active ingredient. Antimicrobials that were reported in International Units (IU) (e.g., Penicillins) were converted to kg. Antimicrobial class includes drugs of different molecular weights, with some drugs reported in different salt forms.

[3] This category includes the following: Feed, Intramammary, and Water. To protect confidential business information, the routes of administration for the Not Medically Important antimicrobial drugs are not separately presented.

Table 12a

Not medically important[1] antimicrobial drugs approved for use in food-producing animals
Actively marketed in 2019
Domestic sales and distribution data
Reported by indications

Indications	Annual Totals (kg)[2]	% Total
Production Indications Only[3]	95,226	2%
Production/Therapeutic[4] *Indications*	4,167,540	79%
Therapeutic Indications Only[4]	1,016,332	19%
Total	***5,279,098***	***100%***

[1] Not Medically Important refers to any antimicrobial class not listed in Appendix A of FDA's Guidance for Industry #152.

[2] kg = kilogram of active ingredient. Antimicrobial class includes drugs of different molecular weights, with some drugs labeled in different salt forms. Antimicrobials that are labeled in International Units (IU) (e.g., Penicillins) were converted to kg.

[3] Production Indications (e.g., increased rate of weight gain or improved feed efficiency).

[4] Therapeutic Indications (e.g., treatment, control, or prevention of disease).

Table 12b

Not medically important[1] antimicrobial drugs approved for use in food-producing animals
Actively marketed 2010-2019
Domestic sales and distribution data
Reported by indications

Indications	2010 Annual Totals (kg)[2]	2011 Annual Totals (kg)[2]	2012 Annual Totals (kg)[2]	2013 Annual Totals (kg)[2]	2014 Annual Totals (kg)[2]	2015 Annual Totals (kg)[2]	2016 Annual Totals (kg)[2]	2017 Annual Totals (kg)[2]	2018 Annual Totals (kg)[2]	2019 Annual Totals (kg)[2]	% Change 2010 - 2019	% Change 2018 - 2019
Production[3] or Production/Therapeutic[4] Indications[5]	3,622,315	3,790,628	3,972,057	3,900,298	4,259,148	4,329,598	4,350,075	4,229,651	4,453,964	4,262,766	18%	-4%
Therapeutic Indications Only[4]	1,435,473	1,522,712	1,753,270	1,691,454	1,623,073	1,545,399	1,319,721	1,144,504	1,076,819	1,016,332	-29%	-6%
Total	***5,057,788***	***5,313,340***	***5,725,327***	***5,591,752***	***5,882,221***	***5,874,997***	***5,669,796***	***5,374,156***	***5,530,784***	***5,279,098***	***4%***	***-5%***

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[1] Not Medically Important refers to any antimicrobial class not listed in Appendix A of FDA’s Guidance for Industry #152.

[2] kg = kilogram of active ingredient. Antimicrobial class includes drugs of different molecular weights, with some drugs labeled in different salt forms. Antimicrobials that are labeled in International Units (IU) (e.g., Penicillins) were converted to kg.

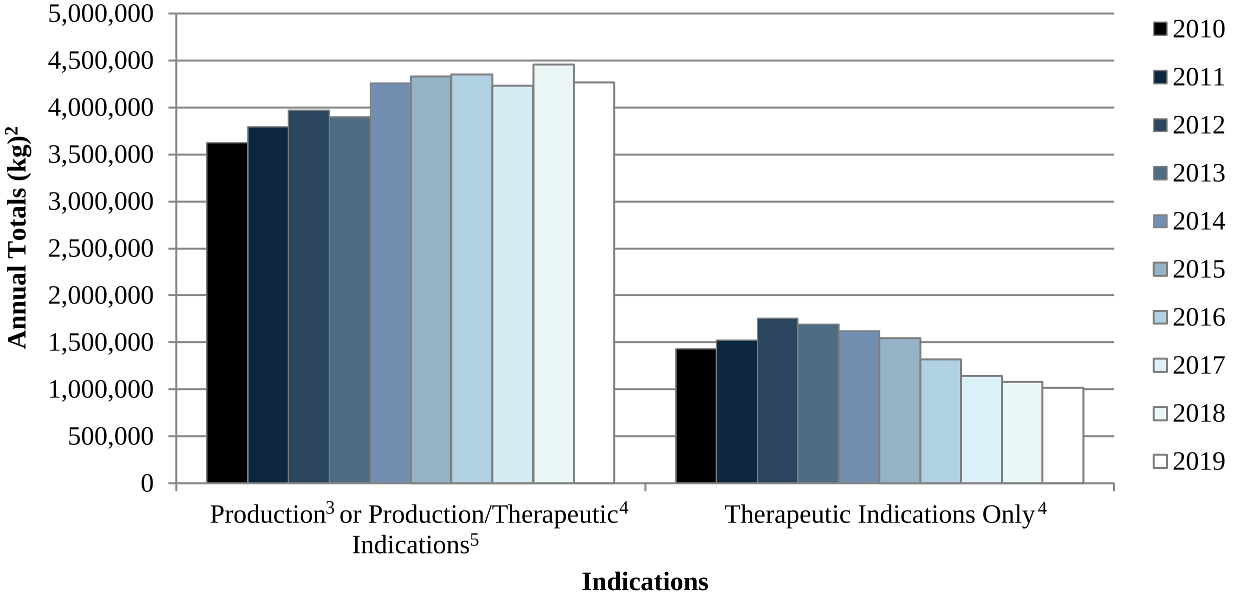
[3] Production Indications (e.g., increased rate of weight gain or improved feed efficiency).

[4] Therapeutic Indications (e.g., treatment, control, or prevention of disease).

[5] There were fewer than three distinct sponsors (excluding 2012 through 2019 for the Not Medically Important category) marketing antimicrobial animal drugs with only production indications (i.e., with no therapeutic indications). To protect confidential business information these data cannot be independently reported and are, therefore, combined with the data for drugs with both production and therapeutic (production/therapeutic) indications.

Figure 12b

Not medically important[1] antimicrobial drugs approved for use in food-producing animals
Actively marketed 2010-2019
Domestic sales and distribution data
Reported by indications



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[1] Not Medically Important refers to any antimicrobial class not listed in Appendix A of FDA's Guidance for Industry #152.

[2] kg = kilogram of active ingredient. Antimicrobial class includes drugs of different molecular weights, with some drugs labeled in different salt forms. Antimicrobials that are labeled in International Units (IU) (e.g., Penicillins) were converted to kg.

[3] Production Indications (e.g., increased rate of weight gain or improved feed efficiency).

[4] Therapeutic Indications (e.g., treatment, control, or prevention of disease).

[5] There were fewer than three distinct sponsors (excluding 2012 through 2018 for the Not Medically Important category) marketing antimicrobial animal drugs with only production indications (i.e., with no therapeutic indications). To protect confidential business information these data cannot be independently reported and are, therefore, combined with the data for drugs with both production and therapeutic (production/therapeutic) indications.

Table 13a

Not medically important[1] antimicrobial drugs approved for use in food-producing animals
Actively marketed 2010-2019
Domestic sales and distribution data
Reported by dispensing status

Dispensing Status	**2010 Annual Totals (kg)[2]**	**2011 Annual Totals (kg)[2]**	**2012 Annual Totals (kg)[2]**	**2013 Annual Totals (kg)[2]**	**2014 Annual Totals (kg)[2]**	**2015 Annual Totals (kg)[2]**	**2016 Annual Totals (kg)[2]**	**2017 Annual Totals (kg)[2]**	**2018 Annual Totals (kg)[2]**	**2019 Annual Totals (kg)[2]**	**% Change 2010 - 2019**	**% Change 2018 - 2019**
All Dispensing Statuses[3]	5,057,788	5,313,340	5,725,327	5,591,752	5,882,221	5,874,997	5,669,796	5,374,156	5,530,784	5,279,098	4%	-5%

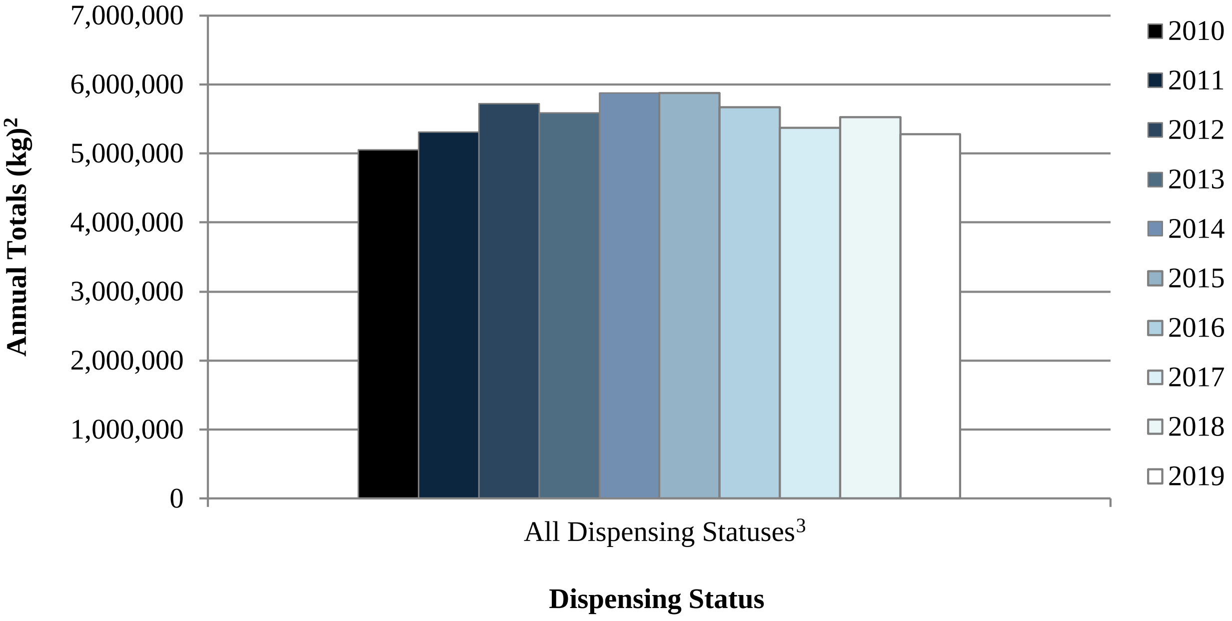
[1] Not Medically Important refers to any antimicrobial class not listed in Appendix A of FDA's Guidance for Industry #152.

[2] kg = kilogram of active ingredient. Antimicrobial class includes drugs of different molecular weights, with some drugs labeled in different salt forms. Antimicrobials that are labeled in International Units (IU) (e.g., Penicillins) were converted to kg.

[3] The All Dispensing Statuses category includes the following: OTC, Rx/OTC (excluding 2010 through 2015 and 2019), and VFD (excluding 2010 through 2015). There were fewer than three distinct sponsors marketing antimicrobial animal drugs in these categories. To protect confidential business information these data cannot be independently reported and are, therefore, combined into the All Dispensing Statuses category.

Figure 13a

Not medically important[1] antimicrobial drugs approved for use in food-producing animals
Actively marketed 2010-2019
Domestic sales and distribution data
Reported by dispensing status



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[1] Not Medically Important refers to any antimicrobial class not listed in Appendix A of FDA's Guidance for Industry #152.

[2] kg = kilogram of active ingredient. Antimicrobials that were reported in International Units (IU) (e.g., Penicillins) were converted to kg. Antimicrobial class includes drugs of different molecular weights, with some drugs reported in different salt forms.

[3] The All Dispensing Statuses category includes the following: OTC, Rx/OTC (excluding 2010 through 2015 and 2019), and VFD (excluding 2010 through 2015). There were fewer than three distinct sponsors marketing antimicrobial animal drugs in these categories. To protect confidential business information these data cannot be independently reported and are, therefore, combined into the All Dispensing Statuses category.

References

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  - https://www.fda.gov/animal-veterinary/safety-health/antimicrobial-resistance
- **FDA/CVM Webpage on Antimicrobial Resistance**
  - https://www.fda.gov/animal-veterinary/antimicrobial-resistance/national-antimicrobial-resistance-monitoring-system
- **FDA/CVM Webpage on the National Antimicrobial Resistance Monitoring System (NARMS)**
  - https://www.fda.gov/animal-veterinary/antimicrobial-resistance/national-antimicrobial-resistance-monitoring-system
- **FDA/CVM Webpage on Judicious Use of Antimicrobials**
  - https://www.fda.gov/animal-veterinary/antimicrobial-resistance/judicious-use-antimicrobials
- **FDA/CDER Webpage on Antimicrobial Resistance**
  - https://www.fda.gov/drugs/information-drug-class/antimicrobial-resistance-information-consumers-and-health-professionals
- **FDA Guidance for Industry #152**
  - “Evaluating the Safety of Antimicrobial New Animal Drugs with Regard to Their Microbiological Effects on Bacteria of Human Health Concern”
  - https://www.fda.gov/regulatory-information/search-fda-guidance-documents/cvm-gfi-152-evaluating-safety-antimicrobial-new-animal-drugs-regard-their-microbiological-effects
- **FDA Guidance for Industry #209**
  - “The Judicious Use of Medically Important Antimicrobial Drugs in Food-Producing Animals”
  - https://www.fda.gov/regulatory-information/search-fda-guidance-documents/cvm-gfi-209-judicious-use-medically-important-antimicrobial-drugs-food-producing-animals
- **FDA Guidance for Industry #213**
  - “New Animal Drugs and New Animal Drug Combination Products Administered in or on Medicated Feed or Drinking Water of Food-Producing Animals: Recommendations for Drug Sponsors for Voluntarily Aligning Product Use Conditions with GFI #209”
  - https://www.fda.gov/regulatory-information/search-fda-guidance-documents/cvm-gfi-213-new-animal-drugs-and-new-animal-drug-combination-products-administered-or-medicated-feed
- **FDA Final Rule on Antimicrobial Animal Drug Sales and Distribution Reporting**
  - https://www.federalregister.gov/documents/2016/05/11/2016-11082/antimicrobial-animal-drug-sales-and-distribution-reporting
- **FDA Proposed Rule on Antimicrobial Animal Drug Sales and Distribution Reporting**
  - https://www.federalregister.gov/documents/2015/05/20/2015-12081/antimicrobial-animal-drug-sales-and-distribution-reporting

Beta-Agonists: What Are They and Why Do We Use Them in Livestock Production?

What are beta-adrenergic receptor agonists?

Beta-adrenergic receptor agonists (beta-agonists, for short) are synthetic compounds that mimic some of the effects of naturally-occurring compounds by binding to beta-receptors on the surface of cells within the muscle, fat and other tissues of animals [1, 4]. Beta-agonists are used in human medicine for the treatment of conditions such as asthma [5]. However, other types of beta-agonists are used in livestock production to enhance growth and alter body composition.

How do they work?

Beta-agonists used in livestock production are mixed into animal feeds at precise levels [3]. They are consumed by animals during the last few weeks of life prior to marketing. Once they are absorbed into the bloodstream from the digestive tract, beta-agonists bind to a specific type of receptors on the surface of cells called beta-adrenergic receptors [4]. They stimulate the activity of these receptors leading to their name-beta-adrenergic receptor agonists. This stimulation results in a chain of events within the cell that alter metabolism, growth and other cellular events resulting in changes in the growth of muscle and fat tissue within the animal [1].

What beta-agonists are available for use in livestock production? In what species?

There are two beta-agonists compounds approved by the FDA for use in food animal species in the United States —ractopamine hydrochloride and zilpaterol hydrochloride. Ractopamine is approved for use in swine, turkeys and cattle, while zilpaterol is only approved for use in cattle [1, 3]. There are no beta-agonists approved for use in chicken or sheep. Ractopamine and zilpaterol are also approved for use in other countries around the world such a Brazil, Canada, South Korea and Mexico.

People are worried about antibiotic resistance due to the use of antibiotics in livestock production. Should we worry that the use of beta-agonists in livestock production will make the beta-agonists used in human medicine less effective?

Resistance to beta-agonists is not a concern for two reasons.

First, the goal of beta-agonist use in livestock is very different from that of antibiotics. Antibiotics are used to stop the growth of or kill bacteria. Antibiotic resistance develops due to changes in bacteria that make them able to survive antibiotic treatment. This makes certain bacteria resistant to certain antibiotics, decreasing the effectiveness of antibiotics to treat bacterial infections in humans and in animals. Beta-agonists, in contrast, target the cells of the individual animal that consumes them and not foreign cells within that animal. Bacteria are not affected by beta-agonists and therefore, cannot develop any resistance to them.

Second, the beta-agonists used in livestock production are different from those used in human medicine. The compounds ractopamine and zilpaterol are not used to treat any human condition or disease.

What are the benefits of using beta-agonists for livestock production?

Beta-agonists, like other technologies used in livestock production, increase the efficiency of production of lean meat. In swine, the use of ractopamine increases weight gain and reduces the amount of feed needed for that gain. It also leads to an increase in lean meat and at times, a reduction in fat in the carcass, therefore increasing lean meat yield [2]. Zilpaterol and ractopamine in cattle both increase weight gain and improve the efficiency of gain. Lean meat yield is also increased in cattle fed beta-agonists [1].

These improvements in production have many positive outcomes. Improved efficiency reduces the resources (grains, water, land) needed to produce meat. This improves the overall sustainability of livestock production by allowing more meat to be produced with less inputs [1].

How are beta-agonists different from steroid implants?

Implants contain natural and synthetic hormones and alter the hormone status of the animal to promote growth. Implants are placed in the ear of the cattle and require no withdrawal time prior to slaughter. Steroids are not approved for use in swine or poultry. Beta agonists, on the other hand, do not affect the hormone status of the animal. They are administered as medicated feed additives. Withdrawal times vary among products.

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This fact sheet was written by Anna Dilger, Ph.D., University of Illinois
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Beta-agonists, The Environment and Cattle Fatigue (Part 1)

In this part 1 of a two-part series, a K-State veterinarian provides a look into how environmental factors, including heat stress, coupled with the use of beta-agonists potentially plays a role in cattle fatigue.

Kansas State University | Published on: Sep 18, 2021

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In this part 1 of a two-part series, a K-State veterinarian provides a look into how environmental factors, including heat stress, coupled with the use of beta-agonists potentially plays a role in cattle fatigue.

In agricultural production, maintaining a level of excellence that includes environmental sustainability, animal welfare and food safety, while keeping food affordable for consumers is top-of-mind for many farmers and ranchers, as well as the researchers looking to help them find solutions to ensure this level of excellence.

As consumers shop at their local grocery stores and markets, they might notice that beef products are double or triple the price of other protein sources, and rightfully so, might hold beef to an even higher standard of excellence, said Dan Thomson, Kansas State University veterinarian, professor and director of the Beef Cattle Institute.

“Beef is one of the purest, most wholesome and most humanely raised forms of protein that we produce worldwide,” Thomson said. “As a beef industry, we are being asked day in and day out to take a holistic view of technology.”

The use of beta-agonists in cattle feeding is among the modern feedlot technologies making waves in the beef industry. K-State researchers, including Thomson, are among the many researchers who are examining how beta-agonists affect cattle performance and how the feed supplement might cause cattle, particularly in the summer months, to be slow-moving and stiff-muscled once they arrive at packing facilities.

“We’re going to learn more about the last 30 days on feed,” Thomson said of research on beta-agonists. “Do we have heat stress mitigation plans in place at the feeding facilities? Are we pushing that boundary of having too heavy weight carcasses? Are we using low-stress cattle handling techniques? How far away from the load out facility are the fat cattle being moved? Are we shipping them during the afternoon in the heat of the day, or are we shipping them at 2 a.m.? Are the truckers trained to properly transport these animals? How long do they wait at the slaughter facility? All of these different risk factors are going to have to be bundled in.”

History of beta-agonist use

Feedlots have used beta-agonists, a cattle feed supplement approved by the U.S. Food and Drug Administration (FDA) and considered safe from a food safety perspective, to improve the cattle’s natural ability to convert feed into more lean muscle.

Zilmax, formally known as zilpaterol hydrocholoride, is one of only two beta-agonists approved for cattle feeding on the market. However, Merck Animal Health, manufacturer of Zilmax, voluntarily suspended sales of the product last September when major U.S. meat packer Tyson announced it would stop buying cattle fed Zilmax due to an animal welfare concern, which questioned if the product affected the ambulatory ability, or movement, of cattle.

Thomson said that because the slow-moving cattle reports were more consistent during the summer months, he has questioned how heat stress and feeding beta-agonists might together create what he calls “cattle fatigue syndrome.”

“This isn’t a new phenomenon,” Thomson said. “We’ve seen this in other species. The swine industry 15 to 20 years ago discovered pig fatigue syndrome. It occurred about the time they started feeding beta-agonists at a very high level to pigs. Market hogs would arrive at the plant, and they were stiff, open-mouth breathing, had blotchy skin, muscle tremors and were going through stress.”

Thomson said many in the swine industry started calling these pigs “NANI” pigs, meaning non-ambulatory, non-injured.

“So these pigs show up (at the packing facility), and they don’t have any clinical signs of injury besides that they don't move," Thomson said. "(Researchers) did diagnostic tests to look at the difference between non-ambulatory pigs and pigs within the same truckload that were able to move. They found elevated serum lactate and creatine phosphokinase (CPK) levels, which are both indicative of depletion of muscle glucose or muscle damage in these big, heavily muscled animals."

Regardless of beta-agonist use in feeding pigs, Thomson said, the swine industry went from having about a 250-lb. average out weight to a 300-lb. average out weight on market hogs. So the hogs had more weight to carry around at the packing facility.

To see if beta-agonists played a role in the movement concerns, researchers did a series of tests on market hogs that were not fed beta-agonists. They put some through a stressful situation prior to shipping them to slaughter, while the others did not experience any stress.

"They were able to recreate the same syndrome that we're now seeing in some cattle," Thomson said. "Generally, physical stress, whether they were on a beta-agonist or not, showed clinical signs of fatigue in these market hogs."

Still, the swine industry has since cut the dose of beta-agonists in feeding by about 75 percent, Thomson said.

A closer look at cattle fatigue syndrome

The beef industry has a really good start on understanding what cattle fatigue syndrome is, Thomson said, but the reason more research must be done is that, like the NANI pigs, the syndrome has shown up in cattle that were fed a beta-agonist and cattle that were not fed a beta-agonist.

"In our research, when we've looked at cattle that are not stressed and they're on one of the beta-agonists on the market, we've not seen anything but an increase in heart rate by about 10 beats per minute and no difference in lactate or CPK levels," Thomson said. "However, we have to understand that when we have seen the issues with this fatigue cattle syndrome at packing facilities, it's during the summer months when we have heat stress."

Moving forward, Thomson said the industry needs to better-understand the clinical and physiological responses of beta-agonists in cattle, if dosages in cattle feeding rations might need to be altered and if there is a potential genetic component to it as well.

Advice for feedlot operators

Thomson said that he is very pro-technology. While Merck recently announced that it is too early to determine when Zilmax will return to the market (http://www.merck-animal-health-usa.com/news/2013-12-13.aspx), many feedlots might have switched to using a competing beta-agonist called Optaflexx, or ractopamine.

As long as beta-agonists are available, approved by the FDA, accepted by the consumer and work in a particular management system to improve efficiency of animals and profitability, then it is fine to use them, he said. But, the industry must always look at ways to improve and make sure technologies are continuously helping.

“We’re given a job, task and responsibility, and we don’t take it lightly,” Thomson said.

This story is part 1 of a two-part series on how beta-agonists and environmental factors potentially play a role in cattle fatigue and feed efficiency. Click here to learn about beta-agonists, the environment and feed efficiency (link to part 2).

To watch an interview with Thomson on this subject, log on to the K-State Research and Extension YouTube channel (http://www.youtube.com/watch?v=LjSNCKcvOOg).

K-State Research and Extension is a short name for the Kansas State University Agricultural Experiment Station and Cooperative Extension Service, a program designed to generate and distribute useful knowledge for the well-being of Kansans. Supported by county, state, federal and private funds, the program has county Extension offices, experiment fields, area Extension offices and regional research centers statewide. Its headquarters is on the K-State campus, Manhattan.

Story by:
Katie Allen, Communications Specialist, News Media and Marketing Services –

ENVIRONMENTAL HEALTH

Understanding Concentrated Animal Feeding Operations and Their Impact on Communities

NALBOH

National Association of Local Boards of Health

Understanding
Concentrated Animal Feeding Operations
and Their Impact on Communities

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Foreword

The National Association of Local Boards of Health (NALBOH) is pleased to provide *Understanding Concentrated Animal Feeding Operations and Their Impact on Communities* to assist local boards of health who have concerns about concentrated animal feeding operations (CAFOs) or large industrial animal farms in their communities. The Environmental Health Services Branch of the Centers for Disease Control and Prevention (CDC), National Center for Environmental Health (NCEH) encouraged the development of this product and provided technical oversight and financial support. This publication was supported by Cooperative Agreement Number 5U38HM000512. Its contents are solely the responsibility of the authors and do not necessarily represent the official views of the CDC.

