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EXTENSION EDUCATION SYMPOSIUM: The future of biosecurity and antimicrobial use in livestock production in the United States and the role of extension[1]

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ABSTRACT: As the global population continues to grow, food needs will increase as well. The amount of land and other resources devoted to agriculture production is not expected to grow significantly, leading most to agree that the substantial increases in food production to meet food security needs will come through the development of technologies that improve production efficiency. Diseases are constant threats to efficiency in all segments of agriculture. In livestock production, many of the bacterial pathogens that infect food animals are controlled through the use of antimicrobials. Antimicrobials are currently used in the United States not only to treat specific diseases, but also as feed additives to prevent bacterial disease in general or to improve growth performance. In recent years, there have been several proposals in the United States, both at state and federal levels, aimed at curtailing or dramatically reducing the use antimicrobials as feed additives, creating a policy similar to that of the European Union. Here we review the current policies on antimicrobial use in the European Union and their impact on food animal production. In addition, we discuss the future of antimicrobial use in food animal production in the United States and the increasing role of biosecurity programs. Finally, we discuss the role of Cooperative Extension Service in creating improved biosecurity programs and extension programs that provide policy makers and voters information on modern food animal production practices and technologies so that policies and regulations are effective and appropriate.

Key words: antibiotics, antimicrobials, biosecurity, extension, livestock

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INTRODUCTION

Many factors, including religion, personal income, commodity price, traditions, and personal preference, influence the demand for animal protein provided by livestock production. Frequently, as affluence in developing countries improves, demand for animal protein expands. According to the World Health Organization (**WHO**), worldwide per capita consumption of livestock products increased from 24.2 kg/yr in 1964 to 1966 to 36.4 kg/yr in 1997 to 1999 and was projected to reach 45.3 kg/yr by 2030. During the same period, worldwide per capita milk consumption increased from 73.9 to 78.1 kg/yr and was projected to reach 89.5 kg/yr in 2030 (WHO, 2003a). Yet, despite increases in total caloric intake and animal protein intake, the Food and Agriculture Organization (**FAO**) of the United Nations estimated that 925 million people were undernourished in 2010 (FAO, 2010).

The world population is expected to grow from 6.8 billion today to 9.3 billion in 2050 (United Nations, 2011), requiring 200 million metric tons of additional meat production (FAO, 2009). As agriculture becomes increasingly more globalized, disruptions to food production, processing, and distribution as a result of natural disasters, disease, economic constraints, or terrorist

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actions can have far-reaching effects on food insecurity, further destabilizing the world.

Preventing animal disease, as well as the spread of those diseases once introduced into an animal population, is one of the keys to fighting hunger, malnutrition, and poverty. Antimicrobials are an integral tool in the control of bacterial diseases in livestock production. In the United States, antimicrobials are not only used to treat established diseases. Rather, they are also used as feed additives to prevent disease in general and, in some cases, to improve efficiency. The use of antimicrobials as feed additives in food animal production remains very controversial, and the practice is banned in many countries, including those in the European Union.

In the past 10 yr, numerous proposals, both at the federal and state levels, have sought to limit the use of antimicrobials in livestock production in the United States (Tables 1 and 2). Thus far, such legislation has not been enacted, but it is prudent to predict that policies regarding antimicrobial use in food animal production may change in the United States as well, resulting in policies that more closely resemble those of the European Union.

In the European Union, eliminating antimicrobial feed additives resulted in some immediate effects on animal health and efficiency. If past is prologue, eliminating prophylactic use of antimicrobials in the United States would result in similar disruptions, at least in the short term, and would require heightened disease prevention and biosecurity measures that prevent the introduction of infectious diseases into a specific areas, such as a farm, state, or country. In addition, new technologies will likely be necessary to not only maintain efficiency, but also increase production to meet growing food demands. Here we discuss the current state of antimicrobial use in food animal production in the United States and highlight the increasing role of biosecurity programs. Finally, we discuss the role of the Cooperative Extension Service in promoting effective biosecurity measures and communicating with non-agriculture audiences that are increasingly called upon to decide the appropriateness of newly developed technologies aimed at improving agriculture production.