The mission of NALBOH is to strengthen boards of health, enabling them to promote and protect the health of their communities, through education, technical assistance, and advocacy. Boards of health are responsible for fulfilling three public health core functions: assessment, policy development, and assurance. For a health agency, this includes overseeing and ensuring that there are sufficient resources, effective policies and procedures, partnerships with other organizations and agencies, and regular evaluation of an agency's services.

NALBOH is confident that *Understanding Concentrated Animal Feeding Operations and Their Impact on Communities* will help local board of health members understand their role in developing ways to mitigate potential problems associated with CAFOs. We trust that the information provided in this guide will enable board of health members to develop and sustain monitoring programs, investigate developing policy related to CAFOs, and create partnerships with other local and state agencies and officials to improve the health and well-being of communities everywhere.

A special thanks to Jeffrey Neistadt (NALBOH's Director – Education and Training), NALBOH's Environmental Health subcommittee, and any local board of health members and health department staff who were contacted during the development of this document for their contributions and support.

Notes

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Introduction

Livestock farming has undergone a significant transformation in the past few decades. Production has shifted from smaller, family-owned farms to large farms that often have corporate contracts. Most meat and dairy products now are produced on large farms with single species buildings or open-air pens (MacDonald & McBride, 2009). Modern farms have also become much more efficient. Since 1960, milk production has doubled, meat production has tripled, and egg production has quadrupled (Pew Commission on Industrial Animal Farm Production, 2009). Improvements to animal breeding, mechanical innovations, and the introduction of specially formulated feeds and animal pharmaceuticals have all increased the efficiency and productivity of animal agriculture. It also takes much less time to raise a fully grown animal. For example, in 1920, a chicken took approximately 16 weeks to reach 2.2 lbs., whereas now they can reach 5 lbs. in 7 weeks (Pew, 2009).

New technologies have allowed farmers to reduce costs, which mean bigger profits on less land and capital. The current agricultural system rewards larger farms with lower costs, which results in greater profit and more incentive to increase farm size.

AFO vs. CAFO

A CAFO is a specific type of large-scale industrial agricultural facility that raises animals, usually at high-density, for the consumption of meat, eggs, or milk. To be considered a CAFO, a farm must first be categorized as an animal feeding operation (AFO). An AFO is a lot or facility where animals are kept confined and fed or maintained for 45 or more days per year, and crops, vegetation, or forage growth are not sustained over a normal growing period (Environmental Protection Agency [EPA], 2009). CAFOs are classified by the type and number of animals they contain, and the way they discharge waste into the water supply. CAFOs are AFOs that contain at least a certain number of animals, or have a number of animals that fall within a range and have waste materials that come into contact with the water supply. This contact can either be through a pipe that carries manure or wastewater to surface water, or by animal contact with surface water that runs through their confined area. (See Appendix A)

History

AFOs were first identified as potential pollutants in the 1972 Clean Water Act. Section 502 identified “feedlots” as “point sources” for pollution along with other industries, such as fertilizer manufacturing. Consequently, a permit program entitled the National Pollutant Discharge Elimination System (NPDES) was created which set effluent limitation guidelines and standards (ELGs) for CAFOs. CAFOs have since been regulated by NPDES or a state equivalent since the mid-1970s. The definitions of what was considered an AFO or CAFO were created by the EPA for the NPDES process in 1976. These regulations remained in effect for more than 25 years, but increases and changes to farm size and production methods required an update to the permit system.

The regulations guiding CAFO permits and operations were revised in 2003. New inclusions in the 2003 regulations were that all CAFOs had to apply for a NPDES permit even if they only discharged in the event of a large storm. Large poultry operations were included in the regulations, regardless of their waste disposal system, and all CAFOs that held a NPDES permit were required to develop and implement a nutrient management plan. These plans had CAFOs identify ways to treat or process waste in a way that maintained nutrient levels at the appropriate amount.

The 2003 CAFO rule was subsequently challenged in court. A Second Circuit Court of Appeals decision required alteration to the CAFO permitting system. In *Water Keeper et al. vs. the EPA*, the court directed the EPA to remove the requirement for all CAFOs to apply for NPDES. Instead, the court required that nutrient management plans be submitted with the permit application, reviewed by officials and the public, and the terms of the plan be incorporated into the permit.

As a result of this court decision, the CAFO rule was again updated. The current final CAFO rule, which was revised in 2008, requires that only CAFOs which discharge or propose to discharge waste apply for permits. The EPA has also provided clarification in the discussion surrounding the rule on how CAFOs should assess whether they discharge or propose to discharge. There is also the opportunity to receive a no discharge certification for CAFOs that do not discharge or propose to discharge. This certification demonstrates that the CAFO is not required to acquire a permit. And while CAFOs were required to create nutrient management plans under the 2003 rule, these plans were now included with permit applications, and had a built-in time period for public review and comment.

Benefits of CAFOs

When properly managed, located, and monitored, CAFOs can provide a low-cost source of meat, milk, and eggs, due to efficient feeding and housing of animals, increased facility size, and animal specialization. When CAFOs are proposed in a local area, it is usually argued that they will enhance the local economy and increase employment. The effects of using local materials, feed, and livestock are argued to ripple throughout the economy, and increased tax expenditures will lead to increase funds for schools and infrastructure.

Environmental Health Effects

The most pressing public health issue associated with CAFOs stems from the amount of manure they produce. CAFO manure contains a variety of potential contaminants. It can contain plant nutrients such as nitrogen and phosphorus, pathogens such as *E. coli*, growth hormones, antibiotics, chemicals used as additives to the manure or to clean equipment, animal blood, silage leachate from corn feed, or copper sulfate used in footbaths for cows.

Depending on the type and number of animals in the farm, manure production can range between 2,800 tons and 1.6 million tons a year (Government Accountability Office [GAO], 2008). Large farms can produce more waste than some U.S. cities—a feeding operation with 800,000 pigs could produce over 1.6 million tons of waste a year. That amount is one and a half times more than the annual sanitary waste produced by the city of Philadelphia, Pennsylvania (GAO, 2008). Annually, it is estimated that livestock animals in the U.S. produce each year somewhere between 3 and 20 times more manure than people in the U.S. produce, or as much as 1.2–1.37 billion tons of waste (EPA, 2005). Though sewage treatment plants are required for human waste, no such treatment facility exists for livestock waste.

While manure is valuable to the farming industry, in quantities this large it becomes problematic. Many farms no longer grow their own feed, so they cannot use all the manure they produce as fertilizer. CAFOs must find a way to manage the amount of manure produced by their animals. Ground application of untreated manure is one of the most common disposal methods due to its low cost. It has limitations, however, such as the inability to apply manure while the ground is frozen. There are also limits as to how many nutrients from manure a land area can handle. Over application of livestock wastes can overload soil with macronutrients like nitrogen and phosphorous and micronutrients that have been added to animal feed like heavy metals (Burkholder et al., 2007). Other manure management strategies include pumping liquefied manure onto spray fields, trucking it off-site, or storing it until it can be used or treated. Manure can be stored in deep pits under the buildings that hold animals, in clay or concrete pits, treatment lagoons, or holding ponds.

Animal feeding operations are developing in close proximity in some states, and fields where manure is applied have become clustered. When manure is applied too frequently or in too large a quantity to an area, nutrients overwhelm the absorptive capacity of the soil, and either run off or are leached into the groundwater. Storage units can break or become faulty, or rainwater can cause holding lagoons to overflow. While CAFOs are required to have permits that limit the levels of manure discharge, handling the large amounts of manure inevitably causes accidental releases which have the ability to potentially impact humans.

The increased clustering and growth of CAFOs has led to growing environmental problems in many communities. The excess production of manure and problems with storage or manure management can affect ground and surface water quality. Emissions from degrading manure and livestock digestive processes produce air pollutants that often affect ambient air quality in communities surrounding CAFOs. CAFOs can also be the source of greenhouse gases, which contribute to global climate change.

All of the environmental problems with CAFOs have direct impact on human health and welfare for communities that contain large industrial farms. As the following sections demonstrate, human health can suffer because of contaminated air and degraded water quality, or from diseases spread from farms. Quality of life can suffer because of odors or insect vectors surrounding farms, and property values can drop, affecting the financial stability of a community. One study found that 82.8% of those living near and 89.5% of those living far from CAFOs believed that their property values decreased, and 92.2% of those living near and 78.9% of those living far from CAFOs believed the odor from manure was a problem. The study found that real estate values had not dropped and odor infestations were not validated by local governmental staff in the areas. However, the concerns show that CAFOs remain contentious in communities (Schmalzried and Fallon, 2007). CAFOs are an excellent example of how environmental problems can directly impact human and community well-being.

Groundwater

Groundwater can be contaminated by CAFOs through runoff from land application of manure, leaching from manure that has been improperly spread on land, or through leaks or breaks in storage or containment units. The EPA's 2000 National Water Quality Inventory found that 29 states specifically identified animal feeding operations, not just concentrated animal feeding operations, as contributing to water quality impairment (Congressional Research Service, 2008). A study of private water wells in Idaho detected levels of veterinary antibiotics, as well as elevated levels of nitrates (Batt, Snow, & Alga, 2006). Groundwater is a major source of drinking water in the United States. The EPA estimates that 53% of the population relies on groundwater for drinking water, often at much higher rates in rural areas (EPA, 2004). Unlike surface water, groundwater contamination sources are more difficult to monitor. The extent and source of contamination are often harder to pinpoint in groundwater than surface water contamination. Regular testing of household water wells for total and fecal coliform bacteria is a crucial element in monitoring groundwater quality, and can be the first step in discovering contamination issues related to CAFO discharge. Groundwater contamination can also affect surface water (Spellman &

Whiting, 2007). Contaminated groundwater can move laterally and eventually enter surface water, such as rivers or streams.

When groundwater is contaminated by pathogenic organisms, a serious threat to drinking water can occur. Pathogens survive longer in groundwater than surface water due to lower temperatures and protection from the sun. Even if the contamination appears to be a single episode, viruses could become attached to sediment near groundwater and continue to leach slowly into groundwater. One pollution event by a CAFO could become a lingering source of viral contamination for groundwater (EPA, 2005).

Groundwater can still be at risk for contamination after a CAFO has closed and its lagoons are empty. When given increased air exposure, ammonia in soil transforms into nitrates. Nitrates are highly mobile in soil, and will reach groundwater quicker than ammonia. It can be dangerous to ignore contaminated soil. The amount of pollution found in groundwater after contamination depends on the proximity of the aquifer to the CAFO, the size of the CAFO, whether storage units or pits are lined, the type of subsoil, and the depth of the groundwater.

If a CAFO has contaminated a water system, community members should be concerned about nitrates and nitrate poisoning. Elevated nitrates in drinking water can be especially harmful to infants, leading to blue baby syndrome and possible death. Nitrates oxidize iron in hemoglobin in red blood cells to methemoglobin. Most people convert methemoglobin back to hemoglobin fairly quickly, but infants do not convert back as fast. This hinders the ability of the infant's blood to carry oxygen, leading to a blue or purple appearance in affected infants. However, infants are not the only ones who can be affected by excess nitrates in water. Low blood oxygen in adults can lead to birth defects, miscarriages, and poor general health. Nitrates have also been speculated to be linked to higher rates of stomach and esophageal cancer (Bowman, Mueller, & Smith, 2000). In general, private water wells are at higher risk of nitrate contamination than public water supplies.

Surface Water

The agriculture sector, including CAFOs, is the leading contributor of pollutants to lakes, rivers, and reservoirs. It has been found that states with high concentrations of CAFOs experience on average 20 to 30 serious water quality problems per year as a result of manure management problems (EPA, 2001). This pollution can be caused by surface discharges or other types of discharges. Surface discharges can be caused by heavy storms or floods that cause storage lagoons to overfill, running off into nearby bodies of water. Pollutants can also travel over land or through surface drainage systems to nearby bodies of water, be discharged through manmade ditches or flushing systems found in CAFOs, or come into contact with surface water that passes directly through the farming area. Soil erosion can contribute to water pollution, as some pollutants can bond to eroded soil and travel to watersheds (EPA, 2001). Other types of discharges occur when pollutants travel to surface water through other mediums, such as groundwater or air.

Contamination in surface water can cause nitrates and other nutrients to build up. Ammonia is often found in surface waters surrounding CAFOs. Ammonia causes oxygen depletion from water, which itself can kill aquatic life. Ammonia also converts into nitrates, which can cause nutrient overloads in surface waters (EPA, 1998). Excessive nutrient concentrations, such as nitrogen or phosphorus, can lead to eutrophication and make water inhabitable to fish or indigenous aquatic life (Sierra Club Michigan Chapter, n.d.). Nutrient over-enrichment causes algal blooms, or a rapid increase of algae growth in an aquatic environment (Science Daily, n.d.). Algal blooms can cause a spiral of environmental problems to an aquatic system. Large groups of algae can block sunlight from underwater plant life, which are habitats for much aquatic life. When algae growth increases in surface water, it can also dominate other resources and cause plants to die. The dead plants provide fuel for bacteria to grow and increased bacteria use more of the water's oxygen supply. Oxygen depletion once again causes indigenous aquatic life to die. Some algal blooms can contain toxic algae and other microorganisms, including *Pfiesteria*, which has caused large fish kills in North Carolina, Maryland, and the Chesapeake Bay area (Spellman & Whiting, 2007). Eutrophication can cause serious problems in surface waters and disrupt the ecological balance.

Water tests have also uncovered hormones in surface waters around CAFOs (Burkholder et al., 2007). Studies show that these hormones alter the reproductive habits of aquatic species living in these waters, including a significant decrease in the fertility of female fish. CAFO runoff can also lead to the presence of fecal bacteria or pathogens in surface water. One study showed that protozoa such as *Cryptosporidium parvum* and *Giardia* were found in over 80% of surface water sites tested (Spellman & Whiting, 2007). Fecal bacteria pollution in water from manure land application is also responsible for many beach closures and shellfish restrictions.

Air Quality

In addition to polluting ground and surface water, CAFOs also contribute to the reduction of air quality in areas surrounding industrial farms. Animal feeding operations produce several types of air emissions, including gaseous and particulate substances, and CAFOs produce even more emissions due to their size. The primary cause of gaseous emissions is the decomposition of animal manure, while particulate substances are caused by the movement of animals. The type, amount, and rate of emissions created depends on what state the manure is in (solid, slurry, or liquid), and how it is treated or contained after it is excreted. Sometimes manure is "stabilized" in anaerobic lagoons, which reduces volatile solids and controls odor before land application.

The most typical pollutants found in air surrounding CAFOs are ammonia, hydrogen sulfide, methane, and particulate matter, all of which have varying human health risks. Table 1 on page 6 provides information on these pollutants.

Most manure produced by CAFOs is applied to land eventually and this land application can result in air emissions (Merkel, 2002). The primary cause of emission through land application is the volatilization of ammonia when the manure is applied to land. However, nitrous oxide is also created when nitrogen that has been applied to land undergoes nitrification and denitrification. Emissions caused by land application occur in two phases: one immediately following land application and one that occurs later and over a longer period as substances in the soil break down. Land application is not the only way CAFOs can emit harmful air emissions—ventilation systems in CAFO buildings can also release dangerous contaminants. A study by Iowa State University, which was a result of a lawsuit settlement between the Sierra Club and Tyson Chicken, found that two chicken houses in western Kentucky emitted over 10 tons of ammonia in the year they were monitored (Burns et al., 2007).

Most studies that examine the health effects of CAFO air emissions focus on farm workers, however some have studied the effect on area schools and children. While all community members are at risk from lowered air quality, children take in 20-50% more air than adults, making them more susceptible to lung disease and health effects (Kleinman, 2000). Researchers in North Carolina found that the closer children live to a CAFO, the greater the risk of asthma symptoms (Barrett, 2006). Of the 226 schools that were included in the study, 26% stated that there were noticeable odors from CAFOs outdoors, while 8% stated

Table 1 Typical pollutants found in air surrounding CAFOs.

CAFO Emissions	Source	Traits	Health Risks
Ammonia	Formed when microbes decompose undigested organic nitrogen compounds in manure	Colorless, sharp pungent odor	Respiratory irritant, chemical burns to the respiratory tract, skin, and eyes, severe cough, chronic lung disease
Hydrogen Sulfide	Anaerobic bacterial decomposition of protein and other sulfur containing organic matter	Odor of rotten eggs	Inflammation of the moist membranes of eye and respiratory tract, olfactory neuron loss, death
Methane	Microbial degradation of organic matter under anaerobic conditions	Colorless, odorless, highly flammable	No health risks. Is a greenhouse gas and contributes to climate change.
Particulate Matter	Feed, bedding materials, dry manure, unpaved soil surfaces, animal dander, poultry feathers	Comprised of fecal matter, feed materials, pollen, bacteria, fungi, skin cells, silicates	Chronic bronchitis, chronic respiratory symptoms, declines in lung function, organic dust toxic syndrome

they experience odors from CAFOs inside the schools. Schools that were closer to CAFOs were often attended by students of lower socioeconomic status (Mirabelli, Wing, Marshall, & Wilcosky, 2006).

There is consistent evidence suggesting that factory farms increase asthma in neighboring communities, as indicated by children having higher rates of asthma (Sigurdarson & Kline, 2006; Mirabelli et al., 2006). CAFOs emit particulate matter and suspended dust, which is linked to asthma and bronchitis. Smaller particles can actually be absorbed by the body and can have systemic effects, including cardiac arrest. If people are exposed to particulate matter over a long time, it can lead to decreased lung function (Michigan Department of Environmental Quality [MDEQ] Toxics Steering Group [TSG], 2006). CAFOs also emit ammonia, which is rapidly absorbed by the upper airways in the body. This can cause severe coughing and mucous build-up, and if severe enough, scarring of the airways. Particulate matter may lead to more severe health consequences for those exposed by their occupation. Farm workers can develop acute and chronic bronchitis, chronic obstructive airways disease, and interstitial lung disease. Repeated exposure to CAFO emissions can increase the likelihood of respiratory diseases. Occupational asthma, acute and chronic bronchitis, and organic dust toxic syndrome can be as high as 30% in factory farm workers

(Horrigan, Lawrence, & Walker, 2002). Other health effects of CAFO air emissions can be headaches, respiratory problems, eye irritation, nausea, weakness, and chest tightness.

There is evidence that CAFOs affect the ambient air quality of a community. There are three laws that potentially govern CAFO air emissions—the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA, also known as the Superfund Act), the Emergency Planning & Community Right to Know Act (EPCRA), and the Clean Air Act (CAA). However, the EPA passed a rule that exempts all CAFOs from reporting emissions under CERCLA. Only CAFOs that are classified as large are required to report any emission event of 100 pounds of ammonia or hydrogen sulfide or more during a 24-hour period locally or to the state under EPCRA (Michigan State University Extension, n.d.). The EPA has also instituted a voluntary Air Quality Compliance Agreement in which they will monitor some CAFO air emissions, and will not sue offenders but instead charge a small civil penalty. These changes have attracted criticism from environmental and community leaders who state that the EPA has yielded to influence from the livestock industry. The changes also leave ambiguity as to whether emission standards and air quality near CAFOs are being monitored.

Greenhouse Gas and Climate Change

Aside from the possibility of lowering air quality in the areas around them, CAFOs also emit greenhouse gases, and therefore contribute to climate change. Globally, livestock operations are responsible for approximately 18% of greenhouse gas production and over 7% of U.S. greenhouse gas emissions (Massey & Ulmer, 2008). While carbon dioxide is often considered the primary greenhouse gas of concern, manure emits methane and nitrous oxide which are 23 and 300 times more potent as greenhouse gases than carbon dioxide, respectively. The EPA attributes manure management as the fourth leading source of nitrous oxide emissions and the fifth leading source of methane emissions (EPA, 2009).

The type of manure storage system used contributes to the production of greenhouse gases. Many CAFOs store their excess manure in lagoons or pits, where they break down anaerobically (in the absence of oxygen), which exacerbates methane production. Manure that is applied to land or soil has more exposure to oxygen and therefore does not produce as much methane. Ruminant livestock, such as cows, sheep, or goats, also contribute to methane production through their digestive processes. These livestock have a special stomach called a rumen that allows them to digest tough grains or plants that would otherwise be unusable. It is during this process, called enteric fermentation, that methane is produced. The U.S. cattle industry is one of the primary methane producers. Livestock production and meat and dairy consumption has been increasing in the United States, so it can only be assumed that these greenhouse gas emissions will also rise and continue to contribute to climate change.

Odors

One of the most common complaints associated with CAFOs are the odors produced. The odors that CAFOs emit are a complex mixture of ammonia, hydrogen sulfide, and carbon dioxide, as well as volatile and semi-volatile organic compounds (Heederik et al., 2007). These odors are worse than smells formerly associated with smaller livestock farms. The anaerobic reaction that occurs when manure is stored in pits or lagoons for long amounts of time is the primary cause of the smells. Odors from waste are carried away from farm areas on dust and other air particles. Depending on things like weather conditions and farming techniques, CAFO odors can be smelled from as much as 5 or 6 miles away, although 3 miles is a more common distance (State Environmental Resource Center, 2004).

Because CAFOs typically produce malodors, many communities want to monitor emissions and odors. Quantifying odor from industrial farming can be challenging because it is a mixture of free and particle-bound compounds, which can make it hard to identify what specifically is causing the odor. Collecting data on specific gases, such as hydrogen sulfide, can be used as a proxy for odor levels.

CAFO odors can cause severe lifestyle changes for individuals in the surrounding communities and can alter many daily activities. When odors are severe, people may choose to keep their windows closed, even in high temperatures when there is no air conditioning. People also may choose to not let their children play outside and may even keep them home from school. Mental health deterioration and an increased sensitization to smells can also result from living in close proximity to odors from CAFOs. Odor can cause negative mood states, such as tension, depression, or anger, and possibly neurophysciatric abnormalities, such as impaired balance or memory. People who live close to factory farms can develop CAFO-related post traumatic stress disorder, including anxiety about declining quality of life (Donham et al., 2007).

Ten states use direct regulations to control odors emitted by CAFOs. They prohibit odor emissions greater than a set standard. States with direct regulations use scentometers, which measure how many times an odor has to be doused with clean air before the smell is undetectable. An additional 34 states have indirect methods to reduce CAFO odors. These include: setbacks, which specify how far CAFO structures have to be from other buildings; permits, which are the most typical way of regulating CAFOs; public comment or involvement periods; and operator or manure placement training.

Insect Vectors

CAFOs and their waste can be breeding grounds for insect vectors. Houseflies, stable flies, and mosquitoes are the most common insects associated with CAFOs. Houseflies breed in manure, while stable and other flies breed in decaying organic material, such as livestock bedding. Mosquitoes breed in standing water, and water on the edges of manure lagoons can cause mosquito infestations to rise. Flies can change from eggs to adults in only 10 days, which means that substances in which flies breed need to be cleaned up regularly.

Flies are typically considered only nuisances, although insects can agitate livestock and decrease animal health. The John Hopkins Bloomberg School of Public Health found evidence that houseflies near poultry operations may contribute to the dispersion of drug-resistant bacteria (Center for Livable Future, 2009). Since flies are attracted to and eat human food, there is a potential for spreading bacteria or pathogens to humans, including microbes that can cause dysentery and diarrhea (Bowman et al., 2000). Mosquitoes spread zoonotic diseases, such as West Nile virus, St. Louis encephalitis, and equine encephalitis.

Residences closest to the feeding operations experience a much higher fly population than average homes. To lower the rates of insects and any accompanying disease threats, standing water should we cleaned or emptied weekly, and manure or decaying organic matter should be removed twice weekly (Purdue Extension, 2007). For more specific insect vector information, please refer to NALBOH's vector guide (*Vector Control Strategies for Local Boards of Health*).

Pathogens

Pathogens are parasites, bacterium, or viruses that are capable of causing disease or infection in animals or humans. The major source of pathogens from CAFOs is in animal manure. There are over 150 pathogens in manure that could impact human health. Many of these pathogens are concerning because they can cause severe diarrhea. Healthy people who are exposed to pathogens can generally recover quickly, but those who have weakened immune systems are at increased risk for severe illness or death. Those at higher risk include infants or young children, pregnant women, the elderly, and those who are immunosuppressed, HIV positive, or have had chemotherapy. This risk group now roughly compromises 20% of the U.S. population.

Table 2 Select pathogens found in animal manure.