HISTORY

The use of antimicrobials in food animal production remains one of the more controversial agricultural practices in the United States. Currently, the drugs are largely used to treat specific bacterial diseases, but they are also frequently included as feed additives to prevent bacterial diseases or improve growth efficiency. The inclusion of antimicrobials as feed additives is often termed subtherapeutic use, whereas the treatment of specific diseases is often termed therapeutic use. These terms are based largely on the differences in the actual dose being administered for the different purposes and are arguably inaccurate because dosages traditionally considered as subtherapeutic have a long-acknowledged therapeutic effect of disease prevention (Lucas, 1972). Regardless, inclusion of antimicrobials as feed additives remains the most controversial use of the drugs and is most frequently targeted in calls to change antimicrobial use policy.

The practice of including antimicrobials as feed additives dates to the late 1940s. Research groups determining whether supplemental vitamin B_{12} could overcome protein shortages in poultry diets discovered that including other feed ingredients, namely fungal extracts, resulted in increased BW gains. The fungal extracts contained unrefined antimicrobials, and this study, along with simi-

Table 1. Timeline of federal legislative attempts at limiting or eliminating the use of antimicrobials for disease prevention or growth promotion in food animals[1]

Item	Legislation
1	Preservation of Essential Antimicrobials for Human Diseases Act of 1999 (introduced in the House; H.R.3266.IH; 106th Congress)
2	Antimicrobial Resistance Prevention Act of 2001 (introduced in the House; H.R.1771.IH; 107th Congress)
3	Preservation of Antimicrobials for Human Treatment Act of 2002 (introduced in the Senate; S.2508.IS; 107th Congress)
4	Preservation of Antimicrobials for Human Treatment Act of 2002 (introduced in the House; H.R.3804.IH; 107th Congress)
5	To protect children's health by ensuring that chickens and chicken products purchased for national school nutrition programs have not been fed or administered fluoroquinolone antimicrobials (introduced in the House; H.R.3022.IH; 108th Congress)
6	Preservation of Antimicrobials for Medical Treatment Act of 2003 (introduced in the Senate; S.1460.IS; 108th Congress)
7	Preservation of Antimicrobials for Medical Treatment Act of 2003 (introduced in the House; HR2932.IH; 108th Congress)
8	Preservation of Antimicrobials for Medical Treatment Act of 2005 (introduced in the Senate; S.742.IS; 109th Congress)
9	Preservation of Antimicrobials for Medical Treatment Act of 2005 (Introduced in the House; HR2562.IH; 109th Congress
10	Strategies to Address Antimicrobial Resistance Act (introduced in the House; H.R.3697.IH; 110th Congress)
11	Strategies to Address Antimicrobial Resistance Act (introduced in the Senate; S.2313.IS)
12	Preservation of Antimicrobials for Medical Treatment Act of 2007 (introduced in the Senate; S.549.IS; 110th Congress)
13	Preservation of Antimicrobials for Medical Treatment Act of 2007 (introduced in the House; H.R.962.IH; 110th Congress)
14	Strategies to Address Antimicrobial Resistance Act (introduced in the House; H.R.2400.IH; 111th Congress
15	Preservation of Antimicrobials for Medical Treatment Act of 2009 (introduced in the Senate; S.619.IS; 111th Congress)
16	Preservation of Antimicrobials for Medical Treatment Act of 2009 (introduced in the House; HR1549.IH; 111th Congress)
17	Poison-Free Poultry Act of 2009 (introduced in the House; H.R. 3624; 111th Congress)
18	Preservation of Antimicrobials for Medical Treatment Act of 2011 (introduced in the House; HR.965.IH; 112th Congress)

[1]H.R. = House of Representatives; S = Senate.

Table 2. State legislative attempts to limit or eliminate the use of antimicrobials for disease prevention or growth promotion in food animals[1]

Item	Legislation
1	California SB 2043 (2002)
2	Hawaii HB 2790 and SB 2166 (2002)
3	Minnesota SB 2824 (2002)
4	Arkansas HB 2379 (2003)
5	Maine LD 1126 (2005)
6	Minnesota SF No. 986 (2005)
7	Ohio SB 73 (2005)
8	Wisconsin AB 837 (2005)
10	Maine LD 1126 (2006)
11	Iowa (2006)
14	Pennsylvania HB 2195 (2008)
15	Pennsylvania: SB 398 (2009)
16	California SB 416 and SB 562 (2009)
17	Pennsylvania (2010)

[1]SB = Senate bill; HB = House bill; LD = legislative document; SF = Senate file; AB = assembly bill.

lar studies, offered the first evidence that including small amounts of antimicrobials in livestock and poultry feeds can improve BW gains and efficiency while preventing disease, both clinical and subclinical (for review, see Jones and Ricke, 2003; Dibner and Richards, 2005).