Pathogen	**Disease**	**Symptoms**
Bacillus anthracis	Anthrax	Skin sores, headache, fever, chills, nausea, vomiting
Escherichia coli	Colibacilosis, Coliform mastitis-metris	Diarrhea, abdominal gas
Leptospira pomona	Leptospirosis	Abdominal pain, muscle pain, vomiting, fever
Listeria monocytogenes	Listerosis	Fever, fatigue, nausea, vomiting, diarrhea
Salmonella species	Salmonellosis	Abdominal pain, diarrhea, nausea, chills, fever, headache
Clostirdum tetani	Tetanus	Violent muscle spasms, lockjaw, difficulty breathing
Histoplasma capsulatum	Histoplasmosis	Fever, chills, muscle ache, cough rash, joint pain and stiffness
Microsporum and *Trichophyton*	Ringworm	Itching, rash
Giardia lamblia	Giardiasis	Diarrhea, abdominal pain, abdominal gas, nausea, vomiting, fever
Cryptosporidium species	Cryptosporidosis	Diarrhea, dehydration, weakness, abdominal cramping

Sources of infection from pathogens include fecal-oral transmission, inhalation, drinking water, or incidental water consumption during recreational water activities. The potential for transfer of pathogens among animals is higher in confinement, as there are more animals in a smaller amount of space. Healthy or asymptomatic animals may carry microbial agents that can infect humans, who can then spread that infection throughout a community, before the infection is discovered among animals.

When water is contaminated by pathogens, it can lead to widespread outbreaks of illness. Salmonellosis, cryptosporidiosis, and giardiasis can cause nausea, vomiting, fever, diarrhea, muscle pain, and death, among other symptoms. *E.coli* is another serious pathogen, and can be life-threatening for the young, elderly, and immunocompromised. It can cause bloody diarrhea and kidney failure. Since many CAFO use sub-therapeutic antibiotics with their animals, there is also the possibility that disease-resistant bacteria can emerge in areas surrounding CAFOs. Bacteria that cannot be treated by antibiotics can have very serious effects on human health, potentially even causing death (Pew Charitable Trusts, n.d.).

There is also the possibility of novel (or new) viruses developing. These viruses generate through mutation or recombinant events that can result in more efficient human-to-human transmission. There has been some speculation that the novel H1N1 virus outbreak in 2009 originated in swine CAFOs in Mexico. However, that claim has never been substantiated. CAFOs are not required to test for novel viruses, since they are not on the list of mandatory reportable illness to the World Organization for Animal Health.

Antibiotics

Antibiotics are commonly administered in animal feed in the United States. Antibiotics are included at low levels in animal feed to reduce the chance for infection and to eliminate the need for animals to expend energy fighting off bacteria, with the assumption that saved energy will be translated into growth. The main purposes of using non-therapeutic doses of antimicrobials in animal feed is so that animals will grow faster, produce more meat, and avoid illnesses. Supporters of antibiotic use say that it allows animals to digest their food more efficiently, get the most benefit from it, and grow into strong and healthy animals.

The trend of using antibiotics in feed has increased with the greater numbers of animals held in confinement. The more animals that are kept in close quarters, the more likely it is that infection or bacteria can spread among the animals. Seventy percent of all antibiotics and related drugs used in the U.S. each year are given to beef cattle, hogs, and chickens as feed additives. Nearly half of the antibiotics used are nearly identical to ones given to humans (Kaufman, 2000).

There is strong evidence that the use of antibiotics in animal feed is contributing to an increase in antibiotic-resistant microbes and causing antibiotics to be less effective for humans (Kaufman, 2000). Resistant strains of pathogenic bacteria in animals, which can be transferred to humans thought the handling or eating of meat, have increased recently. This is a serious threat to human health because fewer options exist to help people overcome disease when infected with antibiotic-resistant pathogens. The antibiotics often are not fully metabolized by animals, and can be present in their manure. If manure pollutes a water supply, antibiotics can also leech into groundwater or surface water.

Because of this concern for human health, there is a growing movement to eliminate the non-therapeutic use of antibiotics with animals. In 2001, the American Medical Association approved a resolution to ban all low-level use of antibiotics. The USDA has developed guidelines to limit low-level use, and some major meat buyers (such as McDonald's) have stopped using meat that was given antibiotics that are also used for humans. The World Health Organization is also widely opposed to the use of antibiotics, calling for a cease of their low-level use in 2003. Some U.S. legislators are seeking to ban the routine use of antibiotics with livestock, and there has been legislation proposed to solidify a ban. The Preservation of Antibiotics for Medical Treatment Act (PAMTA), which was introduced in 2009, has the support of over 350 health, consumer, and environmental groups (H.R. 1549/S. 619). The act, if passed, would ban seven classes of antibiotics important to human health from being used in animals, and would restrict other antibiotics to therapeutic and some preventive uses.

Other Effects – Property Values

Most landowners fear that when CAFOs move into their community their property values will drop significantly. There is evidence that CAFOs do affect property values. The reasons for this are many: the fear of loss of amenities, the risk of air or water pollution, and the increased possibility of nuisances related to odors or insects. CAFOs are typically viewed as a negative externality that can't be solved or cured. There may be stigma that is attached to living by a CAFO.

The most certain fact regarding CAFOs and property values are that the closer a property is to a CAFO, the more likely it will be that the value of the property will drop. The exact impact of CAFOs fluctuates depending on location and local specifics. Studies have found differing results of rates of property value decrease. One study shows that property value declines can range from a decrease of 6.6% within a 3-mile radius of a CAFO to an 88% decrease within 1/10 of a mile from a CAFO (Dakota Rural Action, 2006). Another study found that property value decreases are negligible beyond 2 miles away from a CAFO (Purdue Extension, 2008). A third study found that negative effects are largest for properties that are downwind and closest to livestock (Herriges, Secchi, & Babcock, 2005). The size and type of the feeding operation can affect property value as well. Decreases in property values can also cause property tax rates to drop, which can place stress on local government budgets.

Considerations for Boards of Health

Right-to-Farm Laws

With all of the potential environmental and public health effects from CAFOs, community members and health officials often resort to taking legal action against these industrial animal farms. However, there are some protections for farms in place that can make lawsuits hard to navigate. Right-to-farm laws were created to address conflicts between farmers and non-farming neighbors. They seek to override common laws of nuisance, which forbid people to use their property in ways that are harmful to others, and protect farmers from unreasonable controls on farming.

All 50 states have some form of right-to-farm laws, but most only offer legal protections to farms if they meet certain specifications. Generally, they must be in compliance with all environmental regulations, be properly run, and be present in a region first before suburban developments, often a year before the plaintiff moves to that area. These right-to-farm laws were originally created in the late 1970s and early 1980s to protect family farms from suburban sprawl, at a time when large industrial farms were not the norm. As industrial farms grew in size and number, the agribusiness industry lobbied for and achieved the passage of stricter laws in the 1990s, many of which are now being challenged in court by homeowners and small family farmers. Opponents to these laws argue that they deprive them of their use of property and therefore violate the Fifth Amendment to the Constitution.

Some state courts have overturned their strict right-to-farm laws, such as Iowa, Michigan, Minnesota, and Kansas. Others such as Vermont have rewritten their laws. Vermont's updated right-to-farm bill protects established farm practices as long as there is not a substantial adverse effect on health, safety, or welfare.

Boards of health need to be aware of what legal protection their state offers farms. Right-to-farm laws can hinder nuisance complaints brought about by community members. State laws can prevent local government or health officials from regulating industrial farms.

Board of Health Involvement with CAFOs

Boards of health are responsible for fulfilling the three public health core functions: assessment, policy development, and assurance. Boards of health can fulfill these functions through addressing problems stemming from CAFOs in their communities. Specific public health services that can tackled regarding CAFOs include monitoring health status, investigating health problems, developing policies, enforcing regulations, informing and educating people about CAFOs, and mobilizing community partnerships to spread awareness about environmental health issues related to CAFOs.

Assessment: Board of health members should ensure that there is an effective method in place for collecting and tracking public complaints about CAFOs and large animal farms. Since environmental health specialists at local health departments are often responsible for investigating complaints, the board of health must take measures to ensure that they are properly trained and educated about CAFOs. It is possible that the board of health may be responsible or choose to do some investigations itself. Schmalzried and Fallon (2008) advocate that local health districts adopt a proactive approach for addressing public concerns about CAFOs, stating that health districts can offer some services that may help ease public frustration with CAFOs. A fly trapping program can establish a baseline for the average number of flies present prior to the start-up of CAFOs or large animal farms, which can then establish if a fly nuisance exists in the area. Testing for water quality and quantity can provide evidence if CAFOs are suspected of affecting private water supplies. Boards of health can also monitor exposure incidences that occur in emergency rooms to determine if migrant or farm workers are developing any adverse health conditions as a result of their work environments. Establishing these programs benefit both members of the community and provide information to future animal farm operators, and local boards of health should recommend them if they've been receiving complaints about CAFOs.

Policy Development: Boards of health in many states can adopt health-based regulations about CAFOs, however, they may be met with some resistance. Humbolt County, Iowa, adopted four health-based ordinances concerning CAFOs that became models for regulations in other states, but the Iowa Supreme Court ruled the ordinances were irreconcilable with state laws. Boards of health that choose to regulate CAFOs can also be subject to pressure from outside forces, including possible lawsuits or withdrawal of funding. Boards of health should also consider working with other local officials to institute regulations on CAFOs, such as zoning ordinances.

Assurance: Boards of health can execute the assurance function by advocating for or educating about better environmental practices with CAFOs. Board members may receive complaints from the public about CAFOs, and boards can hold public meetings to receive complaints and hear public testimony about farms. If boards of health are not capable of regulating industrial farms in their communities, they can still try to collaborate with other local agencies that have jurisdiction. Board of health members can educate other local agencies and public officials about CAFOs and spread awareness about the environmental and health hazards. They can request a public hearing with the permitting agency of the

CAFO to express their concerns about the potential health effects. They can also work with agricultural and farm representatives to teach better environmental practices and pollution reduction techniques.

In many states, boards of health are empowered to adopt more stringent rules than the state law if it is necessary to protect public health. Board of health members should examine their state laws before they take any action regarding CAFOs to determine the most appropriate course of action. Any process should include an investigative period to gather evidence, public hearings, and a time for public review of draft policies.

Board of Health Case Studies

Tewksbury Board of Health, Massachusetts

Locals have complained about Krochmal Farms, a pig farm, for many years, but complaints have increased recently. The addition of a hog finishing facility to the farm coincided with the time that community member complaints grew. Most complaints are centered on the odor coming from the farm. The complaints were originally just logged when phone calls were received; however, the health department added a data tracking system as the number of complaints increased. After a complaint is received, the sanitarian or health director does a site visit to investigate.

The health director in Tewksbury filed an order of prohibition against the farm, which is allowed under Massachusetts law 111, section 143, for anything that threatens public health. The order of prohibition was appealed and the matter was taken to the board of health for a grievance hearing. The board of health hearing included months of testimony about the pig farm. The board of health is also doing a site assignment, which determines if a location is appropriate for treating, storing, or disposing of waste, including agricultural waste. The site assignment process includes both the Department of Environmental Protection (DEP) and the local board of health. The board of health holds a public hearing process, while the DEP reviews the site assignment application. The board of health grants the site assignment only if it is concurrently approved by the DEP.

The health director in Tewksbury points out that the only laws the board of health is able to regulate the farm under are nuisance laws. There have been efforts by the community to do a home rule petition to address the air quality and pest management complaints. The home rule petition is currently working its way through the Massachusetts state house. The status of the petition is unknown.

The board of health has tried to work directly with the pig farm to manage complaints. The farm contains manure composting facilities and the health district has requested advance notice to warn the community before manure is treated or applied to the soil. The farm has adopted a new manure management system. This system uses Rapp technology to control odors and reduce ammonia and hydrogen sulfide levels. However, questions still remain as to whether this addition will fully solve the odor issue. Typically, systems using Rapp technology include an oil cap that floats on manure holding pools and helps seal odors inside. These techniques have been researched and proven to reduce odors. However, the Tewksbury farm did not install the oil cap, and it is unknown whether the exclusion of the cap will hinder the technology's ability to reduce odors.

The complaints about the farm primarily concern the odor that emanates from the farm. The complaints do include mention of health side effects, including nausea and burning eyes. The health director has also heard concerns about potential environmental effects from the pig manure. Community members are worried the manure runoff is entering and contaminating Sutton Brook, since there has been flooding in that area. There has been no confirmation of this occurring. The board of health is aware that the farm has a nutrient management plan, but they are not allowed to request and find out what is incorporated in that plan.

The Tewksbury piggery is technically not classified as a CAFO, though it is believed to be the largest pig farm in the commonwealth of Massachusetts. The area around it has become densely populated and the community members state that they just want to live peacefully with the farm. The board of health has submitted multiple grant applications to study the health effects associated with the farm. After the site assignment process is complete, the board of health will decide how it will regulate the farm. At the beginning of 2010, the board of health was still working on drafting regulations for the pig farms.

Wood County Board of Health, Ohio

Wood County, Ohio, contains two existing large dairy farms, both of which were proposed in 2001 to be expanded to over 1500 cows each. It is also the site for three other proposed dairy farms. There is a large community effort that supports restricting the operation and expansion of these farms, mainly represented by the community group Wood County Citizens Opposed to Factory Farms. The Wood County Board of Health became involved in investigating these dairy farms through this community group and other local officials. The Trustees of Liberty Township requested assistance from the Wood County Board of Health in supporting a moratorium on factory farm operations until local regulations were in effect. The trustees believed that manure runoff from the farms could contaminate local waterways, lower the ground water table, increase the presence of insect vectors, and devalue local properties.

The Wood County Health Director, in cooperation with the board of health, contacted nearby counties to determine what actions they had taken against farms in their communities. While the health director and board of health investigated action in the form of a nuisance regulation against the farms, they were advised that nuisance lawsuits filed against farms in Ohio were held to a tough standard, and they would be forced to demonstrate with scientific proof that the farms have a substantial adverse effect on health. They found that no other board of health in Ohio had opted to regulate farming operations and relied on the enforcement of existing state laws.

The board of health held a public forum to hear public opinion regarding the industrial farms. Ultimately, the Wood County Board of Health took actions other than regulations to help protect the health and environment of its community. They helped community members protect the safety of their water wells by offering free and low cost water well testing and inspections. They tested area ditch and water ways for fecal coliform bacteria, phosphorous, and nitrates to monitor the impact of farm runoff. They also purchased fly traps to monitor and count fly types to determine if the farms have caused an increase in insect vectors. Board of health members also met with state officials from the Ohio EPA in an effort to facilitate cooperation regarding the factory farms. While the Wood County Board of Health and Health Department chose not to institute any local regulations, they continue to monitor the situation and respond to community complaints.

Cerro Gordo County Board of Health, Iowa

Officials in Cerro Gordo County, Iowa, began looking into regulating animal feeding operations after the number of hog farms in Iowa started to grow. Floods in North Carolina and new regulations in Colorado meant that many hog farms began relocating to Iowa. Many citizens had concerns over the effects of

CAFOs, and the Iowa State Association of Counties wanted to review air quality issues. Officials in Cerro Gordo County originally began working on a regulation that required inspections and was based on public health concerns, since farms were already exempt from any regulations related to zoning. However, Iowa state senators soon introduced legislation that passed and prevented any animal feeding operations from being regulated from a public health angle as well.

As Iowans were now prevented from regulating animal feeding operations in terms of zoning or public health, officials in Cerro Gordo County decided to place a moratorium on the construction of new animal feeding operations in that county. They wanted to temporarily stop the growth of animal feeding operations until they could get better science about their effects. Cerro Gordo County Ordinance #40, the "Animal Confinement Moratorium Ordinance," went into effect on May 14, 2002. Since the moratorium did not address public health or zoning, officials were able to get around the rules and still have a way to temporarily control animal feeding operation growth in their county. The ordinance placed "a 1-year moratorium on any new construction, expansion, or activity occurring on land used for the production, care, feeding, or housing of animals." The ordinance also afforded "local public health officials adequate time to appropriately assess health and environmental concerns that may be related to confined animal feeding operations and concentration of animals; establish objective measurable standards of enforcement; exercise the Board of Health's responsibility to protect and improve the health of the public; refrain from impacting farm operators unfairly; and provide penalties for violations of the provisions hereof pursuant to Chapter 137, Code of Iowa" (Cerro Gordo County, 2002).

The moratorium was first adopted by the Cerro Gordo County Board of Health. It was then presented to the county board of supervisors by the health director on behalf of the board of health. Before the board of health adopted the moratorium, they held an investigative meeting in which representatives from the Iowa Farm Bureau and other industry spokespeople exchanged opinions on the issue of animal feeding operations. The moratorium was created through a collaboration between local and county officials—health department staff, the board of health, and the board of supervisors. The moratorium did not receive any help or backing from state officials, who were concerned about the political nature of the ordinance. However it did receive backing from a *Globe Gazette* editorial.

The moratorium was immediately met with resistance from state officials. The Cerro Gordo County Board of Supervisors was contacted by a local legislator, and the Iowa Farm Bureau stated they would challenge the county budget. The Iowa Farm Bureau threatened to take the county to court. There were concerns over the cost of a court trial, which was estimated to be as high as $60,000. The county attorney doubted the legality of the moratorium and ultimately recommended removing it. The moratorium was in effect until June of 2005, when it was repealed by the county board of supervisors.

Since the moratorium was repealed there have been a few hog farms built in Cerro Gordo County, but the decline in pork prices has prevented any large growth of hog farms. Health officials believe that if the county had not implemented the animal confinement moratorium, there would have been many more farms built in their county, since many hog farms were built in counties south of Cerro Gordo County. There is now a process for siting new animal confinement operations in Iowa that uses a Master Matrix scoring system. The Cerro Gordo County Board of Supervisors tracks the Master Matrix system, but so far no animal feeding operations in Iowa who have applied using this system have been denied the right to build.

Conclusion

Concentrated animal feeding operations or large industrial animal farms can cause a myriad of environmental and public health problems. While they can be maintained and operated properly, it is important to ensure that they are routinely monitored to avoid harm to the surrounding community. While states have differing abilities to regulate CAFOs, there are still actions that boards of health can and should take. These actions can be as complex as passing ordinances or regulations directed at CAFOs or can be simply increasing water and air quality testing in the areas surrounding CAFOs. Since CAFOs have such an impact locally, boards of health are an appropriate means for action. Boards of health should take an active role with CAFOs, including collaboration with other state and local agencies, to mitigate the impact that CAFOs or large industrial farms have on the public health of their communities.

Appendix A: Regulatory Definitions of Large CAFOs, Medium CAFOs, and Small CAFOs

Animal Sector	Size Thresholds (number of animals)		
	Large CAFOs	**Medium CAFOs[1]**	**Small CAFOs[2]**
Cattle or cow/calf pairs	1,000 or more	300-999	Less than 300
Mature dairy cattle	700 or more	200-699	Less than 200
Veal calves	1,000 or more	300-999	Less than 300
Swine (over 55 pounds)	2,500 or more	750-2,500	Less than 750
Swine (under 55 pounds)	10,000 or more	3,000-9,999	Less than 3,000
Horses	500 or more	150-499	Less than 150
Sheep or lambs	10,000 or more	3,000-9,999	Less than 3,000
Turkeys	55,000 or more	16,500-54,999	Less than 16,500
Laying hens or broilers[3]	30,000 or more	9,000-29,999	Less than 9,000
Chickens other than laying hens[4]	125,000 or more	37.500-124,999	Less than 37,500
Laying hens[4]	82,000 or more	25,000-81,999	Less than 25,000
Ducks[4]	30,000 or more	10,000-29,999	Less than 10,000
Ducks[3]	5,000 or more	1,500-4,999	Less than 1,500

Data: Environmental Protection Agency

[1] Must also meet one of two “method of discharge” criteria to be defined as a CAFO or must be designated.

[2] Never a CAFO by regulatory definition, but may be designated as a CAFO on a case-by-case basis.

[3] Liquid manure handling system

[4] Other than a liquid manure handling system

Appendix B: Additional Resources

American Public Health Association. *Precautionary moratorium on new concentrated animal feed operations*. http://www.apha.org/advocacy/policy/policysearch/default.htm?id=1243

Center for a Livable Future. http://www.livablefutureblog.com/

Environmental Health Sciences Research Center. *Iowa concentrated animal feeding operation air quality study*. http://www.public-health.uiowa.edu/ehsrc/CAFOstudy.htm

Environmental Protection Agency. *Animal feeding operations*. http://cfpub.epa.gov/npdes/home.cfm?program_id=7

Food and Water Watch. http://www.foodandwaterwatch.org/

Impacts of CAFOs on Rural Communities. http://web.missouri.edu/ikerdj/papers/Indiana%20--%20CAFOs%20%20Communities.htm#_ftn1

Land Stewardship Project. http://www.landstewardshipproject.org/index.html

Midwest Environmental Advocates. http://www.midwestadvocates.org/

National Agriculture Law Center. *Animal feeding operations reading room*. http://www.nationalaglawcenter.org/readingrooms/afos

National Association of Local Boards of Health. *Vector control strategies for local boards of health*. http://www.nalboh.org/publications.htm

Pew Charitable Trusts. *Human health and industrial farming*. http://www.saveantibiotics.org/index.html

Pew Commission on Industrial Animal Farm Production. http://www.ncifap.org/

Purdue Extension. *Concentrated animal feeding operations*. http://www.ansc.purdue.edu/CAFO/

State Environmental Resource Center. http://serconline.org

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Land, irrigation water, greenhouse gas, and reactive nitrogen burdens of meat, eggs, and dairy production in the United States

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Livestock production impacts air and water quality, ocean health, and greenhouse gas (GHG) emissions on regional to global scales and it is the largest use of land globally. Quantifying the environmental impacts of the various livestock categories, mostly arising from feed production, is thus a grand challenge of sustainability science. Here, we quantify land, irrigation water, and reactive nitrogen (Nr) impacts due to feed production, and recast published full life cycle GHG emission estimates, for each of the major animal-based categories in the US diet. Our calculations reveal that the environmental costs per consumed calorie of dairy, poultry, pork, and eggs are mutually comparable (to within a factor of 2), but strikingly lower than the impacts of beef. Beef production requires 28, 11, 5, and 6 times more land, irrigation water, GHG, and Nr, respectively, than the average of the other livestock categories. Preliminary analysis of three staple plant foods shows two- to sixfold lower land, GHG, and Nr requirements than those of the nonbeef animal-derived calories, whereas irrigation requirements are comparable. Our analysis is based on the best data currently available, but follow-up studies are necessary to improve parameter estimates and fill remaining knowledge gaps. Data imperfections notwithstanding, the key conclusion—that beef production demands about 1 order of magnitude more resources than alternative livestock categories—is robust under existing uncertainties. The study thus elucidates the multiple environmental benefits of potential, easy-to-implement dietary changes, and highlights the uniquely high resource demands of beef.

food impact | foodprint | geophysics of agriculture | multimetric analysis

Appreciation of the environmental costs of food production has grown steadily in recent years (e.g., refs. 1–3), often emphasizing the disproportionate role of livestock (4–12). Although potentially societally important, to date the impacts of this research on environmental policies (7, 13, 14) and individual dietary choices have been modest. Although pioneering early environmental burden estimates have tended to address wide food classes (notably the animal-based portion of the diet; e.g., refs. 9 and 15), most policy objectives and individual dietary choices are item specific.

For example, a person may consider beef and chicken mutually interchangeable on dietary or culinary grounds. However, even if an individual estimate of the environmental cost of one item exists, it is often not accompanied by a directly comparable study of the considered alternative. Even in the unlikely event that both estimates are available, they are unlikely to consider the costs in terms of more than one metric, and often rely on disparate methodologies. Therefore, environmentally motivated dietary choices and farm policies stand to benefit from more finely resolved environutritional information. Although early work yielded a short list of item-specific environmental cost estimates (16), those estimates were often based on meager data, and addressed a single environmental metric (typically energy), thus requiring expansion, updating, and further analysis to enhance statistical robustness (8).

Current work in the rapidly burgeoning field of diet and agricultural sustainability falls mostly into two complementary approaches. The first is bottom–up, applying rigorous life cycle assessment (LCA) methods to food production chains (17–22). Whereas early LCAs focused primarily on greenhouse gas (GHG) emissions (23–26), or in some cases GHGs and energy use (5, 27), more recent LCAs often simultaneously address several additional key metrics (17, 19–21, 28, 29), notably land, water, and reactive nitrogen (Nr, nitrogen fertilizer) use. Some studies also include emissions of such undesirable gases (in addition to GHGs) as smog precursors or malodors (30, 31), or adverse contributions to stream turbidity or erosional topsoil loss (e.g., refs. 32–34). This bottom–up approach is extremely important, and is poised to eventually merge with the top–down national efforts described in the next paragraph. This merger is not imminent, however, because the bottom–up approach considers one or at most a handful of farms at a time. Because of wide differences due to geography (35), year-to-year fluctuations (36), and agrotechnological practice (17, 37), numerous LCAs are required before robust national statistics emerge. Eventually, when a large and diverse LCA sample is at hand, the picture at the national level will emerge. Currently, however, the results from an LCA conducted in Iowa, for example, are unlikely to represent Vermont or Colorado. Given the current volume and

Significance

Livestock-based food production is an important and pervasive way humans impact the environment. It causes about one-fifth of global greenhouse gas emissions, and is the key land user and source of water pollution by nutrient overabundance. It also competes with biodiversity, and promotes species extinctions. Empowering consumers to make choices that mitigate some of these impacts through devising and disseminating numerically sound information is thus a key socioenvironmental priority. Unfortunately, currently available knowledge is incomplete and hampered by reliance on divergent methodologies that afford no general comparison of relative impacts of animal-based products. To overcome these hurdles, we introduce a methodology that facilitates such a comparison. We show that minimizing beef consumption mitigates the environmental costs of diet most effectively.