Over the past 6 decades, a great deal of research has focused on determining exactly how the inclusion of antimicrobials in feeds improves growth. Most agree that several mechanisms of action are at play. The drugs can dramatically alter the microbiota of the gut, resulting in decreased bacterial loads and thinner intestinal walls; both enhance absorption of nutrients. The gastrointestinal tracts of animals fed antimicrobials often contain fewer lesions and other signs of pathology or infection. There are also metabolic impacts because the immune systems of animals fed antimicrobials share some characteristics with those of pathogen-free animals, which are, in general, more efficient. Finally, including the drugs in the feed is known to prevent subclinical diseases, which can impair growth efficiency (for reviews, see Visek, 1978; Dibner and Richards, 2005; Niewold, 2007).

The dialogue relevant to the benefits vs. risks of antimicrobials encompasses very complex and broad issues including human health, animal health and well-being, food production and safety, diverse opinions of the science, philosophical differences, and of course, politics. The discussions have drawn upon many diverse data sets, some of which are not compatible, but have been compared nevertheless, often without acknowledgment of the limitations or apologies. The European response to this dialogue has been greater restriction on the use of antimicrobials in livestock production, namely, prohibitions on the use of antimicrobials for growth promotion or disease prevention.

Concerns over selection for antimicrobial resistance in bacteria have driven much of the discussions and actions, which have their root in the 1969 Swann Committee, a committee formed in the United Kingdom to address these issues (Swann, 1969). The major conclusions of the Swann Committee included recognition that "the administration of antimicrobials to farm livestock, particularly at sub-therapeutic levels, poses certain hazards to human and animal health." The report recommended to the British government that antimicrobials important to human medicine be prohibited from use as growth promotants in livestock production. Chlortetracycline, oxytetracycline, penicillin, tylosin, and sulphonamides in particular were highlighted as unsuitable for this purpose (Swann, 1969).

Shortly thereafter, a US Food and Drug Administration (**FDA**) Task Force (1970) concluded that 1) antimicrobial resistance was increasing in bacteria associated with both livestock and humans, 2) livestock receiving antimicrobials often serve as reservoirs for important zoonotic pathogens, and 3) subtherapeutic use of antimicrobials in livestock favors the development of resistant organisms (FDA, 1972). In 1977, the FDA, similar to the 1969 Swann Committee, recommended restricting the use of penicillins and tetracyclines in livestock because of their importance in human medicine.

More recently, the Institute of Medicine conducted a review of scientific literature examining the impact of antimicrobial use in livestock on the development of resistance and human health. The group found cause for concern over the increased number of foodborne illness outbreaks associated with antimicrobial-resistant *Salmonella* (Institute of Medicine, NRC, 1999). At the same time, their report was unable to conclude that subtherapeutic use of antimicrobials in livestock translated to increased human morbidity or mortality (Institute of Medicine, NRC, 1999). Similarly, the World Health Organization, in 1998, concluded that the use of antimicrobials in livestock production led to increases in resistance in foodborne pathogens such *Salmonella*, *Campylobacter*, and *Escherichia coli* (WHO, 2001). In 2009, the FDA Deputy Commissioner of Food and Drugs testified before the US Congress that the use of antimicrobials for growth promotion should be eliminated (FDA, 2009).

The European response started in 1986, when Sweden banned the inclusion of antimicrobials in livestock feeds for growth promotion. In 1995, Denmark prohibited the use of avoparcin due to cross-resistance to vancomycin, and in 1998, the European Union followed suit. Denmark then banned the use of the streptogramin virginiamycin. The European Union further restricted antimicrobial use in livestock in 1999 when the use of bacitracin, spiramycin, tylosin, and virginiamycin was eliminated. In that same year, Denmark began phasing out all prophylactic and growth-promotant antimicrobial use in livestock production. Finally, the European Union banned the use of all in-feed antimicrobials in 2006 (Castanon, 2007). All remaining antimicrobial feed additives, including ionophores, will be eliminated in 2012.

It is important to note that European Union policy was based on the precautionary principle, which states "when an activity raises threats of harm to the environment or human health, precautionary measures should be taken even if some cause and effect relationships are not fully established scientifically" (Wingspread Statement on the Precautionary Principle, 1998). The result was a decided shift in the burden of proof. Currently, removal of any ban can only be justified by demonstrating that the growth-promoting antimicrobials do no harm (to our knowledge no bans have been lifted). It is of note that the FDA-Center for Veterinary Medicine (**FDA-CVM**) uses the standard of a "reasonable certainty of no harm."

Several countries in the European Union have developed surveillance systems to monitor changes in the antimicrobial resistance in response to changes in antimicrobial policies. Perhaps the most comprehensive is the Danish Integrated Antimicrobial Resistance Monitoring and Research Programme (**DANMAP**, 2010). This program monitors antimicrobial use in both human medicine and livestock production, as well as antimicrobial resistance in bacteria isolated from both humans and food animals. The collected data and commentary regarding trends are released in an annual report.

The data in the yearly DANMAP reports are often used by both sides of the debate to either justify or vilify the ban. What is clear is that after the 1999 phase-out of in-feed antimicrobials, the overall amount of antimicrobials used in livestock production decreased. Whereas the amount of antimicrobials used at therapeutic dosages to treat specific diseases has almost doubled, total use of antimicrobials in livestock production decreased substantially from approximately 200 t in 1994 to approximately 128 t in 2008 (DANMAP, 2010).

Resistance levels are monitored in a variety of bacterial species. In some cases, the number of isolates tested and the lack of proper statistical analysis should temper any conclusions (e.g., foodborne pathogens). Nevertheless, resistance levels have decreased in several cases. In generic *E. coli* isolated from poultry, cattle, and swine, the most visible decreases were in resistance to tetracycline, streptomycin, and sulfonamides. Resistance to nalidixic acid and penicillins has remained largely unchanged. In the case of swine, resistance to penicillins has actually increased. In gram-positive bacteria (*Enterococcus* spp.), resistance to avoparcin, virginiamycin, avilomycin, and macrolides has decreased in both poultry and swine. Curiously, resistance to tetracycline has seemingly increased in *Enterococcus* spp. isolated from pigs (DANMAP, 2010). In human isolates, resistance patterns seem independent from those found in livestock isolates. Resistance has either increased (ciprofloxacin and nalidixic acid) or remained unchanged (ampicillin, cefuroxime, gentamicin, mecilliunum, and sulfonamides) in *E. coli* isolates. In some cases, the use of certain classes of antimicrobials has increased in human medicine, and there has been a corresponding increase in resistance to those drugs in bacterial isolates from humans (DANMAP, 2010).

Similar programs are conducted by other European Union countries including Norway (Norwegian Monitoring System for Antimicrobial Resistance in Veterinary Microbes; NORM/NORM-VET, 2010) and Sweden (Swedish Veterinary Antimicrobial Resistance Monitoring; SVARM, 2010). In addition, the European Centre for Disease Control and Prevention conducts a European Union-wide surveillance program that monitors antimicrobial resistance in participating countries (European Antimicrobials Resistance Surveillance Network, 2011).

IMPACT ON LIVESTOCK PRODUCTION

The extent to which banning antimicrobial feed additives has affected livestock production in the European Union is routinely debated. In some cases, the action resulted in some immediate health problems and decreased efficiency (Stein, 2002; Aarestrup et al., 2010). Assessments of the longer-term effect on production are somewhat difficult given some significant changes in the structure and economics of the livestock industry in European Union countries (e.g., increased exportation of weaned pigs) as well as production practices that have occurred after the ban (e.g., increased weaning ages). In Sweden, removal of antimicrobial feed additives from swine diets initially resulted in decreased feed efficiency as feed consumed to reach 25 kg increased by 2 to 3 kg. Similarly, time to 25 kg increased by 5 to 6 d. In Denmark, removing antimicrobial feed additives decreased ADG in pigs in the nursery phase by 19 g/d (Stein, 2002). Mortality rates increased initially, but have decreased in recent years. Similarly, the number of feed units per kilogram of BW gain increased, but peaked in 2005 (Aarestrup et al., 2010). In terms of morbidity, both countries saw increased postweaning *E. coli* and clostridial infections and increases in the number of treatments for newly weaned pigs. The ban did not appear to have significant, long-term effects on growing or finishing pigs. In poultry, greater incidences of necrotic enteritis (*Clostridium perfringens*) were seen, but not to the extent predicted (Aarestrup et al., 2010). As clostridial infections are thought to be somewhat controlled by the inclusion of antimicrobial feed additives, these problems could be exacerbated by the proposed ban on ionophores slated for 2012.