Author contributions: G.E., A.S., and R.M. designed research; G.E., A.S., and R.M. performed research; G.E., A.S., T.M., and R.M. analyzed data; and G.E., A.S., and R.M. wrote the paper.

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scope of LCA research, and the complexity and variability of the problem, LCAs are still too few and too local to adequately sample the multifaceted, diverse US food system, and thus to collectively become nationally scalable.

The second agricultural sustainability research thrust, into which this study broadly falls, is a top–down analysis of national (10, 16, 38) or global (8, 39–41) production statistics. The top–down approach we follow here is conceptually straightforward, as described schematically in Fig. 1. The environmental needs (land, irrigation water, etc.) of feed production are collected and distributed among the feed-consuming animal categories. This is termed the partitioning step, and is based on information about the number of animals raised or slaughtered mass in each category, as well as the characteristic feed ration in each category. The burdens attributed to each category are divided by the caloric or protein mass output of that animal category, yielding the final result, the environmental burden per consumed unit (e.g., agricultural land needed per ingested kilocalorie of poultry). This method is mainly appealing because it (*i*) circumvents the variability issues raised above by using national or global aggregations; and (*ii*) it is based on relatively solid data. For the United States in particular, US Department of Agriculture (USDA) data tend to be temporally consistent, nearly all-inclusive (e.g., records of the main crops are based on close to 100% of the production), and are reported after some (albeit modest) quality control. The key challenge with this approach is obtaining defensible numerical values and uncertainty ranges for the tens if not hundreds of parameters needed in the calculations, many of which are poorly constrained by available data. Such parameters include, for example, the average feed required per animal per day or per kilogram of weight gain, or the relative fraction of pasture in beef and dairy diets. The values vary as a function of, at least, season, geographical location, and agrotechnology used. One research effort, focused on a single location, is unlikely to yield definitive results. Significant progress in both approaches is primarily realized through the tenacious and painstaking amassing of many independent analyses over time; analyses from which robust, meaningful statistics can be derived. Because of the challenges associated with each of the research thrusts discussed above, quantitatively robust, multimetric estimates that are comparable across different categories and represent the average national environmental burdens have yet to be devised. Although estimates of total national energy use and GHG emissions by agriculture do exist (e.g., refs. 4, 5, 42, and 43), they require further statistical evaluation. The costs in terms of land, irrigation water, and Nr are even less certain.

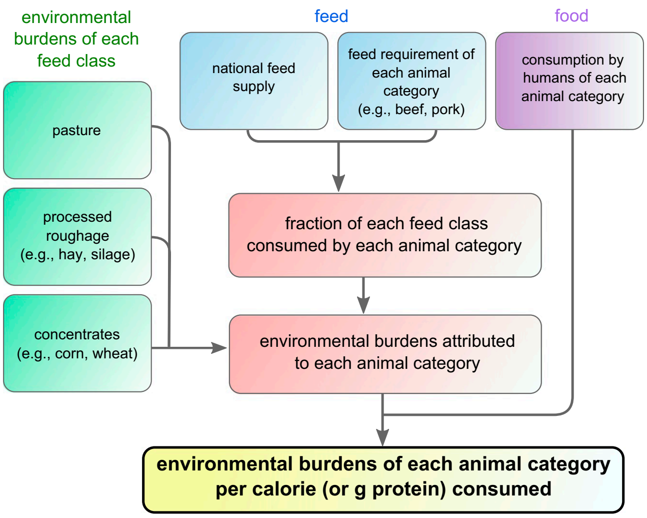

Fig. 1. A simplified schematic representation of the information flow in calculating environmental burdens per consumed calorie or gram of protein. Feed supply and requirements (blue boxes at top) previously yielded (38) the fraction of each feed class consumed by each animal category; e.g., pork requires 23 ± 9% of concentrated feed. Combined with the environmental burdens (green boxes at left; land, irrigation water, and nitrogen fertilizer for each of the three feed classes), these fractions yield the burdens attributed to each animal category. Finally, dividing those overall environmental burdens attributed to each of the five livestock categories by the number of calories (or grams of protein) nationally consumed by humans in the United States, we reach the final result of this paper (yellow box at bottom). Most input data (left and top boxes) is known with relative accuracy based on USDA data, whereas environmental burdens of pasture and average feed requirements are less certain.

Applying a top–down, uniform methodology throughout, here we present estimates of land, irrigation water, GHG, and Nr requirements of each of the five main animal-based categories in the US diet—dairy, beef, poultry, pork, and eggs—jointly providing 96% of the US animal-based calories. We do not analyze fish for two reasons. First, during the period 2000–2013, fish contributed ≈14 kcal per person per day, ≈0.5% of the total and 2% of the animal-based energy (750 kcal per person per day) in the mean American diet (44). In addition, data addressing feed use by fisheries and aquaculture are very limited and incomplete (relative to the five categories considered). We do not claim to cover all important environmental impacts of livestock production. Rather, we focus on key metrics that can be reliably defined and quantified at the national level with currently available data.

Results

We base our calculations on annual 2000–2010 data for land, irrigation water, and fertilizer from the USDA, the Department of the Interior, and the Department of Energy (see *SI Text* and ref. 13 for details). We consider three feed classes: concentrates, which include crops (corn, soybean, wheat, and other minor crops) along with byproducts, processed roughage (mainly hay and silage), and pasture. Data used include land area required for feed production (9); Nr application rates for crops, hay, and pasture; crop-specific irrigation amounts; and category-specific animal GHG emissions (17, 19–23, 28, 45, 46). For GHG emissions we also use LCA data to cover not only feed production but also manure management and enteric fermentation.

We use these data to calculate the amount of resources (e.g., total land or irrigated water) required for the production of all feed consumed by each edible livestock. We then partition the resources needed for the production of these three feed classes among the five categories of edible livestock. These two steps (38) rely on numerical values of several parameters that current data constrain imperfectly. Key among those are the feed demands of individual animals—e.g., 1.8 kg dry matter (DM) feed per 1 kg of slaughtered broiler—for which we could not find a nationwide reputed long-term dataset. Although some of the poorly known parameters impact the overall results minimally, a few of those impact the results significantly. As such, these steps add uncertainty to our results for which our presented uncertainty estimates may account only partially. The partition of feed is performed according to the fraction of the national livestock feed consumption characterizing each category, using recently derived partition coefficients (see Table S1 and ref. 38). Finally, we divide the resource use of each category by the US national animal caloric consumption, obtaining a category-specific burden per unit of consumed energy. For clearer presentation, we report burdens per megacalorie, where a megacalorie is 10^3 kilocalories (also colloquially termed “10^3 calories” in popular US nutritional parlance), equivalent to roughly half of the recommended daily energy consumption for adults. That is, we focus on the environmental performance per unit of energy of each food category. This is by no means a unique or universally

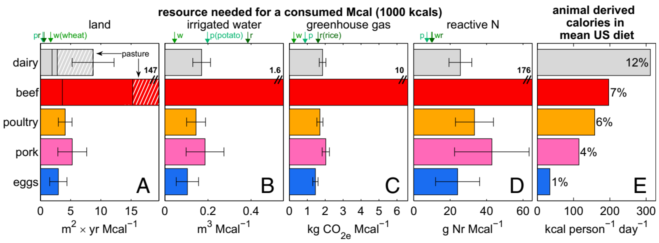

Fig. 2. (*A*–*D*) Environmental performance of the key livestock categories in the US diet, jointly accounting for >96% of animal-based calories. We report performance in resources required for producing a consumed Mcal (1 Mcal = 10^3 kcal, roughly half a person's mean daily caloric needs). For comparison, resource demands of staple plants potatoes (denoted p), rice (r), and wheat (w) are denoted by arrows above *A*–*D*. *E* displays actual US consumption of animal-based calories. Values to the right of the bars denote categories' percentages in the mean US diet. The demands of beef are larger than the figure scale and are thus written explicitly next to the red bars representing beef. Error (uncertainty) bars indicate SD. In *A*, for beef and dairy, demand for pastureland is marked with white hatching, and a vertical line separates demand for cropland (to the left), and processed roughage land (to the right).

superior choice. Other metrics, such as environmental costs per gram of protein (16), may be useful in other contexts or favored by some readers. We thus repeat our calculations using the protein metric, as shown in *SI Text*, section 6 and Fig. S1, conflating nutritional and environmental considerations (e.g., refs. 13 and 47).

We correct for feed consumption by other animals (goats, sheep, and horses) as well as export–import imbalances of individual animal categories. As pasture data coverage is poor, we derive the nitrogen fertilizer used for pasture as the residual between the overall agricultural use totals and the sums of crops and processed roughage totals, all well constrained by data. GHG emissions associated with the production of the various animal categories are derived from previous studies, considering CO_2, CH_4, and N_2O (17, 19–21, 28, 45, 46) from manure management, enteric fermentation, direct energy consumption, and fertilizer production inputs. An extended technical discussion of the methodology including data uncertainty and limitations is given in *SI Text*. Note however that using full life cycle GHG estimates (as we do here) renders the GHG approach distinct from those for the other metrics, which address only the feed production phase in total production.

The animal-based portion of the US diet uses ≈0.6 million km^2 for crops and processed roughage, equivalent to ≈40% of all US cropland or ≈2,000 m^2 per person. The total requirements, including pasture land, amount to ≈3.7 million km^2, equivalent to ≈40% of the total land area of the United States or ≈12,000 m^2 per person. Feed production requires ≈45 billion m^3 of irrigation water, equal to ≈27% of the total national irrigation use (48), or ≈150 m^3 per person per year, which is comparable to overall household consumption. It also uses ≈6 million metric tons of Nr fertilizer annually, about half of the national total. Finally, GHG emissions total 0.3×10^{12} kg CO_{2e} which is ≈5% of total US emissions (49), or 1.1 t per person per year, equivalent to about 20% of the transportation sector emissions.

We find that the five animal categories are markedly dichotomous in terms of the resources needed per consumed calories as shown in Fig. 2 *A*–*D*. Beef is consistently the least resource-efficient of the five animal categories in all four considered metrics. The resource requirements of the remaining four livestock categories are mutually similar. Producing 1 megacalorie of beef requires ≈28, 11, 5, and 6 times the average land, irrigation water, GHG, and Nr of the other animal categories. Fig. 2 thus achieves the main objective of this paper, enabling direct comparison of animal based food categories by their resource use. Its clearest message is that beef is by far the least environmentally efficient animal category in all four considered metrics, and that the other livestock categories are comparable (with the finer distinctions Fig. 2 presents).

A possible objection to the above conclusion is that beef production partly relies on pastureland in the arid west, land that is largely unfit for any other cultivation form. Whereas most western pastureland is indeed unfit for any other form of food production, the objection ignores other societal benefits those arid lands may provide, notably ecosystem services and biodiversity. It further ignores the ≈0.16 million km^2 of high-quality cropland used for grazing and the ≈0.46 million km^2 of grazing land east of longitude 100°W that enjoy ample precipitation (50) and that can thus be diverted to food production. Even when focusing only on agricultural land, beef still towers over the other categories. This can be seen by excluding pasture resources and summing only crops and processed roughage (mostly hay and silage, whose production claims prime agricultural land that can be hypothetically diverted to other crops). After this exclusion, 1 Mcal of beef still requires ≈15 m^2 land (Fig. 2*A*), about twofold higher than the second least-efficient category.

As a yardstick, in Fig. 2 we compare animal categories to three plant staples for which we were able to gather data on all four metrics analyzed. Results for potatoes, wheat, and rice (*SI Text*, section 9) are shown by three downward pointing arrows at the top of Fig. 2 *A*–*D* accompanied by their initial letters (e.g., "r" for rice). Compared with the average resource intensities of these plant items per megacalorie, beef requires 160, 8, 11, and 19 times as much land, irrigation water, GHG, and Nr, respectively, whereas the four nonbeef animal categories require on average 6, 0.5, 2, and 3 times as much, respectively (Fig. S2). Although potentially counterintuitive, the irrigation water requirements reflect the fact that the bulk of land supplying livestock feed is rainfed, i.e., not irrigated. For example, for the two key caloric contributors to the diet of US livestock, corn and soy,

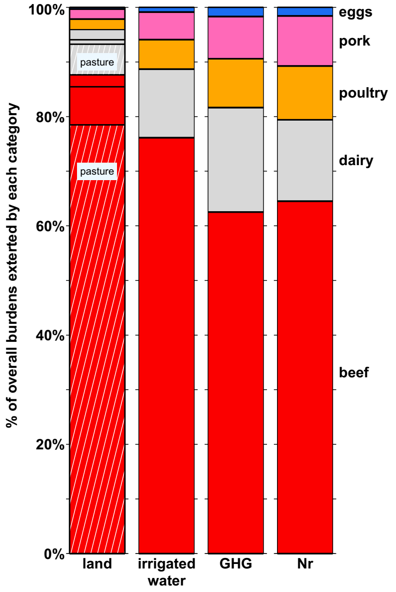

Fig. 3. Percentage of the overall national environmental burdens exerted by the individual animal categories. The results are obtained by multiplying the values of Fig. 2*E*, recast as annual overall national caloric consumption, by the resource per megacalorie of Fig. 2 *A*–*D*. Beef requires ≈88% of all US land allocated to producing animal-based calories, partitioned (from the bottom up) among pasture (≈79%), processed roughage (≈7%), and concentrated feed (≈2%). The land demands of dairy are displayed in the same format.

only 14% and 8% of the respective allocated lands are irrigated (≈44,000 km^2 and 25,000 km^2 of ≈300,000 km^2 each).

Our conclusions from the comparison among the five considered livestock categories are also valid, albeit slightly numerically modified, when analyzed per unit of protein consumed rather than on a caloric basis as shown in Fig. S1 and *SI Text*, section 6. For the analyzed plant items, whose protein content is lower, the differences are smaller by comparison with the livestock categories, as Fig. S1 shows. A detailed comparison of plant items calls for a dedicated future study. Such a study should also analyze high-protein plants such as soy and beans. We currently do not correct for differing protein digestibility whose relatively small quantitative effect (51) does not qualitatively change our results. We also do not account for differences in essential amino acid content. We note that the practical implications of protein sources in diverse diets are still vigorously debated (52) among nutritionists, and that the combined amino acid mass in current wheat, corn, rice, and soybean production exceeds the USDA recommended intake of these nutrients for the global human population.

Fig. 3 shows the partitioning of the total environmental burdens in the four metrics associated with feed production for the five livestock categories. We obtain these totals by multiplying the per calorie burdens depicted in Fig. 2 *A–D* by the caloric use shown in Fig. 2*E*. Fig. 3 thus identifies categories that dominate overall animal-based burdens, taking note of both resource efficiency and actual consumption patterns. Breaking down the total annual national burdens in each metric, Fig. 3 shows the dominance of beef over the environmental requirements of all other animal categories combined.

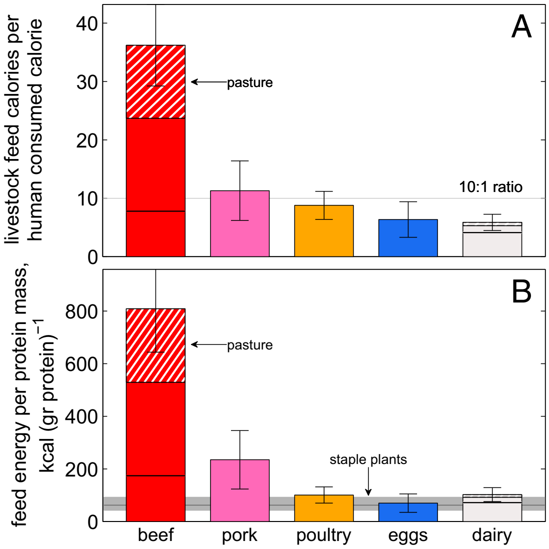

Fig. 4. Feed-to-food and feed-to-protein conversion factors of different livestock categories. The bar height of each category in *A* shows the total livestock feed calories used divided by the human-consumed calories they yield. For example, the value of ≈9 for poultry indicates that, on average, 9 feed calories fed to poultry yield 1 calorie consumed by humans. Note that this factor includes the approximately twofold loss reported by the USDA in the post-farm gate supply chain from primary production through retail to the consumer. The often-quoted 10:1 conversion factor per trophic level arising from studies in ecology is marked as a gray line. *B* depicts the conversion factors from livestock feed to human-consumed protein mass. For beef and dairy, the contribution of concentrates, processed roughage, and pasture is presented from the bottom to the top, respectively. The gray area marks the upper and lower bounds of the three staple plants. Error (uncertainty) bars indicate SD. See *SI Text* for calculation details.

The broad resource demand ranges of Fig. 2 *A–D* partly stem from differences in the basic biology-governed capacity of different farm animals to convert feed energy into calories consumed by humans. Fig. 4*A* quantifies these conversion factors from feed to consumed food for current US agricultural practices and exhibits a wide range, with beef three to six times less efficient than the other (largely mutually comparable) livestock categories. Modern, mostly intensive, US beef production is thus an energy conversion pathway about fourfold less efficient than other livestock. This value is in line with earlier analyses (53) and updates those analyses to reflect current data and practices. Comparing Figs. 2 and 4 suggests that biology does not explain all of the unusually high resource requirements of beef depicted in Fig. 2. Such results and methodology can also be used to quantify the tradeoffs associated with beef production relying primarily on grazing versus on processed roughage and concentrates; whereas grass-fed beef requires more pasture land, its irrigation water and Nr fertilizer needs are lower. In Fig. 4*B* we further show the conversion factor from feed calories to protein mass for each of the animal categories.

Discussion

How does the relative resource consumption calculated in this study compare with the caloric composition of the current mean US diet? In stark contrast with Fig. 2 *A–D*, Fig. 2*E* shows this composition and demonstrates the suboptimality of current US consumption patterns of animal-based foods with respect to the four environmental metrics considered. Beef, the least efficient against all four metrics, is the second most popular animal category in the mean US diet, accounting for 7% of all consumed calories. Interestingly, dairy, by far the most popular category, is not more efficient than pork, poultry, or eggs.

Because our results reflect current US farm policies and agrotechnology, the picture can change markedly in response to changes in agricultural technology and practice, national policies, and personal choice. By highlighting the categories that can most effectively reduce environmental resource burdens, our results can help illuminate directions corrective legislative measures should ideally take. Although our analysis is based on US data, and thus directly reflects current US practices, globalization-driven rapid diffusion of US customs, including dietary customs, into such large and burgeoning economies as those of China or India, lends a global significance to our analysis.

Corrective legislative measures are particularly important because, in addition to ethnic and cultural preferences, current consumption patterns of several food types partly track government policies (such as price floors, direct subsidies, or countercyclical measures). For example, at least historically, the caloric dominance of dairy in the US diet is tied to governmental promotion of dairy through marketing and monetary means (54), and meat ubiquity partly reflects governmental support for grain production, a dominant subsidy recipient in the agricultural sector. Our results thus offer policymakers a method for calculating some of the environmental consequences of food policies. Our results can also guide personal dietary choices that can collectively leverage market forces for environmental betterment. Given the broad, categorical disparities apparent in our results, it is clear that policy decisions designed to reduce animal-based food consumption stand to significantly reduce the environmental costs of food production (55) while sustaining a burgeoning populace.

Materials and Methods

Analysis Boundaries. For land, water, and Nr, we confine our analysis to resources used for feed production. First, on-farm use of these resources has been shown to be negligible by comparison. In addition, data addressing on-farm requirements are more geographically and temporally disparate, not always directly mutually comparable, and thus difficult to scale up into the national level our analysis requires.

We focus on irrigation water (i.e., blue water), neglecting direct precipitation on plants (i.e., green water) as the latter is not directly accessible for alternative human uses. Disregarding green water follows recent studies (10, 56, 57) that favor this approach and point out the large differences between results of studies that focus on irrigation water and those based on combining all water resources.

Beside feed-related costs, livestock production also involves non-CO_2 GHG emissions due to manure management and enteric emissions. These GHG burdens are included in the published LCAs we use in this study (refs. 17, 19–21, 23, 28, 29, and 58 and *SI Text*, section 7).

In analyzing the eutrophication potential of Nr, we address fertilizer use only, excluding manure and emissions of volatile nitrogenous compounds, which are considered in the GHG metric. The decision to focus the biogeochemistry portion of the work on nitrogen has several distinct motivations. First, N is by far the most widely applied nutrient, with application rates by nutrient mass approximately threefold higher than those of the other two agriculturally widely used nutrients, phosphate and potash. Second, because the geographical focus is North America, which has been glaciated recently, its soils and the fresh water systems that drain them are rarely P limited (59). Consequently, N dominates eutrophication and hypoxia in the estuaries and coastal ecosystems surrounding North America (60). Third, our focus on feed production implicitly focuses on the Midwest. This emphasizes the Gulf of Mexico Dead Zone, where N limitation dominates dissolved oxygen levels (61).

Correction for Export–Import. In evaluating national feed use, we take note of domestic consumption only, excluding and correcting for domestically produced exported feed. We similarly correct for net export–import of animal-based food items. To do so, we multiply the overall national resource use by a factor that reflects the export–import imbalance as a fraction of the total consumed calories of each animal category. For example, if 14% of the total pork produced is exported whereas imported pork is 5%, then we multiply each resource used domestically for pork production by 0.91. More details are given in *SI Text*.

Plant Staple Item Choice. We selected for analysis items for which we were able to gather information covering all four metrics, and that are a calorically significant part of the US diet. We note that low-caloric-content plant items, such as lettuce, have relatively high-resource burdens per calorie. As a result, these items do not lend themselves naturally to evaluation by either the per calorie or per gram protein metrics, and probably require a more nuanced, more revealing metric.

Feed Requirements and Fraction of Total Feed Supply of the Animal Categories. Our calculation of the total annual DM intake of each animal category begins with USDA data on livestock headcounts, slaughter weights, and feed requirements per head or slaughtered kilogram (ref. 38 and references therein). (See Dataset S1 for the raw data used and detailed analysis thereof.) We combine the intake requirements with USDA estimates of overall US feed production and availability by feed class (*SI Text*, section 2.1) (38), distinguishing and treating individually concentrated feed ("concentrates," meaning grains and byproducts), and roughage, subdivided into pasture and processed roughage (the latter combining hay, silage, haylage, and greenchop). Most used data are temporal averages over the years 2000–2010 of USDA reports. All data sources are referenced individually in *SI Text*, section 2.1, including USDA grain, oil, and wheat yearbooks; the 2011 Agriculture Statistics Yearbook; and, for pasture, an earlier study by Eshel et al. (38). The soy calculations are an exception to this pattern. They comprise soy feed and residual use plus 60% of crushed (i.e., the caloric and economic fraction of crushed soybean that goes into soybean meal feed). These data jointly yield our feed requirement estimates for each livestock category–feed class combination. The calculations presented take note of several issues. First, feed used by sheep and goats, whose meat jointly constitutes <1% of the American human diet's calories (44), and the more substantial amount of feed consumed by horses, is estimated. These feed values are subtracted from the national available feed totals, to arrive at the feed consumed by the five major edible livestock categories. A second issue is that pasture feed contributions are unknown, and are thus inferred by subtracting the known overall concentrates and processed roughage availability from the total livestock feed requirements. The concentrated feed requirements of poultry, pork, and eggs, which only consume concentrated feed, follow directly from their total feed requirements. From the fractions the three feed classes constitute in dairy rations reported in the cited literature, dairy's total requirements by feed class are obtained (38). Next, beef concentrated feed use is calculated as the total national supply of concentrates minus the combined use by poultry, pork, eggs, and dairy. Following a similar procedure, the processed roughage requirement of beef is inferred as the total available minus the fraction consumed by dairy. Finally, pasture needs of beef are inferred by subtracting from the known total beef feed needs the calculated contributions to these needs made by concentrates and processed roughage. More information is given in *SI Text* and in ref. 38.

We note that the USDA maintains records related to consumption of the main feed sources by the five livestock categories as part of the data yielding Animal Unit indices (62). In principle, this data can facilitate the sought partitioning. However, the underlying conversion factors used to translate headcounts into Animal Units have not changed since the late 1960s, when the USDA first introduced the indices. Because they are based on outdated farm practices markedly different from those used today, using them for environmental cost partitioning is questionable (63).

Byproducts in Beef Feed. One can suggest that beef should be credited in the environmental impact calculus for its ability to use as feed byproducts that would otherwise constitute waste in need of environmentally acceptable disposal. We do not follow this approach here for two reasons. First, such credits do not currently exist, and devising them in an environmentally and arithmetically sound manner is a major undertaking in its own right that we deem outside the current scope. On a more practical level, in addition, our preliminary analysis has established that the total mass of all byproducts (excluding soy meal) is less than 10% of the feed requirements of beef, and thus of small quantitative effect.