Antimicrobial Use in the United States

Almost 50 compounds classified by the FDA as antimicrobials are approved for use in food animals in the United States. This list includes ionophores (i.e., anticoccidials), which are not related to traditional antimicrobials and are not used in human medicine. Several groups have offered estimates as to the amount of antimicrobials used in livestock production in the United States with widely dissimilar results (Mellon et al., 2001; AHI, 2004). A more recent report from the FDA estimates that close to 15,000 t of antimicrobials are produced in the United States for livestock each year (FDA, 2010). A portion of this total (i.e., 12.4%) is exported. Of the antimicrobials sold for use in the United States, the majority are ionophores (28.6%) or tetracyclines (35.3%). It is important to note, however, that the dosage of antimicrobial per kilogram of animal BW can vary among indications and antimicrobials. Thus, overall estimates of total volume may not be accurate indicators of use patterns.

CURRENT AND PAST LEGISLATION CONCERNING THE USE OF ANTIMICROBIALS IN LIVESTOCK PRODUCTION

The animal agriculture industry in the United States has been continually challenged with numerous attempts to restrict the use of antimicrobials in livestock and poultry. Consumer reaction and government policy has been driven by calls for additional research, risk assessments, and case-by-case responses to concerns, which has resulted in some policy changes, albeit not on the scale of those in the European Union. As an example, avoparcin was never approved for use in food animals in the United States based on data showing the link between avoparcin use in poultry and vancomycin resistance in community *Enterococcus* spp.

A key response in the United States followed the Brown Amendment, which led to the formation of the Antimicrobial Food Safety Section of the FDA-CVM. This team also formalized the process of assessing the impact of potential antimicrobials on human food safety, leading to the development of FDA Guidance 152, which serves as an outline to its approval process for new antimicrobials for livestock production.

On June 28, 2010, the FDA solicited public comments on a broad policy statement titled Draft Guidance For Industry #209, "The Judicious Use of Medically Important Antimicrobial Drugs in Food-Producing Animals" (Docket FDA-2010-D0094). The Draft Guidance is the current thinking of the agency about the use antimicrobials in food animals and how it possibly relates to antimicrobial resistance in humans. The intent of the agency is to define what constitutes judicious use and to provide veterinary oversight of antimicrobial drugs, (particularly those deemed medically important to human medicine) in food-producing animals. The recently reintroduced Preservation of Antimicrobials for Medical Treatment Act (**PAMTA**; House of Representatives Bill 965.IH) is a legislative attempt first introduced in 1999 (Table 1) seeking to ban the use of antimicrobials in livestock that are medically important to human medicine and eliminate "nontherapeutic" uses. To date, PAMTA has not been enacted by the US Congress.

Starting in 2002, several states have also introduced legislation that would significantly reduce or eliminate the use of antimicrobials as growth promotants (Table 2), either by eliminating certain uses of antimicrobials in food producing animals or prohibiting the sale of food products from animals medicated with such antimicrobials. Like federal legislation, state bills have thus far not been made it to law.

CONSUMER PERCEPTION

In 2008, Pfizer Animal Health conducted a quantitative field study of more than 2,000 non-vegans to gauge consumer opinion on food animal production practices and the use of antimicrobials in particular. The study first established baseline views of the participants regarding agriculture and food safety, and then participants were given basic descriptions of food animal production practices, the role of medicines, and the different regulatory bodies and actions that govern the use of pharmaceuticals in livestock production. Attitude changes were then measured by comparing postdescription opinions with predescription opinions.