Aggregating and Allocating Environmental Burdens. We calculate and aggregate resources (land, irrigation water, and Nr) associated with individual feed types (various crops and hay types; *SI Text*, sections 2.2–2.4) into the three feed classes (concentrates, processed roughage, and pasture) by combining data on feed use, crop yields, irrigation, and nitrogen fertilizer application rates for each crop type and for pasture lands (*SI Text*, section 3). We then partition the overall resource use of each feed class among the five animal categories using the partition coefficients previously calculated (Table S1 and ref. 38) to determine the resources attributable to each animal category (*SI Text*, section 4).

Finally, we divide the total resource use of each animal category (mass GHG emitted and Nr applied, volume of water used for irrigation, and allocated land area for feed) by the contribution of that category to the total US caloric intake, obtaining the resource requirements per human-destined megacalorie. Replacing human destined calories with human-destined protein mass, we use a similar methodology to calculate resource requirements per unit of human-consumed protein (Fig. S1 and *SI Text*, section 6).

Derivation of Uncertainty Estimates. The uncertainty ranges for the raw data are based on variability among independent data sources or interannual variability. In the few cases where neither is available, we use as default an uncertainty of 10% of the parameter value.

We calculate uncertainty estimates using two distinct approaches. Dataset S1 contains traditional formal error propagation. We went to some length to properly handle cases with nonzero cross-covariance. A typical but by no means unique example of this involves feed requirements of, say, beef and the total feed requirement of all animal categories (which includes beef). In addition, we use Monte Carlo bootstrapping Matlab code (Mathworks) to perform 10,000 repeats, in each choosing at random subsets of the raw data, obtaining the end results, and deriving uncertainty ranges in the reported calculations from the distribution of end results thus obtained. Both methods yield similar but not identical uncertainty estimates. We believe the discrepancies, ≈10% on average, stem from imperfect account of all cross-correlations by the formal error propagation. We present the uncertainty estimates (SDs) based on the formal (parametric) error propagation, as we favor the method most easily available for future researchers.

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PROPUBLICA

Regulation

America’s Food Safety System Failed to Stop a Salmonella Epidemic. It’s Still Making People Sick.

by Bernice Yeung, Michael Grabell, Irena Hwang and Mollie Simon

Oct. 29, 8 a.m. EDT

For years, a dangerous salmonella strain has sickened thousands and continues to spread through the chicken industry. The USDA knows about it. So do the companies. And yet, contaminated meat continues to be sold to consumers.

Photo Illustration by Justin Metz for ProPublica

In May 2018, a rare and virulent strain of salmonella caught the attention of America’s top disease detectives. In less than two months, the bacteria had sickened more than a dozen people, nearly all of them on the East Coast. Many said they’d eaten chicken, and federal food safety inspectors found the strain in chicken breasts, sausages and wings during routine sampling at poultry plants.

But what seemed like a straightforward outbreak soon took a mystifying turn. Cases surfaced as far away as Texas and Missouri. A 1-year-old boy from Illinois and a 105-year-old woman from West Virginia fell ill. There was a teenager who’d just returned from a service trip in the Dominican Republic and a woman who’d traveled to Nicaragua. But there were also people who hadn’t traveled at all.

Victims were landing in the hospital with roiling stomach pains, uncontrollable diarrhea and violent bouts of vomiting. The source of the infections seemed to be everywhere.

Even more alarming was that this strain of salmonella, known as multidrug-resistant infantis, was invincible against nearly all the drugs that doctors routinely use to fight severe food poisoning.

With a public health threat unfolding across the country, you might have expected federal regulators to act swiftly and decisively to warn the public, recall the contaminated poultry and compel changes at chicken plants. Or that federal investigators would pursue the root cause of the outbreak wherever the evidence led.

None of that happened.

Instead, the team at the Centers for Disease Control and Prevention closed the outbreak investigation nine months later even though people were continuing to get sick. The U.S. Department of Agriculture, which oversees meat and poultry, was not only powerless to act but said nothing to consumers about the growing threat. So supermarkets and restaurants continued selling chicken tainted with drug-resistant infantis.

And they continue to do so today.

An eight-month ProPublica investigation into this once rare, but now pervasive form of salmonella found that its unchecked spread through the U.S. food supply was all but inevitable, the byproduct of a baffling and largely toothless food safety system that is ill-equipped to protect consumers or rebuff industry influence.

Several European countries have dramatically reduced salmonella in poultry by combating it on the farms where chickens are raised. But over the past 25 years, the U.S. has failed to bring down the incidence of salmonella food poisoning — even as the rates for E. coli and other bacteria have fallen dramatically.

Consumers may get the impression that the meat and poultry they find at supermarkets is safe because it bears the USDA seal of approval. But the agency doesn’t prohibit companies from selling chicken contaminated with dangerous salmonella like infantis. And even when people get sick, it has no power to order recalls.

Instead, the agency relies on standards it can’t enforce and that don’t target the types of salmonella most likely to make people sick. The USDA’s Food Safety and Inspection Service, unlike its counterparts in some countries, has no authority to control salmonella on farms, where the bacteria often spreads. And even when there’s persistent evidence of contamination in a plant’s products, the USDA can’t use those findings to suspend operations. All the agency can do is conduct a general review of the plant, and that rarely leads to a shutdown.

“It’s a system that’s untenable,” said Sarah Sorscher, a consumer advocate at the Center for Science in the Public Interest.

ProPublica, as part of its food safety investigation, has created an online database that lets consumers look up the salmonella records of the plants that processed their chicken and turkey.

Last week, after repeated interview requests from ProPublica and years of criticism from consumer groups, the USDA announced that it was rethinking its approach to salmonella. The agency didn’t announce any concrete changes but said it would set up pilot projects and hold meetings in an effort to come up with a plan.

“Whether it should have been done sooner or could have been done sooner, the good news is we’re doing it,” said Sandra Eskin, the agency’s deputy undersecretary for food safety. “We’re going to really take a look at everything we could look at and, I hope, develop a different approach that winds up being more effective.”

Scientific advancements over the last decade have provided the USDA with tools to identify the most dangerous strains of salmonella. But the agency isn’t using those tools to prevent it from spreading in our food supply.

To piece together how food safety officials and the poultry industry allowed infantis to spread, ProPublica used the same genetic data available to the USDA and other agencies, analyzing seven years of infantis samples taken from food and patients and catalogued by the National Institutes of Health.

Through dozens of public records requests, ProPublica was then able to link the genetic information on those 8,000 samples to the foods that victims ate and the processing plants the chicken samples came from.

The analysis, along with hundreds of internal government records and interviews with nearly two dozen scientists, allowed us to uncover that the infantis outbreak never abated and has continued to run rampant through the chicken industry.

In fact, ProPublica found that more than twice a day this year, on average, USDA inspectors detected multidrug-resistant infantis in poultry that’s genetically similar to the outbreak strain. Each month, the CDC continues to receive dozens of reports of people getting sick from it.

“Many people are still becoming ill, and some of them gravely ill,” Robert Tauxe, director of the CDC’s Division of Foodborne, Waterborne and Environmental Diseases, told ProPublica.

One internal CDC presentation noted that this single strain is “responsible for an estimated 11,000-17,000 illnesses per year.” But the CDC is limited in its ability to protect American consumers from foodborne illnesses. It has no power to order companies to take action or to provide information that would help it solve outbreaks.

And the CDC, despite noting that the strain was "widespread in the chicken industry," took the spotlight off infantis when it closed its outbreak investigation in February 2019. Tauxe said the investigation ended because the agency had learned as much as it could. "That does not mean that the outbreak was over," he said. "In fact, we think it may still be expanding."

> “ **ProPublica found that more than twice a day this year, on average, USDA inspectors detected multidrug-resistant infantis in poultry that's genetically similar to the outbreak strain.**

As the CDC has contended with infantis, the agency has held several private meetings with the chicken industry, which has publicly downplayed the threat of the strain and its ability to do something about it.

But since closing the investigation, neither federal health officials nor the USDA has said anything to consumers about what the CDC quietly regards as an "epidemic."

Marva Lamping knew none of this in July 2019 when she took her longtime partner, Arthur Sutton, out to celebrate his 70th birthday at their favorite Mexican restaurant in Bend, Oregon. As Lamping tested her luck at the restaurant's video slot machines, Sutton snacked on chips and salsa while waiting for a platter of chicken enchiladas.

That night, Sutton began vomiting repeatedly, his stomach aching so badly that he couldn't lay down. By the next morning, the pain was unbearable, and Lamping rushed him to the emergency room.

At the hospital, doctors would discover that Sutton's intestines were leaking. Again and again, surgeons opened his abdomen to repair the tears and cut out dead segments of his bowels.

Doctors had quickly identified the cause of Sutton's ailments as salmonella. But for reasons they couldn't understand, his body was wasting away.

None of the antibiotics were working.

Missed Opportunities

As sudden as the infantis outbreak seemed to investigators at the CDC, it wasn't the first time the government had seen this strain, known as Infantis Pattern 1080. In the three years before the outbreak started, USDA inspectors had found the strain 74 times. But they could do nothing to stop the chicken from going to supermarkets and restaurants nationwide.

By the summer of 2018, people all over the country were falling ill. And as investigators studied the cases, clues soon emerged from the USDA, which oversees meat and poultry, and the Food and Drug Administration, which regulates almost all other foods.

The FDA had received a complaint that a dog had recurring diarrhea after eating raw pet food, and samples of chicken-and-vegetable dog food tested positive for multidrug-resistant infantis. A few months later, a Chicago woman fell sick with the outbreak strain after feeding her dog the same brand. Could the pet food be the source of the outbreak? Possibly, but not all the victims had a dog.

There was another lead. Victims reported eating Perdue Farms chicken more than any other brand. Public health officials in Pennsylvania and Minnesota found the outbreak strain in packages of Perdue wings, thighs and drumsticks in three supermarkets. And when USDA inspectors found the strain in raw chicken, more than a quarter of the samples came from Perdue plants.

The FDA's investigation had quickly led to a pet food recall. But while the FDA prohibits salmonella in the foods it oversees — including dog and cat food — the USDA allows it in raw meat and poultry destined for human consumption.

When people fall ill, the USDA can only request that a company voluntarily recall its products. But to do even that for salmonella, regulators face a high bar: To ensure a strong case, they're expected to try to find a patient with an unopened package of meat that tests positive for the same strain that made the outbreak victims sick.

"Often, by that time, most of the meat that's going to be eaten has been eaten," said Sorscher of the CSPI.

> **“ While the FDA prohibits salmonella in the foods it oversees — including dog and cat food — the USDA allows it in raw meat and poultry destined for human consumption.**

In June 2018, what could have been a key piece of evidence surfaced. An Illinois victim who'd been hospitalized told investigators that he still had a package of Perdue chicken tenders in his freezer. The USDA could have tested the package, but nobody ever went out to collect it, he said.

Perdue did not respond to more than a dozen calls and emails seeking comment, and it didn't answer questions sent to top company officials.

Wade Fluckey, Perdue's senior director of food safety at the time, told ProPublica that the company was targeted because Perdue has better brand recognition than other chicken companies, which skewed patient interviews.

"I don't know that any one company could say they didn't have it," said Fluckey, now a vice president at a pork processor. "Had they focused on other places, they would have found the same thing."

While no company showed up more frequently than Perdue, food inspectors were finding the Pattern 1080 strain in dozens of chicken processing plants as well as raw pet food and live chickens. To investigators, that was unusual because it meant that the salmonella couldn't have come from a single company or chicken product. It had to be coming from somewhere upstream in the supply chain — perhaps the farms or the few companies that breed nearly all the nation's chickens.

The country's antiquated meat safety system virtually ensured it would be no match for a germ like infantis.

The USDA operates under a law passed in 1906, where inspectors physically examine every carcass for signs of animal disease, illegal additives and spoilage. The system didn't account for invisible pathogens like salmonella and E. coli, which had not yet been linked to eating meat.

That did not change until 1994 after four children died from eating Jack in the Box hamburgers. The USDA made it illegal to sell meat tainted with a strain of E. coli called O157:H7. But it didn't ban salmonella despite a series of high-profile outbreaks in chicken. Instead, the USDA required processing plants to limit how often salmonella was found on their products and began testing for it. Plants that repeatedly violated these standards faced a shutdown.

> “ **The country's antiquated meat safety system virtually ensured it would be no match for a germ like infantis.**

That powerful threat didn't last long. In 1999, a Texas meat processor challenged the USDA's authority to close plants, arguing that salmonella “appears naturally” in raw meat. Two years later, the 5th U.S. Circuit Court of Appeals agreed that Congress hadn't given the agency the power to regulate salmonella that's present before products enter processing plants or to deem a facility unsanitary based on the bacteria alone.

The decision, Supreme Beef Processors v. USDA, has left the agency gun-shy, according to former department officials and food safety advocates. And Mansour Samadpour, a microbiologist who runs a testing and consulting firm that works with the food industry, said the decision distorts the underlying science. Just because salmonella “colonizes” chickens' guts doesn't mean it's “the natural state of the animal,” he said. “It's nonsense.”

The court ruling severely clipped the USDA's powers. So it has tried to pressure plants to improve by creating standards for how often salmonella should be found. Plants are rated on the results, which are published online. Violating those standards doesn't carry a penalty, but it allows the agency to visit the plant and look for more general problems like unsanitary conditions. If they can document significant problems, the USDA can temporarily shut down the plant, though the agency rarely takes such action.

Today, food poisoning sickens roughly 1 in 6 Americans every year, according to the CDC, and salmonella hospitalizes and kills more people than any other foodborne pathogen. Each year, about 1.35 million people get sick from salmonella. While most recover, more than 400 people die and 26,500 people are hospitalized. Some are left with long-term conditions like severe arthritis and irritable bowel syndrome. Salmonella costs the economy an estimated $4.1 billion a year, more than any other type of food poisoning.

Salmonella outbreaks have been linked to other foods like onions, but poultry remains the biggest culprit, and people are eating more of it than ever. On average, people in the U.S. eat nearly 100 pounds of chicken each year, a number that has grown by about 40% in the last 25 years.

> **“ Each year, about 1.35 million people get sick from salmonella. While most recover, more than 400 people die and 26,500 people are hospitalized.**

Cooking poultry to an internal temperature of 165 degrees will kill salmonella. But studies by the USDA and others have found that despite decades of consumer education, home cooks routinely cross-contaminate their kitchens, and few use a meat thermometer to ensure their poultry is cooked properly.

Illnesses haven't declined even as salmonella rates in raw poultry have. And infections are getting harder to treat. The CDC recently found that salmonella infections were becoming increasingly resistant to antibiotics. In contrast, food poisoning related to E. coli O157:H7 has dropped by about 70%.

Consumer advocates, industry consultants and former USDA officials say that's because the agency focuses solely on whether salmonella is found in chicken or turkey at the processing plant.

This approach has been criticized for years. One former meatpacking executive called it "worthless." Even the USDA's own research arm has said the agency's measure for salmonella is "not a good indicator" of food safety.

The USDA doesn't consider two key risk factors: how much salmonella is in the poultry and how dangerous that type of salmonella is. There are 2,500 types of salmonella, but only a fraction cause the vast majority of illnesses.

The industry has greatly reduced the prevalence of one common type of the bacteria, known as salmonella Kentucky, which rarely causes illnesses in the U.S. But it's made far less progress with the types of salmonella most likely to make people sick, the ProPublica analysis found.

The rate of infantis, for example, has more than quintupled over the past six years.

The full extent of the salmonella problem isn't even known. The agency does little testing for salmonella to begin with. On an average day in 2020, the USDA took about 80 samples of raw poultry across hundreds of processing plants. But those plants slaughter more than 25 million chickens and turkeys a day.

In recent years, consumer advocates have recommended the agency ban the sale of raw meat carrying the types of salmonella that most often make people sick. That approach has contributed to improvements in Europe. In the U.S., the FDA has seen a dramatic decrease in salmonella outbreaks tied to eggs since the 1990s when it began targeting the most common type.

> “ **The full extent of the salmonella problem isn’t even known.**

Last month, a few of the largest poultry companies, including Perdue and Tyson, joined with the CSPI and other consumer advocates to urge the USDA to fix the system. But the letter to the agency didn’t outline specific reforms, and a consensus on salmonella regulations has long proved elusive.

The last push came during the Obama administration, but citing the need for more data, the USDA rejected a proposal to ban certain antibiotic-resistant strains. The agriculture secretary at the time was Tom Vilsack, who now leads the agency again under President Joe Biden.

As the food safety project director for the Pew Charitable Trusts before joining the USDA, Eskin also pushed for reform, but her efforts were met with resistance. With food safety directors from some of the largest companies, she helped craft recommendations to Congress to modernize the meat safety system, including setting new limits on salmonella contamination and giving regulators oversight of farms.

The group sought to enlist trade associations, which represent not only the biggest players but hundreds of other companies. But when it comes to regulation, divergent interests often leave the trade groups lobbying for the lowest common denominator. “They shut us down,” she said in an interview before taking her government post. “They’re the ones that blocked us — not the companies, the trade associations.”

Asked what was standing in the way of change, she said, “I’ll make it simple: Powerful interests in the industry do not want it.”

“We Are Basically Only Talking About Protecting Industry”

Just months before the infantis outbreak started, the USDA gathered representatives from the food industry, researchers and regulators at the agency’s brick-and-limestone headquarters in Washington to discuss a scientific breakthrough that one participant called the “biggest thing” for food safety in 100 years.

Whole-genome sequencing had given food safety researchers an unprecedented look at the DNA of foodborne bacteria. New technology, known as “next-generation sequencing,” was creating a trove of new information and revealing connections that could help investigators stop outbreaks before they spun out of control.

As stakeholders took turns presenting slides in the wood-paneled auditorium, some spoke of the possibility that genome sequencing might help solve the stagnant rate of salmonella poisoning.

The new technology would help identify pathogens in foods like raw flour, peaches and romaine lettuce that were once rarely seen as sources of outbreaks.

While whole-genome sequencing couldn't confirm the source of an outbreak without additional evidence, it provided powerful clues about the bacteria's genetic history that could point epidemiologists in the right direction.

But for all the potential, much of the conversation that day in October 2017 centered on how to make this scientific breakthrough palatable to industry. Trade groups had requested the meeting, and they voiced concerns about how the new tool could be used for enforcement or might inaccurately connect companies' products to outbreaks. Speakers, including USDA officials, emphasized the importance of proceeding with caution. They discussed strengthening firewalls to keep testing data private and establishing "safe harbors" from USDA enforcement.

During a roundtable discussion, one representative from the United Fresh Produce Association raised concerns about the idea of companies sharing genome sequencing data with the government. "I think right now, it's viewed as very one-sided," she said. "We see the benefit to the agencies, but it's less clear how a company would directly benefit."

The industry's influence wasn't lost on regulators. Former USDA officials hold key posts at some of the food industry's biggest companies. Indeed, two people who led the 2017 meeting for the agency now work for the food industry.

Sitting in the auditorium, Jørgen Schlundt, the former head of food safety for the World Health Organization, was growing increasingly frustrated. Schlundt had helped achieve dramatic reductions in salmonella in Denmark while working for the country's food agency.

"I understand that I'm in the U.S., but surely this must also be about protecting consumers," he told the audience. "We are basically only talking about protecting industry here. I thought that this was, the basic purpose was to protect consumers, avoid American consumers and other consumers from dying from eating food."

While the USDA tiptoed around the new technology, whole-genome sequencing, which is now used to solve criminal cases and track COVID-19 variants, would prove pivotal to the CDC's infantis investigation.

As the infantis outbreak spread, epidemiologists noticed something unusual: The outbreak strain, Pattern 1080, carried an unusual combination of antibiotic-resistance genes that looked similar to another strain they'd seen before, Louise Francois Watkins, an epidemiologist at the CDC, said in an interview.

At the time, the CDC was still using a method called pulsed-field gel electrophoresis, or PFGE, which produced barcode-like patterns from the bacteria's DNA that scientists used to connect cases. So the investigators asked the lab to line up the patterns and compare the two strains.

"And sure enough," Francois Watkins said, the strains were so similar, they differed by "only a single band" of the barcode. With that clue, they decided to analyze the strains using whole-genome sequencing.

That allowed scientists to compare the individual building blocks in the genomes of bacteria. And the infantis investigators discovered that not only were the two strains genetically similar but that PFGE was masking the scope of the problem.

In fact, Pattern 1080 was just one wave in a much larger surge of drug-resistant infantis — one that had been detected nearly a decade ago in Israel and was now circulating worldwide in countries as far apart as Italy, Peru and Vietnam.

> **“The antibiotics that your doctor is going to pick when they suspect you have a salmonella infection are pretty likely not to be effective.”**
>
> —Louise Francois Watkins, an epidemiologist at the CDC

One of the reasons the U.S. variant is so concerning is that it typically carries a unique gene that makes it especially hard to treat.

“It's resistant to four of the five antibiotics that are commonly recommended for treatment,” Francois Watkins said. “The antibiotics that your doctor is going to pick when they suspect you have a salmonella infection are pretty likely not to be effective.”

The strain is also a major public health concern because it has the ability to pass those genes to other bacteria, adding to the growing global problem of antibiotic resistance.

“We don't want to see resistance climbing in our food supply because it's not going to stay in that one space,” Francois Watkins said.

Whole-genome sequencing had helped investigators discover that the outbreak was actually a widespread problem in the country's chicken supply.

But even with these new revelations, public health officials still lacked one of the most basic tools to control the strain.

“A Gap in Our Regulations”

CDC investigators knew that infantis was spreading in chickens long before the birds arrived at the slaughterhouse. But enlisting the USDA's Food Safety and Inspection Service would be a dead end because the agency has no regulatory authority over farms. The USDA can only force farms to take measures when animals get sick, not when humans do.

That also made it difficult for the CDC investigators to pursue leads involving breeders and feed suppliers to trace back how dangerous bacteria got into the food supply.

“That's a gap in our regulations,” Tauxe of the CDC said.

Nearly all the chickens we eat descend from birds bred by two companies, Aviagen and Cobb-Vantress, a subsidiary of Tyson Foods. This breeding process has allowed consumers to walk into any grocery store and find chicken of the same quality. But that pyramid structure also makes it possible for salmonella to circulate since the bacteria can be transferred from hens to their offspring, and a single breeding flock might produce 3 million chickens over several years. (Both companies declined to comment.)

And nearly every step of their journey from chicken house to our plates presents an opportunity for salmonella to spread.

As far back as 2005, the USDA has held public meetings exhorting the poultry industry to take steps at the farm. It has recommended that farmers change or chemically treat the litter between flocks, use traps and bait to eliminate pests and vaccinate hens and chicks against salmonella.

Denmark, Sweden and Norway have largely eradicated salmonella on farms by keeping chicken houses clean, frequently testing the birds and destroying infected breeding flocks. The United Kingdom has dramatically reduced salmonella illnesses by pressuring the industry to vaccinate.

The structure of the U.S. chicken industry makes it ideally suited to implement such interventions. The same company that slaughters the chickens often owns the hatchery and feed mill, and it contracts with farmers to raise the chickens to its specifications. The catch is that because companies are essentially doing business with themselves, there’s little incentive for any of them to press others to reduce salmonella, the industry consultant Samadpour said.

“If it was four or five different companies,” he said, “the processing plant would tell the farms, ‘If you are more than so much positive, you can’t send it here,’ the farm would tell the hatchery, ‘If the chicks coming in are positive, we are not going to take them.’ They would tell the feed mill that if the feed is contaminated with salmonella, ‘We are not going to bring it in.’ Can you do that? No, it all belongs to you.”

Because more isn’t done on the farm, the birds’ skin and feathers are often highly contaminated with salmonella by the time they reach the processing plant, according to the USDA. And in the plant, there are many ways bacteria can spread.

Birds can be further cross-contaminated when workers cut carcasses into breasts, legs and wings. The USDA recommends workers wash their hands and sanitize knives between each bird. But workers often have a few seconds to make each cut.

Ground chicken, which has become increasingly popular, is especially prone to contamination. Meat sent to the grinder comes from multiple birds, increasing the chance of cross-contamination. The fine texture of ground chicken can also get caught in small pieces of equipment, potentially tainting multiple batches.

While salmonella is found in 8% of the chicken parts tested by the USDA, 25% of ground chicken samples contain the bacteria.

And when the USDA tested for salmonella during the infantis outbreak, more than half of the positive samples were found in ground chicken.

“The Company Can Do Whatever It Wants”

In July 2018, as outbreak investigators began to discover infantis in Perdue products, the USDA had a chance to press the company for answers. Routine salmonella testing had found that the company’s plant in Cromwell, Kentucky, was exceeding the USDA’s salmonella standards, which say no more than 15.4% of chicken parts at a plant should test positive for the pathogen.

So USDA staff were sent to conduct an assessment of the plant, which might have seemed well-timed. Of the 76 plants where the infantis outbreak strain had been found, Cromwell, with 8% of the positive samples, had more than any other facility. But failing the agency’s salmonella standard doesn’t give the USDA the power to do anything more than review the plant’s practices.

The USDA noted that Perdue had responded to its high rate of salmonella by adding more chemical dip tanks and sprays to disinfect the chicken. Because Perdue’s internal sampling data showed the new steps appeared to be reducing the bacteria, the agency gave Perdue more time and recommended “no further action be taken.”

According to the USDA report, Fluckey, then the food safety director at Perdue, told auditors that the agency’s testing didn’t paint an accurate picture of the plant because it wasn’t measuring the quantity of salmonella. He added that Perdue managers hadn’t concentrated on the salmonella types most likely to make people sick because they were focused on “meeting the performance standard.”

A year later, USDA sampling indicated that the plant had continued to violate salmonella standards, with a third of chicken parts testing positive for the bacteria. In addition, the USDA said 12 of Perdue’s samples were highly related genetically to samples from people who’d recently gotten sick.

Still, the agency once again deferred to the company’s testing results, which showed a decrease in the rate of salmonella at the plant. The USDA decided it couldn’t cite the plant and that no action was necessary.

ProPublica found that many plants have repeatedly violated the agency’s standards without being shut down or facing any recent public sanction. According to the most recent data, more than a third of the plants producing ground chicken are violating the USDA standard. And many large companies — including Tyson, Pilgrim’s Pride, Perdue, Koch Foods and the processors that produce chicken for Costco and Whole Foods — currently have plants with high rates of the types of salmonella most likely to make people sick.

> **“ ProPublica found that many plants have repeatedly violated the agency’s standards without being shut down or facing any recent public sanction.**

Whole Foods said it has a team of experts who review the salmonella results of its suppliers and works with them to lower their salmonella rates. The processor, Pine Manor Farms, said it has “worked diligently to make corrections.” Tyson and Costco declined to comment; Pilgrim’s and Koch didn’t respond to questions.

Other Perdue plants where the infantis outbreak strain was found also had a poor track record with salmonella overall. In the last three years, its plants in Rockingham, North Carolina, and Georgetown, Delaware, had more than 35% of their ground chicken samples test positive for the bacteria, and nearly all of them were types commonly linked to human illnesses. Yet neither plant has faced any recent public enforcement action, according to a review of USDA reports. (In April, ProPublica requested detailed files for both plants, but the USDA has yet to provide them.)

In an interview before she joined the USDA, Eskin said the consequences for companies violating the standards aren’t “anything meaningful in terms of enforcement.” “At the end of the day,” she said, “I think the company can do whatever it wants.”

The USDA doesn’t appear to have traced the supply chain for the plants that tested positive for the outbreak strain. Detroit Sausage had one of the highest numbers of samples with the strain.

Phil Peters, one of the owners, said he doesn’t remember anyone from the USDA asking the company who supplied its chicken. “I can’t control something that’s coming in from somewhere else unless I stop using it,” he said.

The company no longer produces chicken sausage because his clients no longer order it. But as a small processor, Peters said, he has little ability to demand chicken companies provide him meat carrying less salmonella. “They’re too big to worry about us,” he said.

A Hidden “Epidemic”

With no powers of its own and stuck with a hesitant regulator in the USDA, the CDC’s investigators needed the industry’s help.

On Aug. 8, 2018, the CDC offered a stark assessment of the outbreak to representatives of the industry’s trade group, the National Chicken Council: Drug-resistant infantis had become a “particular clinical and public health concern” because it was spreading through the chicken industry and increasingly making people sick.

The USDA seemed to take a less urgent approach. After an Aug. 16 foodborne illness investigations meeting with infantis on the agenda, an agency official wrote that there were “zero active illness investigations.” The USDA had begun tracing victims’ grocery purchases, but beyond that, it decided infantis was an “illness cluster” to watch — not a situation that required additional resources.

By then, three months into the outbreak investigation, neither the CDC nor the USDA had said anything to consumers.

People continued to get sick. Twelve days after the USDA meeting, a New York City resident began having stomach cramps. The patient’s spouse told investigators the victim had eaten and shopped in the Flatbush section of Brooklyn. The patient went to the hospital but died two days later, the first known fatality from the infantis outbreak.

For nearly two months, there was still no public warning.

In October 2018, the CDC privately met again with the National Chicken Council. By then, public health officials were convinced that the outbreak strain originated high up in the chicken supply chain.

“The outbreak strain may be persisting in chicken populations, their environments or their feed,” according to the CDC’s presentation to the industry group. “Further investigation is needed to help prevent new illnesses and similar outbreaks in the future.”

The CDC drew up a list of questions for the National Chicken Council:

> How was it possible that so many different companies could have the same strain of salmonella infantis? Were common sources of chickens, eggs or other farming products widely used? Would one or more companies be willing to partner with the CDC and USDA to explore possible connections?

The council didn’t have many answers. According to a government official’s notes, the industry said that it “does a lot to try to reduce salmonella across the board,” but that it didn’t have a specific preventative measure for infantis. An industry representative added that it “might have been helpful to have the discussion 4 years ago,” when the first signs of drug-resistant infantis popped up in processing plants.

A few days after the October meeting, a 2-year-old Michigan girl began rubbing her belly before developing a fever and diarrhea, making her the latest Pattern 1080 patient. Her parents said that before she got sick, she’d eaten chicken nuggets and touched a package of raw chicken in their kitchen.

The next day — more than nine months after the first patient from the outbreak got sick — the CDC issued its first public notice. By then, 92 people in 29 states had been infected with the outbreak strain. But the number was likely far higher: The CDC estimates that for every confirmed salmonella case, an additional 30 are never reported. That meant that nearly 3,000 people had likely been infected.

Though the CDC knew that infantis wasn’t a typical outbreak strain, the notice offered little advice to consumers other than to remind them to follow standard food safety steps when handling raw poultry. The CDC told ProPublica that there was little more it could say to consumers.

Infantis was so pervasive, Tauxe said, that the CDC couldn't tell consumers to avoid any specific kind of chicken or brand.

Instead, public health officials held another private meeting with the chicken industry in February 2019, telling trade organization officials that they considered this strain of infantis to be an "epidemic."

The CDC emphasized how risky this particular bacteria was because of its resistance to first-line drugs used to treat salmonella, especially illnesses involving children and patients with blood infections.

Health officials also presented the clues that had pointed toward Perdue as a potential source of some of the illnesses. The agency wanted to sit down with Perdue, but with no power to compel the company to answer questions, it would be months before a meeting happened.

A little over a week after the February 2019 meeting with industry, the CDC closed its investigation. In its second and last public notice about the outbreak, it said 129 people had gotten sick, 25 had been hospitalized and one person had died. There was no mention of Perdue or any other company.

In ending the investigation, the CDC seemed to send mixed messages. While the agency noted that "illnesses could continue because this salmonella strain appears to be widespread in the chicken industry," it also told Consumer Reports that the decision was prompted by a decrease in new cases.

Infantis Strikes Another Victim

Five months after the CDC closed the infantis investigation, Arthur Sutton and Marva Lamping walked into El Rodeo, a lively Mexican restaurant in Bend, Oregon, where copper art hangs on rustic yellow walls and red-clay mosaics line the archways.

The couple typically went there at least once a month after paying their mortgage or when friends were in town. Sutton's stomach had been bothering him since eating there the week before, but he didn't know why. He decided he was up for going out anyway. It was his 70th birthday, and the couple always went to El Rodeo for their birthdays.

Marva Lamping and Arthur Sutton were regulars at El Rodeo in Bend, Oregon, until Sutton fell ill after eating at the restaurant. Mason Trinca, special to ProPublica

Lamping and Sutton had met 15 years earlier at the local community college when Sutton decided to put his past struggles with addiction to constructive use by becoming a counselor. After math class, a group of students would go out to a Mexican restaurant.

“He just one day said, ‘I noticed when we go out for nachos, that you don’t have a margarita with all the other ladies,’” Lamping said. “And I said, ‘No, I don’t drink and drive.’ And he said: ‘Well, I’ll give you a ride. If you’d like a margarita, I’ll take you.’”

Lamping, 63, was drawn to Sutton’s warm and accepting way of engaging with the world — a demeanor that seemed perfectly suited for his counseling work. Lamping said his clients clearly had a bond with him. Once, while he and Lamping were stuck in construction traffic, a former client working as a flagger recognized Sutton and came over to shake his hand.

Sutton, a large man with a square chin, broad forehead and glasses, was quieter than usual that night as a waiter brought out tortilla chips, salsa and a small oval dish of chopped cabbage slaw mixed with diced jalapenos, tomatoes and cilantro. Lamping went to play a few rounds of video slots in the back of the restaurant before dinner while Sutton dug into the salsa and slaw.

Sutton and Lamping Courtesy of Marva Lamping

Those appetizers would take on grave importance for Lamping after Sutton developed severe food poisoning that night. She said that during its investigation of Sutton’s illness, the county Health Department would ask her if Sutton had eaten salsa and slaw, which an investigator later described in an internal email as the “likely culprit” behind multiple food poisoning cases connected to the restaurant.

El Rodeo’s owner, Rodolfo Arias, said he “didn’t know anything” about the investigation.

An inspection of the restaurant would find concerns with cross-contamination because El Rodeo thawed and washed frozen chicken in the same three-compartment sink in which it washed lettuce, tomatoes and cilantro. Inspectors also noted the faucet was “uncleanable” because it was wrapped in black tape.

Arias denied that his restaurant was responsible for Sutton’s illness. “I don’t think it was possible,” Arias said.

After dinner, the ache in Sutton’s stomach erupted. He began vomiting and couldn’t lay down to sleep. By the next morning, he could no longer stand the pain. He called Lamping at work, where she handles patient admissions at St. Charles Medical Center. She went home and took him to the emergency room, several hundred feet from her desk.

After a CT scan, a doctor diagnosed Sutton, who was obese and had other medical problems, with a hernia. He was discharged with plans for surgery.

But the pain didn’t go away. Ongoing diarrhea sent him to the toilet every 10 minutes. He tried to hide his pain, but Lamping finally convinced him to return to the hospital. “I’m looking into your eyes right now, Arthur,” she remembers telling him. “You’re dying.”

Lamping at her home in Bend in July. Mason Trinca, special to ProPublica

Sutton’s hospital stay, detailed in 2,000 pages of medical records provided by Lamping, would be marked by one wrenching episode after another. In the emergency room, when a nurse put a feeding tube up his nose, blood started gushing out.

Still, Sutton maintained his signature equanimity. Medical staff described him in notes as “very relaxed and accepting and taking it all in stride.”

Initially, the intensive care doctors thought Sutton was still struggling with the effects of a complex hernia. But in the operating room, it became clear that things were worse than doctors imagined. His bowels were severely damaged. Surgeons set about removing dead segments of his intestines and reconnecting the functioning parts. They also noted that Sutton had an acute kidney injury caused by “profound” dehydration and septic shock from a widespread infection.

Over 16 days, Sutton underwent a similar procedure seven more times. Surgeons cut out pieces of dead intestine, centimeter by centimeter, and tried to repair tears and leaks in his bowels. Sutton was going in for surgery so often they placed a medical dressing over his abdomen so they wouldn’t have to cut him open every time.

Throughout, Sutton cycled through periods of decline followed by flashes of normalcy. Sleep-deprived, he began hallucinating that there were monkeys in trees and sailboats emerging from the ceiling. But he was also able to sit in a hallway chair in the sun with Lamping, eat a popsicle and jokingly tell the physical therapist, “You look like Tom Cruise.”

Still, Sutton was deteriorating. One day, Lamping found a note on the bedside table that Sutton had scratched out: “Why is this happening?”

Sutton’s doctors were also puzzled. After the first surgery, they’d quickly identified salmonella as the source of Sutton’s illness and immediately started antibiotics. But after nearly a week, they couldn’t understand why there was no improvement.

What Sutton's doctors didn't yet know was that a pernicious type of bacteria was poisoning Sutton's blood: the strain of multidrug-resistant infantis circulating throughout the chicken industry.

To Industry, the Mystery of Infantis "Went Away"

A month before Sutton got sick, the CDC's top foodborne disease experts held another meeting with the National Chicken Council. This time Perdue and four other big chicken processors were at the table.

Internal agency notes drafted before the meeting showed officials bracing for an unreceptive audience. "They have known about our concerns for years," the notes read. "They know about European practices. As a member-run trade association, their position is often driven by the lowest common denominator. Business margins are 'razor' thin; some companies are unable or unwilling to embrace expensive control strategies upstream."

During the three-hour meeting, the group discussed salmonella prevention and lessons learned from infantis.

But the CDC's message — that infantis was a serious problem that demanded action — doesn't seem to have resonated with Ashley Peterson, the industry representative who organized and attended the meeting. In September 2019, Peterson, the National Chicken Council's senior vice president of scientific and regulatory affairs, told trade magazine Poultry Health Today that infantis wasn't a problem anymore, according to a video of the interview.

"We don't really understand where it came from or why it went away," Peterson said.

Learning of Peterson's comments, Tauxe of the CDC seemed surprised and puzzled.

"It didn't go away," he said. "We have met with the NCC repeatedly and have emphasized with them that it's an ongoing problem. That's wishful thinking of some kind."

National Chicken Council spokesperson Tom Super said Peterson was referring to the CDC investigation ending and only learned later that the CDC was still seeing cases of infantis. He added that the industry has invested tens of millions of dollars a year in food safety and it has never downplayed infantis.

> " **Swifter action might have made the difference for Sutton.**

More than two years after Peterson's comments — as infantis has sickened thousands more people — the trade group still hasn't answered most of the CDC's questions about the strain and has shared little with the agency about efforts to curb it, Tauxe said.

“How it got into the chickens in the first place, and why it expanded across the country through the chickens and why it’s persisting remain open questions for us,” he said. “Stopping it is going to depend on what the industry is willing to step up to and do.”

Super denied that the industry hadn’t answered the CDC’s questions but didn’t provide responses when ProPublica posed them again. “The industry never stopped working to address salmonella infantis — an effort that continues today,” he said.

Swifter action might have made the difference for Sutton.

At the hospital in Oregon, Sutton’s prognosis worsened. By mid-August 2019, the doctors had learned that the type of salmonella ravaging Sutton’s body was infantis. The finding might have helped doctors change course, but it was too late. The bacteria had already taken its toll.

Back in his room after a half-dozen surgeries, Sutton signaled to Lamping, waving two hands to show that he was done. “He just kept going: ‘Enough, enough. No more,’” Lamping said.

After contracting salmonella, Sutton spent more than two weeks in the hospital, where he underwent eight operations. Courtesy of Marva Lamping

She looked at Sutton and shook her head, refusing to give up. But there wasn’t much the doctors could do.

During his eighth visit to the operating room, a surgeon noted that the leak in his bowels was probably so deep that it wasn’t accessible to surgeons: “Any further dissection would be significantly risking more bowel injury and making his current problem worse,” the medical records said.

More than two weeks into his hospital stay, Sutton’s salmonella infection had led to kidney failure. Sutton would need round-the-clock dialysis and a feeding tube to survive.

Lamping and Sutton’s brother, Jim, gathered in Sutton’s room to decide what to do. They agreed that Sutton wouldn’t want to live constantly hooked up to machines.

They told the hospital to stop treatment and move him to comfort care. “Time for him to go to heaven,” Jim Sutton said. After life support was removed, Lamping sat next to the bed and rested her head on Arthur’s hand.

The next day, on Aug. 16, 2019, Arthur Sutton died. The cause was severe blood poisoning and acute organ dysfunction brought on by salmonella. Lamping was paralyzed by grief. Her visions of the future had always included him.

“I watched a man go from happy-go-lucky — someone who should have been with me another 20 years — I lost him,” Lamping said. “I lost him.”

Lamping clutches Sutton’s ring. Mason Trinca, special to ProPublica

Two years later, she still replays Sutton’s battle with salmonella over in her mind, certain that something could have been done differently.

Lamping has focused on potential problems with how their food was handled at El Rodeo and hired a lawyer to file a lawsuit against the restaurant in 2020. She blames the restaurant, in part, because a county health inspection after Sutton died noted that it had told El Rodeo about the “findings from the state health lab on salmonella infantis cases.” In court filings, the restaurant denied the allegations.

But Lamping also says there are things that food safety regulators and the industry could have done long before the chicken arrived at El Rodeo.

“If they know that infantis is in the chicken, if they know it’s there, why are they selling it to us?” Lamping asked.

The USDA, to this day, has never said anything to consumers about the risk of multidrug-resistant infantis.

Because of the pandemic, Lamping and Jim Sutton have had to delay Arthur’s memorial. They hope that someday soon, they’ll be able to gather his friends and family on a hill overlooking a canyon in central Oregon.

They’ll walk through shale rock, wildflowers and junipers, and look over the canyon’s edge where a buck can sometimes be seen running through the sagebrush. They’ll open Sutton’s urn and let the wind carry his ashes away.

About the Data: How ProPublica Analyzed Bacterial Pathogen Presence

Data Used

ProPublica obtained bacterial pathogen genomic sequencing data from the National Center for Biotechnology Information’s Pathogen Detection project. The project integrates data from bacterial pathogens sampled from food, the environment and human patients by participating public health agencies in the United States and around the world. The NCBI analyzes data as it is submitted, and the results are monitored by public health agencies, including the CDC as part of foodborne illness outbreak investigations. The data includes metadata about each bacterial isolate submitted by the person or institute who collected the bacterial sample, as well as computational predictions by NCBI.

Through Freedom of Information Act requests, ProPublica obtained epidemiological information about bacterial samples taken as part of the 2018-19 salmonella infantis outbreak investigation and samples obtained during routine testing in establishments regulated by the USDA’s Food Safety and Inspection Service. ProPublica also obtained epidemiological information connected to patients considered part of this outbreak, including the date of sample collection and details about a patient’s illness, recent food consumption and demographics — details crucial to foodborne illness investigations. Data about bacteria found during USDA inspections also included the type of meat or poultry the sample was obtained from, the date of collection and the name and location of the facility. Integrating these details with the NCBI metadata offered a way to group samples together not just by genetic similarity, but also by location and time.

The USDA posts public datasets containing the results of its salmonella sampling at poultry processing plants since 2015, which detail the collection date, type of poultry product sampled and, if salmonella was present, information on type and any antimicrobial resistance. The datasets include both routine sampling, conducted at every plant, and follow-up sampling, conducted at plants where the agency has identified high levels of salmonella. (Samples from USDA inspections that contain salmonella are reflected in both the NCBI data and the agency’s inspection data.)

Analysis Decisions

To confirm the persistence of multidrug-resistant infantis in food processing facilities, grocery stores and patients with salmonella infections, ProPublica relied on both metadata submitted to NCBI and genetic features computed by NCBI. ProPublica restricted its analysis to isolates in the NCBI data belonging to what was known as SNP cluster PDS000089910.78, as of Oct. 19, 2021. This cluster contains most isolates involved in the infantis outbreak, and the CDC said it is monitoring most of the isolates in the cluster. ProPublica also filtered for isolates that were reported to be serotype infantis by the submitter or, when user-submitted information was unavailable, were computationally predicted to be infantis by the NCBI data processing pipeline.

ProPublica used data about evolutionary modeling computed by NCBI to establish the degree of genetic similarity between bacterial isolates from the outbreak and isolates collected more recently.

ProPublica’s analysis of salmonella rates in poultry plants is based on methods the USDA uses, using the agency’s routine sampling data to calculate positivity rates — that is, the number of positive tests compared with all salmonella tests taken at the facility — for each type of poultry a plant processed. ProPublica also calculated the high-risk salmonella rate for plants, determining the percentage of samples at the facility that tested positive for one of the 30 salmonella types the CDC has found to be most associated with human illnesses.

The USDA inspection data was also used to compare the number of samples found to contain salmonella infantis and salmonella Kentucky with the total number of routine samples taken each year to determine the rate at which each was occurring in the sampling program across all plants and poultry types.

Maryam Jameel contributed reporting, and Andrea Suozzo contributed analysis.

Illustrated explainer by Daniel Hertzberg, special to ProPublica.

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High-density livestock operations, crop field application of manure, and risk of community-associated methicillin-resistant Staphylococcus aureus infection in Pennsylvania

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Affiliations

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Abstract

Importance: Nearly 80% of antibiotics in the United States are sold for use in livestock feeds. The manure produced by these animals contains antibiotic-resistant bacteria, resistance genes, and antibiotics and is subsequently applied to crop fields, where it may put community members at risk for antibiotic-resistant infections.

Objective: To assess the association between individual exposure to swine and dairy/veal industrial agriculture and risk of methicillin-resistant Staphylococcus aureus (MRSA) infection.

Design, setting, and participants: A population-based, nested case-control study of primary care patients from a single health care system in Pennsylvania from 2005 to 2010. Incident MRSA cases were identified using electronic health records, classified as community-associated MRSA or health care-associated MRSA, and frequency matched to randomly selected controls and patients with skin and soft-tissue infection. Nutrient management plans were used to create 2 exposure variables: seasonal crop field manure application and number of livestock animals at the operation. In a substudy, we collected 200 isolates from patients stratified by location of diagnosis and proximity to livestock operations.

Main outcomes and measures: Community-associated MRSA, health care-associated MRSA, and skin and soft-tissue infection status (with no history of MRSA) compared with controls.

Results: From a total population of 446,480 patients, 1539 community-associated MRSA, 1335 health care-associated MRSA, 2895 skin and soft-tissue infection cases, and 2914 controls were included. After adjustment for MRSA risk factors, the highest quartile of swine crop field exposure was significantly associated with community-associated MRSA, health care-associated MRSA, and skin and soft-tissue infection case status (adjusted odds ratios, 1.38 [95% CI, 1.13-1.69], 1.30 [95% CI, 1.05-1.61], and 1.37 [95% CI, 1.18-1.60], respectively); and there was a trend of increasing odds across quartiles for each outcome (P ≤ .01 for trend in all comparisons). There were similar but weaker associations of swine operations with community-associated MRSA and skin and soft-tissue infection. Molecular testing of 200 isolates identified 31 unique spa types, none of which corresponded to CC398 (clonal complex 398), but some have been previously found in swine.

Conclusions and relevance: Proximity to swine manure application to crop fields and livestock operations each was associated with MRSA and skin and soft-tissue infection. These findings contribute to the growing concern about the potential public health impacts of high-density livestock production.

Figures

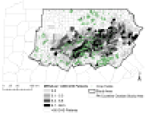

Figure 1. Crop field locations and MRSA...

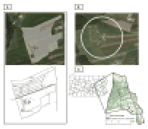

Figure 2. Three methods used to identify...

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Residential Proximity to Large Numbers of Swine in Feeding Operations Is Associated with Increased Risk of Methicillin-Resistant *Staphylococcus aureus* Colonization at Time of Hospital Admission in Rural Iowa Veterans

Margaret Carrel, Marin L. Schweizer, Mary Vaughan Sarrazin, Tara C. Smith and
Eli N. Perencevich

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Abstract

Among 1,036 patients, residential proximity within 1 mile of large swine facilities was associated with nearly double the risk of methicillin-resistant *Staphylococcus aureus* (MRSA) colonization at admission (relative risk, 1.8786 [95% confidence interval, 1.0928-3.2289]; *P* = .0239) and, after controlling for multiple admissions and age, was associated with 1.2nearly triple the odds of MRSA colonization (odds ratio, 2.76 [95% confidence interval, 1.2728-5.9875]; *P* = .0101).

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Global Farm Animal Production and Global Warming: Impacting and Mitigating Climate Change

***Gowri Koneswaran*[1] *and Danielle Nierenberg*[1,2]**

[1]Humane Society of the United States, Washington, DC, USA; [2]Worldwatch Institute, Washington, DC, USA

Background: The farm animal sector is the single largest anthropogenic user of land, contributing to many environmental problems, including global warming and climate change.

Objectives: The aim of this study was to synthesize and expand upon existing data on the contribution of farm animal production to climate change.

Methods: We analyzed the scientific literature on farm animal production and documented greenhouse gas (GHG) emissions, as well as various mitigation strategies.

Discussions: An analysis of meat, egg, and milk production encompasses not only the direct rearing and slaughtering of animals, but also grain and fertilizer production for animal feed, waste storage and disposal, water use, and energy expenditures on farms and in transporting feed and finished animal products, among other key impacts of the production process as a whole.

Conclusions: Immediate and far-reaching changes in current animal agriculture practices and consumption patterns are both critical and timely if GHGs from the farm animal sector are to be mitigated.