After being given basic descriptions of modern food animal production and its regulation, the respondents indicated that knowing that livestock are produced under the care of a veterinarian had the biggest impact in improving their confidence in meat or dairy safety. Likewise, consumers were most likely to trust veterinarians and veterinarian associations on issues related to livestock production, followed by nutritionists, universities, government agencies, grocery stores, agriculture advocacy groups, pharmaceutical companies, food trade associations, restaurant trade associations, and finally, restaurant chains. Respondents were more comfortable with the use of antimicrobials in livestock production when required withdrawal times and state and federal residue monitoring programs and penalties were explained.

One important trend noted was that consumers simply did not find growth promotion to be an acceptable use of antimicrobials in food animal production. In addition to information mentioned previously regarding required withdrawal times and residue monitoring programs, respondents also received information on FDA regulation of the use of antimicrobials in agriculture, meat safety regulation, veterinarian oversight of antimicrobial use, and the role of antimicrobials in preventing disease. This last observation may represent some foreshadowing on the future of antimicrobial feed additives in the livestock industry in the United States, in that facts alone, or at least how they are presented, are not persuasive in justifying using antimicrobials in livestock for anything other than treating sick animals. As the use of public referendum to change livestock care standards becomes more common, it may be that policies on the use of antimicrobials for growth promotion or disease prevention could change in the near future and those changes could be dictated by a public that, by and large, has little to no connection to livestock production. In a broader sense, this reaction indicates a need for the agriculture community to better develop the means by which it communicates with non-agriculture audiences. Failure to effectively connect with non-agriculture audiences could result in their disapproving of new technologies that safely and effectively improve efficiency in food animal production.

INCREASING ROLE OF BIOSECURITY

Increased regulation of antimicrobial use in food animal production, namely the elimination of in-feed antimicrobial additives, may result in the need for augmented biosecurity programs both at the farm and the federal level. The effectiveness of implementing a comprehensive national biosecurity program can be demonstrated by comparing the magnitude of the foot and mouth disease (**FMD**) epidemics in 2001 and 2007 in the United Kingdom. The 2001 outbreak was determined by the United Kingdom Department for Environment, Food and Rural Affairs (**DEFRA**) to have begun on a swine finishing unit (DEFRA, 2002). The inquiry into the origin of the outbreak indicated that FMD may have entered the premises as much as a month before its identification and confirmation. This delay in identification resulted in subsequent spread of FMD by mechanical and human transmission from the abattoir, as well as by airborne transmission to sheep on neighboring properties, which were then dispersed through markets and dealers, thereby infecting 2,025 other premises. To control the 2001 FMD outbreak, 6 million animals (i.e., 4.9 million sheep, 0.7 million cattle, and 0.4 million pigs) were destroyed, resulting in an economic loss of £3.1 billion to agriculture and the food chain plus a significant loss of animal protein to the food supply (DEFRA, 2004). After the massive losses of 2001, a comprehensive response plan, which included the possible use of vaccination, was developed in the event of a future FMD outbreak. Consequently, when FMD was confirmed again after the virus was released from a drain pipe from the Pirbright facility (Surrey, England), a calculated, rapid response occurred that limited the 2007 outbreak to just 8 infected premises (Anderson, 2008).

Adherence to effective biosecurity policies is critical not only in food animal production, but in the wild game, equine, and companion animal industries as well. In 2011, the equine industry in the United States was hit by an equine herpes virus (**EHV**) outbreak that originated at the National Cutting Horse Association (**NCHA**) Western National Championships April 29 to May 8, 2011, in Ogden, Utah. Once the disease was diagnosed, NCHA notified state health officials, who in turn contacted the owners of the 421 horses from 19 states that had been exposed during participation at the event (USDA-APHIS, 2011). Because multiple states were involved, federal health officials provided comprehensive situation reports. A set of standardized recommendations to quarantine, monitor, and work with private veterinarians for treatment was provided to the owners. Strict biosecurity procedures were implemented with suspect and confirmed cases. In addition, equine owners were directed to practice biosecurity measures, such as vaccination, disinfection, contact minimization, and isolation to protect their animals at home and if participating in events. Event organizers were also instructed regarding biosecurity measures to implement. Figure 1 depicts the confirmed EHV type 1 and EHV myeloencephalopathy cases resulting from the outbreak, as well as the number of animals that succumbed to the disease (USDA-APHIS, 2011). With the rapid response, the last new case was reported in the June 16 weekly report, and further reporting was suspended after the report of June 23. Although the economic impact from the value of the horses that died, treatment costs, quarantine costs, cancelled events, lost sales, and hospitality industry losses have not been calculated herein (or elsewhere to our knowledge), the rapid coordinated, collaborative effort resulted in timely containment of this endemic disease.