Key words: animal agriculture, CAFO, climate change, concentrated animal feeding operation, diet, environment, farm animals, farm animal welfare, food choices, global warming, greenhouse gas emissions (GHGs). *Environ Health Perspect* 116:578–582 (2008). doi:10.1289/ehp.11034 available via *http://dx.doi.org/* [Online 31 January 2008]

Although much evidence has been amassed on the negative impacts of animal agricultural production on environmental integrity, community sustainability, public health, and animal welfare, the global impacts of this sector have remained largely underestimated and underappreciated. In a recent review of the relevant data, Steinfeld et al. (2006) calculated the sector's contributions to global greenhouse gas (GHG) emissions and determined them to be so significant that—measured in carbon dioxide equivalent—the emissions from the animal agricultural sector surpass those of the transportation sector.

Global warming and climate change. The three main GHGs are CO_2, methane (CH_4), and nitrous oxide (N_2O) (Steinfeld et al. 2006). Although most attention has focused on CO_2, methane and N_2O—both extremely potent GHGs—have greater global warming potentials (GWPs) than does CO_2. By assigning CO_2 a value of 1 GWP, the warming potentials of these other gases can be expressed on a CO_2-equivalent basis (Paustian et al. 2006; Steinfeld et al. 2006): CH_4 has a GWP of 23, and N_2O has a GWP of 296.

Many impacts of global warming are already detectable. As glaciers retreat, the sea level rises, the tundra thaws, hurricanes and other extreme weather events occur more frequently, and penguins, polar bears, and other species struggle to survive (Topping 2007), experts anticipate even greater increases in the intensity and prevalence of these changes as the 21st century brings rises in GHG emissions. The five warmest years since the 1890s were 1998, 2002, 2003, 2004, and 2005 [NASA (National Aeronautics and Space Administration) 2006]. Indeed, average global temperatures have risen considerably, and the Intergovernmental Panel on Climate Change (IPCC 2007c) predicts increases of 1.8–3.9°C (3.2–7.1°F) by 2100. These temperature rises are much greater than those seen during the last century, when average temperatures rose only 0.06°C (0.12°F) per decade (National Oceanic and Atmospheric Administration 2007). Since the mid-1970s, however, the rate of increase in temperature rises has tripled. The IPCC's latest report (IPCC 2007b) warns that climate change "could lead to some impacts that are abrupt or irreversible."

Anthropogenic influences. Although some natural occurrences contribute to GHG emissions (IPCC 2007c), the overwhelming consensus among the world's most reputable climate scientists is that human activities are responsible for most of this increase in temperature (IPCC 2007a). The IPCC (2007a) concluded

> with high confidence that anthropogenic warming over the last three decades has had a discernible influence on many physical and biological systems.

Although transportation and the burning of fossil fuels have typically been regarded as the chief contributors to GHG emissions and climate change, a 2006 report, *Livestock's Long Shadow: Environmental Issues and Options* [Food and Agriculture Organization of the United Nations (FAO) 2006], highlighted the substantial role of the farm animal production sector. Identifying it as "a major threat to the environment" (FAO 2006), the FAO found that the animal agriculture sector emits 18%, or nearly one-fifth, of human-induced GHG emissions, more than the transportation sector. (Steinfeld et al. 2006).

Our objective was to outline the animal agriculture sector's share of global GHG emissions by synthesizing and expanding upon the data reported in *Livestock's Long Shadow* (FAO 2006) with more recent reports from the IPCC, data from the U.S. Environmental Protection Agency (EPA), and studies on GHGs from agriculture and mitigation strategies [Cederberg and Stadig 2003; International Federation of Organic Agriculture Movements (IFOAM) 2004; IPCC 2007a, 2007b, 2007c; McMichael et al. 2007; Ogino et al. 2007; U.S. EPA 2007a; Verge et al. 2007]. We also investigated links between this sector and the far-reaching impacts of climate change on conflict, hunger, and disease, while underscoring the roles of animal agriculture industries, policy makers, and individual consumers in mitigating this sector's contributions to climate change and global warming.

Discussion

Impacts of growing livestock populations and intensifying production. According to FAOSTAT (FAO 2008), globally, approximately 56 billion land animals are reared and slaughtered for human consumption annually, and livestock inventories are expected to double by 2050, with most increases occurring in the developing world (Steinfeld et al. 2006). As the numbers of farm animals reared for meat, egg, and dairy production rise, so do their GHG emissions. The U.S. Department of Agriculture (USDA 2004) has noted that

> GHG emissions from livestock are inherently tied to livestock population sizes because the livestock are either directly or indirectly the source for the emissions.

Since the 1940s, for example, escalating farm animal populations—in large, confined operations, in particular—have significantly

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increased methane emissions from both animals and their manure (Paustian et al. 2006).

In recent decades, increasing numbers of animals are raised in intensive production systems in which chickens, pigs, turkeys, and other animals are confined in cages, crates, pens, stalls, and warehouse-like grow-out facilities. These production systems are devoid of environmental stimuli, adequate space, or means by which to experience most natural behaviors. Furthermore, because these industrialized, "landless" facilities tend to produce more manure than can be used as fertilizer on nearby cropland (FAO 2005b), manure is instead "distributed to a small, local landmass resulting in soil accumulation and runoff of phosphorus, nitrogen, and other pollutants" (Thorne 2007).

Although extensive or pasture-based farming methods remain the norm in Africa and some parts of Asia, the trend in Latin America and Asia is to increasingly favor intensive production systems over more sustainable and more animal welfare–friendly practices (Nierenberg 2006). According to a 2007 report describing GHG emissions from agriculture (Verge et al. 2007),

> In recent years, industrial livestock production has grown at twice the rate of more traditional mixed farming systems and at more than six times the rate of production based on grazing.

Confining greater numbers of animals indoors and further separating production operations from agricultural land will only exacerbate the environmental problems already posed by this sector, which the FAO has deemed "one of the top two or three most significant contributors to the most serious environmental problems, at every scale from local to global" (Steinfeld et al. 2006).

CO_2 emissions from animal agriculture. Regarded as the most important GHG, CO_2 has the most significant direct-warming impact on global temperature because of the sheer volume of its emissions. Of all the natural and human-induced influences on climate over the past 250 years, the largest is due to increased CO_2 concentrations attributed to burning fossil fuels and deforestation (Bierbaum et al. 2007).

The animal agriculture sector accounts for approximately 9% of total CO_2 emissions, which are primarily the result of fertilizer production for feed crops, on-farm energy expenditures, feed transport, animal product processing and transport, and land use changes (Steinfeld et al. 2006).

Burning fossil fuels to produce fertilizers for feed crops may emit 41 million metric tons of CO_2 per year (Steinfeld et al. 2006). Vast amounts of artificial nitrogenous fertilizer are used to grow farm animal feed, primarily composed of corn and soybeans. Most of this fertilizer is produced in factories dependent on fossil-fuel energy (Steinfeld et al. 2006). The Haber-Bosch process, which produces ammonia in order to create nitrogen-based artificial fertilizer, is used to produce 100 million metric tons of fertilizer for feed crops annually (Steinfeld et al. 2006).

An additional 90 million metric tons of CO_2 per year may be emitted by fossil fuels expended for intensive confinement operations (Steinfeld et al. 2006). Energy uses in these industrial facilities differ substantially from those in smaller-scale, extensive, or pasture-based farms. Although a large portion of the energy used for intensive confinement operations goes toward heating, cooling, and ventilation systems, more than half is expended by feed crop production, specifically to produce seed, herbicides, and pesticides, as well as the fossil fuels used to operate farm machinery in the production of feed crops (Steinfeld et al. 2006).

According to the FAO's estimates, CO_2 emissions from farm animal processing total several tens of millions of metric tons per year (Steinfeld et al. 2006). The amount of fossil fuels burned varies depending on the species and type of animal product. For example, processing 1 kg of beef requires 4.37 megajoules (MJ), or 1.21 kilowatt-hours, and processing 1 dozen eggs requires > 6 MJ, or 1.66 kilowatt-hours (Steinfeld et al. 2006).

That same 1 kg of beef may result in GHGs equivalent to 36.4 kg of CO_2, with almost all the energy consumed attributed to the production and transport of feed (Ogino et al. 2007). Approximately 0.8 million metric tons of CO_2 are emitted annually from the transportation of feed and animal products to the places where they will be consumed (Steinfeld et al. 2006).

Farm animals and animal production facilities cover one-third of the planet's land surface, using more than two-thirds of all available agricultural land including the land used to grow feed crops (Haan et al. 1997). Deforestation, land degradation, soil cultivation, and desertification are responsible for CO_2 emissions from the livestock sector's use of land.

Animal agriculture is a significant catalyst for the conversion of wooded areas to grazing land or cropland for feed production, which may emit 2.4 billion metric tons of CO_2 annually as a result of deforestation (Steinfeld et al. 2006). This sector has particularly devastated Latin America, the region experiencing the largest net loss of forests and greatest releases of stored carbon into the atmosphere, resulting from disappearing vegetation (Steinfeld et al. 2006). One of the chief causes of Latin America's deforestation is cattle ranching (FAO 2005a).

Other important ecosystems are also threatened by increasing farm animal populations. Brazil's Cerrado region, the world's most biologically diverse savannah, produces half of the country's soy crops [Klink and Machado 2005; World Wildlife Fund (WWF) 2007a, 2007b]. As noted by the WWF (2007a), the region's animal species

> are competing with the rapid expansion of Brazil's agricultural frontier, which focuses primarily on soy and corn. Ranching is another major threat to the region, as it produces almost 40 million cattle a year.

Farm animal production also results in releases of up to 28 million metric tons of CO_2/year from cultivated soils (Steinfeld et al. 2006). Soils, like forests, act as carbon sinks and store more than twice the carbon found in vegetation or in the atmosphere (Steinfeld et al. 2006). Human activities, however, have significantly depleted the amount of carbon sequestered in the soil, contributing to GHG emissions (Steinfeld et al. 2006).

Desertification, or the degradation of land in arid, semiarid, and dry subhumid areas, is also exacerbated and facilitated by the animal agriculture sector (FAO 2007). By reducing the productivity and amount of vegetative cover, desertification allows CO_2 to escape into the atmosphere. Desertification of pastures due to animal agriculture is responsible for up to 100 million metric tons of CO_2 emissions annually (Steinfeld et al. 2006).

Nitrogen from fertilizer and feed production. Feeding the global population of livestock requires at least 80% of the world's soybean crop and more than one-half of all corn (Ash M, Nierenberg D, personal communication; Halweil B, Smil V, personal communication), a plant whose growth is especially dependent on nitrogen-based artificial fertilizers. Natural sources of fixed nitrogen, the form easily available as fertilizer for plants, are limited, necessitating artificial fertilizer production. Before the development of the Haber-Bosch process, the amount of sustainable life on Earth was restricted by the amount of nitrogen made available to plants by bacteria and lightning. Modern fertilizer manufacturing, heavily reliant on fossil fuels, has taken a once-limited nutrient and made it available in massive quantities for crop farmers in the industrialized world and, increasingly, the developing world.

According to Elizabeth Holland, a senior scientist with the National Center for Atmospheric Research (Bohan 2007),

> The changes to the nitrogen cycle are larger in magnitude and more profound than the changes to the carbon cycle. . . . But the nitrogen cycle is being neglected.

In addition, the co-chairs of the Third International Nitrogen Conference highlighted the role of farm animal production in the Nanjing Declaration on Nitrogen Management (Zhu et al. 2004), a statement presented to the United Nations Environment Programme, recognizing that

> a growing proportion of the world's population consumes excess protein and calories, which may lead to human health problems. The associated production of these dietary proteins (especially animal products) leads to further disturbance of the nitrogen cycle.

According to Vaclav Smil, a nitrogen cycle expert at the University of Manitoba, "we have perturbed the global nitrogen cycle more than any other, even carbon" (Pollan 2006). Indeed, the overwhelming majority of all crops grown in the industrialized world are nitrogen-saturated, and overuse of nitrogen in crop production, nitrogen runoff into waterways, and the millions of tons of nitrogen found in farm animal manure threaten environmental integrity and public health.

Methane and N_2O. The animal agriculture sector is also responsible for 35–40% of annual anthropogenic methane emissions (Steinfeld et al. 2006) that result from enteric fermentation in ruminants and from farm animal manure. Methane emissions are affected by a number of factors, including the animal's age, body weight, feed quality, digestive efficiency, and exercise (Paustian et al. 2006; Steinfeld et al. 2006).

Ruminants emit methane as part of their digestive process, which involves microbial (enteric) fermentation (Steinfeld et al. 2006; U.S. EPA 2006). Although individual animals produce relatively small amounts of methane (U.S. EPA 2007b), the > 1 billion ruminants reared annually amount to a significant methane source (FAO 2008). Indeed, enteric fermentation generates approximately 86 million metric tons of methane emissions worldwide (Steinfeld et al. 2006).

Typically, cattle confined in feedlots or in intensive confinement dairy operations are fed an unnatural diet of concentrated high-protein feed consisting of corn and soybeans. Although cattle may gain weight rapidly when fed this diet (Pollan 2002), it can cause a range of illnesses (Smith 1998). This diet may also lead to increased methane emissions. The standard diet fed to beef cattle confined in feedlots contributes to manure with a "high methane producing capacity" (U.S. EPA 1998). In contrast, cattle raised on pasture, eating a more natural, low-energy diet composed of grasses and other forages, produce manure with about half of the potential to generate methane (U.S. EPA 1998).

Farm animals produce billions of tons of manure, with confined farm animals in the United States alone generating approximately 500 million tons of solid and liquid waste annually (U.S. EPA 2003). Storing and disposing of these immense quantities of manure can lead to significant anthropogenic emissions of methane and N_2O (U.S. EPA 2007a). For example, according to the Pew Center on Global Climate Change (Paustian et al. 2006), farm animal manure management accounts for 25% of agricultural methane emissions in the United States and 6% of agricultural N_2O emissions. Globally, emissions from pig manure alone account for almost half of all GHG emissions from farm animal manure (Steinfeld et al. 2006).

Farm animal manure is the source of almost 18 million metric tons of annual methane emissions (Steinfeld et al. 2006). Between 1990 and 2005 in the United States, methane emissions from dairy cow and pig manure rose by 50% and 37%, respectively (U.S. EPA 2007a). The U.S. EPA (2007a) traces this increase to the trend toward housing dairy cows and pigs in larger facilities that typically use liquid manure management systems, which were first in use in the 1960s (Miner et al. 2000) but are now found in large dairy operations across the United States and in some developing countries, as well as in most industrial pig operations worldwide.

Although 70% of anthropogenic emissions of N_2O result from crop and animal agriculture combined, farm animal production, including growing feed crops, accounts for 65% of global N_2O emissions (Steinfeld et al. 2006). Manure and urine from farm animals, once deposited on the soil, emit N_2O; in the United States, a 10% rise in N_2O emissions between 1990 and 2005 can be traced, in part, to changes in the poultry industry, including an overall increase in the domestic stock of birds used for meat and egg production (U.S. EPA 2007a).

Conflict, hunger, and disease. As is the case with animal agriculture's impacts on soil, water, and air quality, the sector's contributions to climate change cannot be viewed in a vacuum. Climate change is having far-reaching consequences, perhaps most startlingly seen in growing conflicts among pastoral communities. Environmental degradation has been cited as one of the catalysts for ongoing conflicts in Darfur and other areas of Sudan [United Nations Environment Programme (UNEP) 2007], where the effects of climate change have led to untenable conditions. As temperatures rise and water supplies dry up, farmers and herders are fighting to gain and control diminishing arable land and water (Baldauf 2006).

The UNEP (2007) tied two of its critical concerns in Sudan—land degradation and desertification—to "an explosive growth in livestock numbers." In addition to citing climate change as one factor that led to the Darfur conflict (Ban 2007), United Nations Secretary-General Ban Ki-moon has noted that natural disasters, droughts, and other changes brought about by global warming "are likely to become a major driver of war and conflict" (United Nations 2007).

According to the IPCC (2007a), many areas already suffering from drought will become drier, exacerbating the risks of both hunger and disease. By 2020, up to 250 million people may experience water shortages, and, in some countries, food production may be cut in half (IPCC 2007a). By 2050—the same year by which the FAO projects that meat and dairy production will double from present levels, primarily in the developing world (Steinfeld et al. 2006)—130 million people in Asia may suffer from climate-change–related food shortages (Casey 2007).

Global temperature shifts may also hasten the speed at which infectious diseases emerge and reemerge (Epstein and Mills 2005). According to Francois Meslin of the World Health Organization, "the chief risk factor for emerging zoonotic diseases is environmental degradation by humans, particularly deforestation, logging, and urbanisation" (Fleck 2004). The clear-cutting of forests for soybean cultivation, logging, and other industries enables viruses to exploit such newly exposed niches (Greger 2007).

Strategies and next steps. Mitigating the animal agriculture sector's contributions to climate change necessitates comprehensive and immediate action by policy makers, producers, and consumers. Enhanced regulation is required in order to hold facilities accountable for their GHG emissions. One critical step is accurately pricing environmental services—natural resources that are typically free or underpriced—leading to "overexploitation and pollution" (Steinfeld et al. 2006).

Thus far, most mitigation and prevention strategies undertaken by the animal agriculture sector have focused on technical solutions. For example, researchers are investigating the reformulation of ruminant diets to reduce enteric fermentation and some methane emissions (Connolly 2007). One such remedy is a plant-based bolus, formulated to reduce excessive fermentation and regulate the metabolic activity of rumen bacteria to reduce methane emissions from both the animals and their manure (Drochner W, Nierenberg D, personal communication).

The USDA and U.S. EPA assist in funding anaerobic digester projects domestically and abroad (U.S. EPA 2007c; Sutherly 2007). These digesters, now in use at some large-scale intensive confinement facilities, capture methane from manure to use as a source of energy (Storck 2007), but are typically not economically viable for small-scale farms (Silverstein 2007).

In addition, producers are burning animal waste for fuel. The world's foremost pig producer, Smithfield Foods (Smithfield, VA), and one of the top poultry producers, Tyson Foods (Springdale, AR), are both using animal by-product fats to create biofuels (Johnston 2007; PR Newswire 2007).

McDonald's (Oak Brook, IL) and agribusiness giant Cargill (Wayzata, MN), which was supplying McDonald's with soy for use as chicken feed, recently entered into an agreement with Brazil's other chief soy traders. Engineered by international environmental organization Greenpeace, a 2-year moratorium was enacted in 2007 to prevent purchases of soy from Brazil's newly deforested areas (Kaufman 2007).

As consumers increasingly favor more environmentally friendly products and techniques, reducing consumption of meat, eggs, and milk, as well as choosing more sustainably produced animal products, such as those from organic systems, may prove equally critical strategies. Indeed, organic farming has the potential to reduce GHG emissions and sequester carbon (IFOAM 2004). Also, raising cattle for beef organically on grass, in contrast to fattening confined cattle on concentrated feed, may emit 40% less GHGs and consume 85% less energy than conventionally produced beef (Cederberg and Stadig 2003; Fanelli 2007; Ogino et al. 2007).

However, there remains an immediate need for more research regarding both technical and less technology-dependent strategies to record existing GHG emissions from individual production facilities and to provide lessons to producers and policy makers for reducing the climate-damaging impacts of animal agriculture.

Given the urgency for global action—calls echoed by scientists and world leaders alike—individual consumers must also participate. McMichael et al. (2007) put forth several recommendations, including the reduction of meat and milk intake by high-income countries as "the urgent task of curtailing global greenhouse-gas emissions necessitates action on all major fronts"; they concluded that, for high-income countries, "greenhouse-gas emissions from meat-eating warrant the same scrutiny as do those from driving and flying."

Conclusion

As the numbers of farm animals reared for meat, egg, and dairy production increase, so do emissions from their production. By 2050, global farm animal production is expected to double from present levels. The environmental impacts of animal agriculture require that governments, international organizations, producers, and consumers focus more attention on the role played by meat, egg, and dairy production. Mitigating and preventing the environmental harms caused by this sector require immediate and substantial changes in regulation, production practices, and consumption patterns.

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Impact of antibiotic use in the swine industry

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Impact of antibiotic use in the swine industry

Mary D Barton

Antibiotic resistance in bacteria associated with pigs not only affects pig production but also has an impact on human health through the transfer of resistant organisms and associated genes via the food chain. This can compromise treatment of human infections. In the past most attention was paid to glycopeptide and streptogramin resistance in enterococci, fluoroquinolone resistance in campylobacter and multi-drug resistance in *Escherichia coli* and salmonella. While these are still important the focus has shifted to ESBL producing organisms selected by the use of ceftiofur and cefquinome in pigs. In addition Livestock-associated methicillin-resistant *Staphylococcus aureus* (MRSA) suddenly emerged in 2007. We also need to consider multi-resistant strains of *Streptococcus suis*. Environmental contamination arising from piggery wastewater and spreading of manure slurry on pastures is also a growing problem.

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Introduction

Antimicrobial resistance in human pathogens has been described as a global health challenge by the World Health Organisation (WHO). It is generally accepted that it is use of antibiotics in human medicine that has been the major driver for the emergence of resistant bacteria and dissemination of resistance genes but use of antibiotics in animals also makes a significant contribution. Chantziaris and co-workers [1] have described a strong correlation between use of antimicrobials and the extent of antimicrobial resistance in *Escherichia coli* isolated from livestock in a number of European countries. Interestingly the same correlation with human use of antimicrobials is more difficult to confirm [2]. Increasingly animal health authorities such as the World Organisation for Animal Health (OIE) and the Food and Agriculture Organisation (FAO) have sought to cooperate with the WHO and many countries have taken or are starting to take action to control and reduce antibiotic use in animals [3]. Antibiotics are used extensively in intensive livestock industries such as swine production. This paper will address how and why antibiotics are used and briefly summarise the well-established link between antibiotic use in pigs and resistance in enteric organisms such as salmonella, campylobacter, enterococci and *E. coli* before addressing some of the newer and emerging problems that include methicillin-resistant *Staphylococcus aureus* (MRSA), extended β-lactamase producers, fluoroquinolone, ceftiofur, carbapenem and colistin resistance in coliforms and resistance in *Streptococcus suis*. The threat of environmental contamination will also be mentioned.

Use of antibiotics in pigs

Antibiotics are used in pigs in three main ways — as growth promoters, as prophylactic or metaphylactic treatment to prevent disease and for therapeutic purposes to treat disease.

Traditionally growth promotant use has been the most controversial because this has involved addition to pig feeds of antibiotics that are in the same chemical family as antibiotics that are valuable or critical in the treatment of human infections. Unfortunately the antimicrobial growth promotant (AGP) treatment regime creates the ideal situation for selection of antibiotic resistant bacteria and spread of antibiotic resistance genes between enteric bacteria in the pig intestinal tract in that it involves medication of pig feeds that can be fed for the whole life of the pig using low (generally subtherapeutic) concentrations of the antibiotic. Feed companies can prepare AGP medicated feeds on farmers' instructions and there is often no veterinary oversight of their use. Use of AGPs was banned by the EU in 2006 (a number had been removed from the market before that) and many other countries have significantly restricted AGPs too [3].

Prophylactic (individual animal) and metaphylactic (whole pen or herd) preventive use of antibiotics again involves addition of antibiotics to animal feeds. The intention is that the medicated feed is only used when there is a threat of an outbreak of an infectious disease and is only used for a short period of time, perhaps 5–10 days. However there is clearly the opportunity to use these medicated feeds repeatedly during one cycle of production or to use them for extended periods of time. The concentration of antibiotic in the feed is usually much higher than AGP and often at therapeutic concentrations. In most countries medicated feeds for prophylactic/metaphylactic use require a veterinary prescription. The fact that the purpose for use is disease control means that an even wider range of antibiotics important in human medicine can be used in animal feeds.

An extensive range of antibiotics is used therapeutically in pigs. Generally pigs are dosed individually either orally or by injection although in-feed medication is used. One can question the effectiveness of the latter as the farmer cannot ensure each pig receives the appropriate dose of antibiotic and of course sick animals often experience inappetence. Therapeutic use generally requires a veterinary prescription in countries where supply of antibiotics is regulated. Interestingly US data records that significant quantities of antibiotics are used in animal feeds for therapeutic purposes [4]. Callens and co-workers in Belgium where prudent use guidelines have not been implemented reported that almost half of oral antibiotics given were at inadequate doses and that antibiotics used included some important human antimicrobials such as colistin and amoxicillin [5]. A systematic review has concluded that oral use of antibiotics in animals increases the risk of antibiotic resistant *E. coli* in treated pigs and by extension the risk of transfer of this resistance to humans [6].

There is limited information on the quantities of antimicrobials used in pigs. A Danish study reported an increase in use of tetracyclines between 2002 and 2008 but a decline in use of macrolides, sulphonamides–trimethoprim, cephalosporins and fluoroquinolones [7]. Estimates from the USA indicate that annual usage is highest for chlortetracycline (533 973 kg) and tylosin (165 803 kg) [4] whereas Canadian data suggest the penicillin (35%), tetracyclines (11%) and ceftiofur (8%) were the most frequently used antibiotics, based on reports by veterinary practitioners [8]. Jordan and co-workers reported that in Australia few of the antibiotics used for control of *E. coli* were of significance in human medicine although ceftiofur was used in almost 25% of herds sampled [9]. It is noteworthy that Denmark imposes restrictions on pig producers who use more than twice the average quantities of antimicrobials [10].

Antimicrobial resistance in bacteria associated with pigs

Enterococci

It was the detection of glycopeptide resistance in pigs in 1997 [11•] that stimulated the resurgence of concerns about antibiotic use in livestock and the resulting antimicrobial resistance. The problem was the use of avoparcin as an AGP in pigs and other livestock which had led to the emergence of *van*A vancomycin resistant enterococci (VRE) in humans consuming pork from treated pigs. These findings led to a focus on the antimicrobial resistance profiles of enterococci isolated from animals even though these organisms cause no disease in animals and are simply intestinal tract commensals. *van*B enterococci which cause human infections in many countries are not associated with avoparcin use in animals. Enterococci are intrinsically resistant to many antibiotics but antibiotics of concern include the older antibiotics such as amoxicillin and high-level gentamicin resistance. Resistance in *Enterococcus faecium* to virginiamycin, a streptogramin antibiotic as is quinupristin–dalfopristin is also an issue. This early material has been reviewed by Hammerum and co-workers [12•]. MLST was carried out on pig VRE isolates from 1986 to 2009 from the USA and Europe and it was found that clones of VRE are shared by humans and pigs (*E. faecium* CC5 and CC17 and *E. faecalis* CC2) and that these strains carry identical antibiotic resistance encoding plasmids [13]. Interestingly *E. faecium* belonging to CC5 was reported in the USA in 2010 — the first report of *van*A enterococci in the USA [14]. Avoparcin has not been used as an AGP in the USA. It has also been noted that strains of *E. faecalis* from pigs and humans in Denmark that are highly resistant to gentamicin belong to an identical clonal group [15]. A recent European study of pig *E. faecium* and *E. faecalis* reported that there was some resistance to vancomycin, substantial resistance to quinupristin/dalfopristin, little or no resistance to ampicillin or gentamicin, and no resistance to linozelid (an important human antimicrobial not used in pigs) [16]. In countries where glycopeptide resistance is still an issue in pig isolates resistant organisms can be found in the piggery environment [17,18] or the vancomycin resistance genes may be co-located with other resistance genes such as the *erm*B macrolide resistance gene where the use of macrolides in pigs is selecting for *van*A VRE [19]. Copper and zinc are frequently added to pig feeds so co-location of heavy metal resistance determinants could play a role as well [20,21].

Campylobacter

The pig intestinal tract is a reservoir for both *Campylobacter coli* and *Campylobacter jejuni* although carriage of the former is more common. Resistance rates are generally higher in *C. coli*. Resistance to macrolides is well-established and is associated particularly with decades of use of tylosin as an AGP, prophylactic and therapeutic antibiotic in pigs [22]. Tetracycline and ampicillin resistance are common and in countries where fluoroquinolones are used in livestock significant levels of fluoroquinolone resistance are recorded too [23–25]. Multi-drug resistance is common in campylobacter from pigs and pig farm environments [23]. Fluoroquinolone resistance in campylobacter is still a major issue [25–28] as this restricts options for treating serious human infections. Fluoroquinolones have never been registered for use in livestock in Australia. As a result there is negligible resistance in campylobacter, *E. coli* and salmonella from livestock and much reduced resistance rates in human isolates [29•].

Salmonella

Salmonella infection and subclinical intestinal tract carriage is common in pigs worldwide. Many of the strains from pigs are multi-drug resistant [30]. The common resistances reported over the years are to tetracycline, streptomycin, sulphonamide–trimethoprim and ampicillin. In many cases the resistance genes are carried on transmissible plasmids. A UK study has noted a decline in salmonellosis in pigs from 360 incidents in 1994 to 172 incidents in 2010 [31]. Interestingly Davies suggests that antimicrobial resistance in salmonella is not a particular issue, that the main concern should be transfer of salmonella through the food chain because antimicrobial resistance results in just a slight increase in mortality [32]. However many would not agree with him and point to human infections with salmonella resistant to more critical drugs such as the 3rd and 4th generation cephalosporins (ceftiofur and cefquinome respectively) as these select for resistance to critical human cephalosporins. Resistance to ceftiofur in pig isolates was first reported in 2002 [33] and other reports quickly followed, associating the resistance with the bla_{CMY} gene [34,35]. Cefquinome resistance is much less frequently reported but it may not be investigated as often in veterinary laboratories. Nalidixic acid resistance has been reported in pig salmonella isolates [26,36] and fluoroquinolone resistance although less common has been reported from China [37]. Use of zinc and copper in pig feeds has been linked to the presence of multi-drug resistant salmonella [38].

Escherichia coli

The early history of antimicrobial resistance in commensal *E. coli* from the intestinal tract of pigs is similar to that of salmonella with resistance to tetracyclines, aminoglycosides, sulphonamide–trimethoprim and ampicillin widespread. Many pig isolates are multi-resistant and resistance genes are frequently on plasmids. Resistance to ceftiofur and cefquinome is frequently more common in *E. coli* than in salmonella. Lutz and co-workers found 63% of isolates resistant to ceftriaxone [39] and a Swiss study found up to 44% of ETEC isolates resistant to cefquinome [40,41]. Hammerum has recently reviewed the impact of antimicrobial resistant *E. coli* originating in animals on human health [42•]. Fluoroquinolone resistance has been reported in *E. coli* isolates [43–45] more commonly than in salmonella isolates. Deng and co-workers have demonstrated plasmid-borne transfer of fluoroquinolone resistance in pig *E. coli* strains [46,47•]. Fluoroquinolone resistance in isolates has been strongly correlated with the quantity of the drug used to treat pigs [1]. Colistin which is an old drug retrieved for use in human medicine to treat critical infections is being used in pigs to treat multi-drug resistant enterotoxigenic *E. coli* (ETEC) infections. Not surprisingly colistin resistance has been found in pigs strains [5,16,48] although some consider it less common in Europe [49]. A particular issue to note is the use of apramycin in pigs and its capacity to select for apramycin/gentamicin resistant strains through the carriage of the *aac(3)-IV* gene [50]. ETEC strains of *E. coli* are a significant cause of morbidity and mortality in young pigs and have been a strong driver for use of ceftiofur, cefquinome, fluoroquinolones and colistin due to the extensive antibiotic resistance seen in these strains. The antimicrobial resistance issues are much the same as with commensal *E. coli* except that diseased pigs are unlikely to enter the food chain.

Extended-spectrum β-lactamase and AmpC producing bacteria

While resistances to ceftiofur and cefquinome are of themselves of significance, it is the power of these antibiotics to select for extended spectrum β-lactamases that is the critical issue. AmpC producing *E. coli* and salmonella are well documented [35,39,51] and the selection of CTX-M producing *E. coli* in pigs by treatment with ceftiofur and cefquinome and to a lesser degree by amoxicillin has been documented [52]. The fact that many of these enzymes are encoded by plasmid-carried genes is of particular concern as is the finding that many are carried by healthy animals that will enter the food chain. It is not only *E. coli* and salmonella that are involved but also other enteric organisms that are rarely considered of animal health significance such as enteric *Klebsiella* and also environmental organisms such as *Acinetobacter*. CTX-M enzymes are the most commonly reported enzymes [53–56] but other enzymes have also been found such as SHV and TEM [35,56,57]. Disturbingly Huang and co-workers isolated a number of pig strains of *E coli* carrying *qnr*S1 (fluoroquinolone resistance) and $bla_{\mathrm{CTX\text{-}M\text{-}14}}$ on a multi-drug resistant plasmid [48]. CTX-M producing *Klebsiella pneumoniae* were isolated from USA pig faeces [58] and transfer of *E. coli* plasmids encoding $bla_{\mathrm{CTX\text{-}M\text{-}1}}$ between pigs and piggery workers has been documented in Denmark [59]. Of particular concern is the detection of carbapenemases in bacteria from pigs and piggery environments as carbapenems are not used in pigs. VIM-1 carbapenemase producing *E. coli* have been found in a pig and in an environmental sample on the same piggery and also in pig salmonella isolates [60•,61]. NDM-1 metallo-β-lactamase has been found in an *Acinetobacter* isolate from a diseased pig in China [62]. The $bla_{\mathrm{NDM\text{-}1}}$ gene was carried on a plasmid and assuming there has not been illegal use in pigs these isolates either originated from pig contact with a treated human or a contaminated environment. Seiffert and co-workers have prepared a useful review on animal associated ESBLs and the threat of these strains to human health [63]. It is worth considering that a ban on the use of ceftiofur and cefquinome in animals (livestock and companion animals) could lead to a significant reduction in ESBL producing animal isolates and so reduce human exposure to ESBLs. Denmark has already demonstrated that a ban on use in pigs has led to reduced detection of ESBL producing *E. coli* in slaughter pigs [64].

Methicillin-resistant *Staphylococcus aureus* (MRSA)

Although there have been sporadic reports of MRSA from animals before 2005 it was generally assumed that these strains originated in humans [65]. The emergence of the first pig-associated strain ST398 which then in very few years spread into other livestock species and also from France to most countries around the world reflects the rapid emergence of new pathogens. Most isolates (now referred to as LA-MRSA) from pigs are from healthy animals which simply carry the strain and the lack of disease in colonised pigs may have been the reason for the failure to detect this strain earlier. In addition most veterinary laboratories would assume any coagulase-positive staphylococci isolated from pigs were *Staphylococcus hyicus* and not investigate such isolates any further. However there are now reports of isolation of LA-MRSA from pathological lesions in pigs [66]. Apart from animal to animal spread which is a feature of this strain [67] one of the early features of LA-MRSA was its ready transfer from pigs to humans. Recent work by Graveland and colleagues suggests that LA-MRSA is a poor coloniser of humans and that persistence of human colonisation is dependent on continuing close contact with colonised animals [68]. An interesting study in the USA has found that LA-MRSA colonisation of piggery workers is present in intensive antibiotic-using piggeries but not present in workers from antibiotic-free farms suggesting that antibiotic use in piggeries is a driver for worker colonisation [69]. It is important to note that there are laboratory studies that indicate that LA-MRSA lacks a number of virulence genes [68] and a clinical study from the Netherlands concluded that LA MRSA is not of major public health concern [70]. However CC398 may not be the only LA-MRSA as there is evidence that the SCC*mec* cassette may be spreading into other pig-associated lineages of MRSA [71]. ST 398 LA-MRSA isolates are multi-resistant and have a variable antibiotic resistance phenotype and genotype [72]. Characteristically the isolates are all tetracycline resistant which may relate to their emergence in pigs and resistance to spectinomycin, neomycin is also reported [73] and to macrolides and gentamicin [74].

Streptococcus suis

S. suis is a zoonotic pathogen carried in pigs. Macrolide and tetracycline resistance are very common in pig and human *S. suis* isolates [75–78]. This is probably associated with widespread use of tylosin and tetracyclines in pigs over many decades. It is disturbing that Wang and colleagues have identified a pig isolate with a gene (*cfr*) encoding multi-resistance to five unrelated antimicrobial classes — phenicols, oxazolidinones, lincosamides, pleuromutilins and streptogramin A as well as decreased susceptibility to 16-membered macrolides [79].

Environmental contamination

Use of antibiotics in pigs is associated with resistance in isolates from piggery environments and related areas [17,18,80]. It is clear that this contamination provides a reservoir of resistance genes not only for the piggery but for animals and humans in contact with the contaminated environment [81,82]. In addition there is the risk of surface and groundwater contamination when slurry from piggeries is spread on land [83].

Conclusions

Antimicrobials are used extensively in the pig industry for prevention and treatment of disease. In some countries there is still use for growth promotant purposes and this should be discontinued as soon as possible. A number of the antibiotics used are important in human health and transfer of resistant bacteria and their associated genes via the food chain is likely to compromise treatment of human infections. Glycopeptide resistance due to avoparcin use is still a problem in some countries as is virginiamycin use. Fluoroquinolone resistance in campylobacter is a concern. However the most disturbing issue is the generation of ESBLs through the use of ceftiofur and cefquinome and serious consideration should be given to banning the use of these antibiotics in animals. Methicillin-resistant *S. aureus* clades associated with animals need to monitored and efforts made to determine the antibiotic selection pressure that is driving their emergence. Antibiotic resistance in *S. suis* could compromise therapy in humans if multi-resistant strains become more widespread. Finally attention needs to paid to the risk of extensive spread of resistance genes through environmental contamination associated with piggeries.

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Open letter: why WHO should address industrial animal farming

by Scott Weathers and Sophie Hermanns | 25 May 2017 corporations | food crisis | Blog

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An open letter released this week (http://www.openletteranimalfarming.com/) and signed by over 200 scientists, policy experts and others, urges the new Director-General of the World Health Organization to recognize and address factory farming as a public health challenge.

- Strengthen WHO's Global Action Plan on Antimicrobial Resistance to encourage member states of the WHO to ban the use of growth-promoting antibiotics in animal farming, as well as low-dose "disease

Read the full letter below

Unprecedented and rising levels of industrial animal farming are undermining the highest attainable standard of health that is WHO's mandate. During the 2016 World Health Assembly, Director-General Margaret Chan highlighted (http://www.who.int/dg/speeches/2016/wha-69/en/) climate change, antibiotic resistance, and chronic diseases as "slow-motion disasters." However, their fundamental link to industrial animal farming has continued to be disregarded.

Industrial Animal Farming: A Global Health Challenge

The consumption of meat and other animal products is part of most cultures, yet large-scale industrial animal farming has gone beyond satisfying dietary needs and cultural practices. The extent to which we now produce and consume animal products is harming our health.

Industrial approaches to animal agriculture have spread across many nations and are rapidly increasing in low- and middle-income countries. Factory farms (also known as concentrated animal feeding operations, or CAFOs) use intensive methods to rear poultry, pigs, and cattle on a large scale for food products. Practices such as the indiscriminate use of antibiotics, close confinement of animals, and unsustainably large scale of production have become the industry standard, and each has grave consequences for human health. The problem, however, is getting worse as a rising proportion of global meat consumption comes from factory farms (http://www.worldwatch.org/node/5443). Factory farms produce 67% of poultry meat, 50% of eggs, and 42% of pork globally. [1] A return to more traditional husbandry methods is unlikely to occur, as the prevalence of factory farming has been rapidly increasing in both the high- and low- and middle-income countries.

Although many previous attempts to tackle factory farming have been largely framed around animal welfare or environmental concerns, we believe that limiting the size and adverse practices of factory farming is also central to improving global health.

Antibiotic resistance is a major threat to global health. Seven hundred thousand people die from antimicrobial-resistant diseases each year (https://www.oecd.org/els/health-systems/Antimicrobial-Resistance-in-G7-Countries-and-Beyond.pdf). [2] If current trends continue, diseases caused by drug-resistant microbes could kill up to 9.5 million per year (https://www.oecd.org/health/health-systems/AMR-Policy-Insights-November2016.pdf) by 2050, more than current cancer-deaths (http://www.who.int/mediacentre/factsheets/fs297/en/). [3,4] While quantification of specific morbidity and mortality burdens attributable to industrial agriculture is currently not possible, an increasing body of evidence suggests that antibiotic use in factory farming is a major contributor to resistance. Many industrial farms use low doses of antibiotics to marginally speed growth or prevent diseases in healthy chickens, pigs, and cattle, but do not bear the societal cost of antibiotic overuse. Although factory farms use antibiotics with the aim of keeping animals healthy and to increase productivity, accumulating evidence suggests that growth-promotion uses do not achieve this purpose [5] and alternatives to antibiotic use for disease prevention such as better husbandry practices and vaccines are available and have been used with success.[6]

Total consumption of antibiotics in animal food production is projected to grow by almost 70% between 2010 and 2030 (http://www.pnas.org/content/112/18/5649.full). [5] According to the WHO, two of the three most commonly used classes of antibiotics in U.S. animal farming—penicillins and tetracyclines—are of critical importance to humans. Practices such as the constant low dosing (http://journal.frontiersin.org/article/10.3389/fmicb.2014.00284/full) of antibiotics and environmental pollution through animal waste (https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4388096/) make industrial animal farms the perfect breeding ground for antibiotic resistance by allowing transmission into the environment and nearby community. [7] Several studies have found that the presence of antibiotic-resistant bacteria in livestock is closely associated with their presence in humans, and that decreases in antibiotic resistance have followed reductions in the usage of antibiotics in animals raised for food and humans (https://www.ncbi.nlm.nih.gov/pubmed/11397611). [8, 9, 10] The farming of fish in aquaculture poses similar health risks. [11] Currently, in the EU and the US, over 75% of all antibiotics are used in agriculture (https://www.oecd.org/health/health-systems/AMR-Policy-Insights-November2016.pdf), [12] while BRICS countries are projected to experience a 99% growth (http://www.pnas.org/content/112/18/5649.full) in antimicrobial consumption by 2030, largely due to the continued growth of factory farming. Low- and middle-income countries (LMICs) are estimated to experience rapid growth of both factory farming and antibiotic consumption through agriculture, in part because they may lack the regulatory oversight and veterinary medical workforce that high-income countries have. [13] The consequences of antibiotic resistance will likely be more severe in LMICs because of higher bacterial disease burden (https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3193708/) and the challenges patients face in accessing expensive second and third line antibiotics. [14] Moreover, antibiotic resistance places a great burden on health systems (https://www.oecd.org/health/health-systems/AMR-Policy-Insights-November2016.pdf), leaving weak health systems ill-prepared to deal with increases in resistance.

Climate change is projected to decrease global prosperity and increase wealth inequalities (https://web.stanford.edu/~mburke/climate/BurkeHsiangMiguel2015.pdf). It is also expected to cause an additional 250,000 deaths (http://www.who.int/mediacentre/factsheets/fs266/en/) each year between 2030 and 2050. [15] As the global health community acknowledges the intertwined nature of planetary and human health, it must also confront the role that factory farming plays in climate change. [16] Experts predict that without rapid and drastic shifts in meat production, agriculture will consume half the world's carbon budget necessary for keeping global temperature rises (https://www.theguardian.com/environment/2016/mar/21/eat-less-meat-vegetarianism-dangerous-global-warming) under 2° Celsius by 2050. [17] Importantly, this contribution to climate change is not due solely to the emissions from raising livestock – animal farming is also a large contributor because of the deforestation that must occur (https://journals.law.stanford.edu/stanford-environmental-law-journal-elj/blog/leading-cause-everything-one-industry-destroying-our-planet-and-our-ability-thrive-it) to supply grazing land for cattle and to grow crop feed. The World Bank estimates that between 1970 and 2004, 91% of cleared land in the Amazon has been converted to cattle ranching. [18] Furthermore, factory farming is not only linked to macro-level environmental crises such as climate change, but one of the largest contributors to localized environmental problems like air and water pollution, as well as land and soil degradation. [19] Although it is difficult to predict the multitude of harms that may spill over from livestock production, evidence suggests this deforestation may also be linked to emerging pathogens, an unexpected channel by which animal farming may contribute to the risk of disease pandemics beyond antibiotic resistance. [20] A large proportion of emerging diseases stem from human-animal interaction in the wild, a process that deforestation accelerates. Zoonotic diseases can also emerge from animals in contact with workers in factory farms themselves. [21]

Lastly, the rise of obesity and noncommunicable diseases (NCDs) can be partly attributed to the dramatic dietary changes made possible by factory farming. WHO has
(https://www.sciencedirect.com/science/article/pii/S1470204515004441) and red meat as probably carcinogenic. [22] High meat consumption has been shown to inc
(http://onlinelibrary.wiley.com/doi/10.1111/joim.12543/abstract) for several types of cancer (http://alm.plos.org/works/doi.org/10.1017/s1368980015002062), stroke
(https://www.sciencedirect.com/science/article/pii/S1052305716000677), obesity (https://www.ncbi.nlm.nih.gov/pubmed/24815945),cardiovascular (https://www.nc
(http://circ.ahajournals.org/content/121/21/2271), lung disease (http://www.tandfonline.com/doi/pdf/10.1586/17476348.2015.1105743) and diabetes (https://schola
title=Red%20meat%20consumption%20and%20risk%20of%20type%202%20diabetes%3A%203%20cohorts%20of%20US%20adults%20and%20an%20updated%20meta-
analysis&author=A.%20Pan&author=Q.%20Sun&author=AM.%20Bernstein&author=MB.%20Schulze&author=JE.%20Manson&author=WC.%20Willett&author=FB.%20Hu
1096&publication_year=2011&doi=10.3945%2Fajcn.111.018978). [23] The Institute for Health Metrics and Evaluation estimates (http://thelancet.com/journals/lancet/
meat and red meat contributed to over half a million human deaths (or over 16 million disability-adjusted life years, or DALYs) in 2015 – more deaths worldwide than in
alcohol use disorders. [24] The declining cost of meat and its increasing prevalence in LMICs, facilitated by factory farms, contributes significantly to the rapidly rising

The Path Forward

prevention” antibiotics. This reform may cut unnecessary antibiotic use without additional

The harms caused by large-scale, industrial animal farming are global in nature and felt beyond those who consume meat, dairy, and eggs. Climate change does not recognize borders and neither do drug-resistant infectious diseases. Although they contribute least to the global burden of animal farming, the world's poorest countries are also the most vulnerable to rising water levels, natural disasters caused by climate change, food insecurity, and infectious diseases. Finding solutions to problems posed by industrial animal farms and shifting us toward more healthful agriculture will therefore require the global leadership of WHO.

Just as the WHO has bravely confronted companies that harm human health by peddling tobacco and sugar-sweetened beverages, it must not waver in advocating for the regulation of industrial animal farming.

Conclusion

cost to consumers.

We applaud the WHO's important actions on consumer product industries that jeopardize the right of all people to the highest standard of health. In particular, we recognize the significance of the Framework Convention for Tobacco Control, the inclusion of tobacco reduction in the United Nations Sustainable Development Goals, and WHO's recommendation on sugar consumption.

We call on academics and researchers to apply their energy to document and publicize the harms of industrial animal farming to human, animal, and planetary health.

We call on all candidates for the WHO-Director General position to publicly acknowledge the harm that industrial animal farming inflicts on global health. The next Director General should take necessary steps to limit the expansion of industrial animal farming and encourage dietary recommendations that reduce meat consumption.

Finally, we call on the next WHO-Director General to provide global leadership to support all member states in finding sustainable alternatives to the rapid growth of industrial animal farming and help shift us toward farming methods that protect public health and the environment.

Concluding Policy Recommendations for the next Director General:

- Negotiate country-level standards for antibiotic use in

In order to lead us down the path of agricultural production that is better for people's health than our current industrial animal production system, the WHO should:

animal husbandry, in coordination with the Food and Agricultural Organization. Member states should be encouraged to articulate specific, verifiable standards for what constitutes legal antibiotic use in animal farms.

- Incentivize meat producers to dispose of antibiotics and waste residue properly to prevent environmental contamination and excess greenhouse gas emissions.
- Work with all relevant ministries, including those outside of health, to reduce the size and number of factory farms to better balance dietary need and ecological capacity.
- Discourage member states from subsidizing factory farming and its inputs, which can cause significant harm to the public.
- Consider the application of relevant fiscal policies in member states that would help to reduce meat demand and consumption, especially where consumption exceeds health recommendations. The WHO's internal research expertise is well-suited to investigate the efficacy and tradeoffs of such a policy.
- Encourage member states to adopt nutrition standards and implement health education campaigns which inform citizens of the health risks of meat consumption.
- Work closely with ministers of health and agriculture to formulate policies that advocate for a greater proportion of plant-based foods in the diets of member states.

- Consider funding the scientific development of plant-based and other meat alternatives, which have the potential to eliminate or reduce the harms of factory farming.

[1] Rischkowsky and Pilling 2007 [2] Cecchini et al 2015 [3] OECD 2016

[4] WHO fact sheet “Cancer” 2017 [5] Sneeringer et al 2015 [6] O’Neil 2015 [6] Van Boeckel et al 2015

[7] Silbergeld et al. 2008, You and Silbergeld 2014, Economou and Gousia 2015 [8] Vieira et al 2005

[9] Aarestrup 2005 [10] Schwarz et al., 2001 [11] Sapkota et al 2008 [12] OECD 2016

[13] Lam et al. 2016 [14] Whitby et al, 2001, Filice et al. 2010, Ganguly et al 2011 [15] WHO fact sheet 2016

[16] Steinfeld et al. 2006; Springmann et al., 2016 [17] Bajželj et al. 2014, Hedenus, Wirsenius, Johansson 2014

[18] Margulis 2004 [19] Burkholder et al. 2007, Ilea 2009, Cambra-López 2010).

[20] Lindahl, Grace 2015, Aguirre, Tabor 2008, Patz et al. 2000 [21] Ma et. al 2008 [22] Bouvard et al 2015

[23] Rouhani et al. 2014; Bouvard et al. 2015; Varraso and Camargo 2015; Yang et al. 2016; Wang et al. 2016; Pan et al. 2012; Pan et al. 2011; Micha et al., 2010; Wolk 2017

[24] IHME 2016

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