Not only are biosecurity measures critical to state, national, and international disease control of endemic and foreign animal diseases, they also provide economic benefits to individual producers. Paramount to effective programs are prevention initiatives. For example, implementing basic biosecurity measures for dairy calves can reduce exposure to the *Mycobacterium paratuberculosis* ssp. *avium* organism, which causes Johne's disease, a

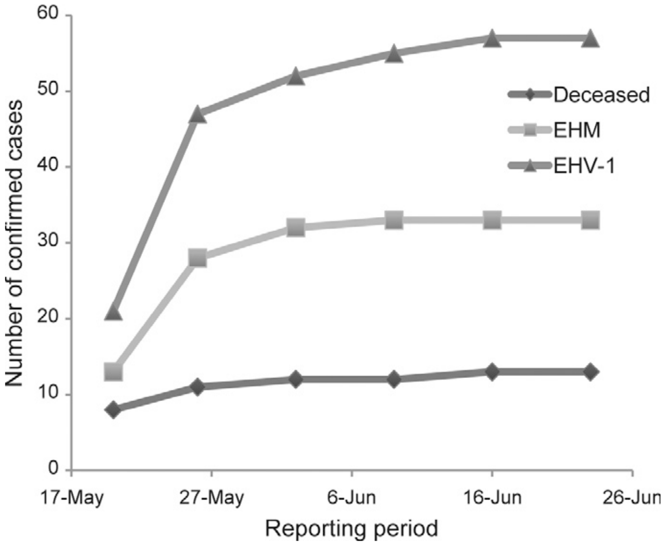

Figure 1. The cumulative number of confirmed equine herpes virus type 1 (EHV-1) and equine herpes virus myeloencephalopathy (EHM) cases resulting from the 2011 disease outbreak in the United States, as well as the number of animals that succumbed to the disease.

chronic intestinal disease that is contracted by calves but expressed in the adult animal. In a study by Villarino et al. (2011), home-raised animals classified as low positive, positive, and strong positive based on their first ELISA test result produced 4,397, 7,724, and 10,972 kg less milk, respectively, during their lifetimes than their negative herdmates. These herds implemented basic biosecurity measures to control Johne's disease, such as testing of dams before calving, disposing of colostrum from Johne's-positive dams, pasteurizing any waste milk fed, sanitizing the calving area, and locating all calf rearing operations away from fecal material from any adult cattle. After 7 yr of implementing these measures, the 2 herds reduced the incidence of ELISA positive animals from 12.7 to <2% (E. Jordan, 2012, unpublished results). Based on the distribution of Johne's-positive animals reported by Villarino et al. (2011), the weighted average lifetime milk reduction for each Johne's-positive cow was 8,474 kg of milk. Assuming the average animal left the herd after their third parturition, 10% of the herd was producing approximately 2,820 kg of milk/yr less before implementing the aforementioned biosecurity measures than after the improvement in herd incidence. Using the May, 2011, milk price of US$19.94/45.45 kg of milk (Hunter, 2011), gross annual income for each 100 cows would be increased by US$12,350 as a result of the reduction in disease. From a global perspective, based on projected consumption of 89.5 kg/yr in 2030 (WHO, 2003a), this increased productivity with the same number of animal units would provide for the annual milk consumption of an additional 310 people.

In the United States, 2 programs, the National Animal Health Laboratory Network and the Extension Disaster Education Network, are designed to address biosecurity issues on a national level. Implementation of biosecurity measures on a local, state, national, and international basis is necessary to protect the world's animal protein supply from losses from disease outbreaks. The resultant improvements in animal health enhance animal performance and efficiency, and, when coupled with other technological and management changes, aid the animal industry in meeting the increasing world demand for animal protein from a limited land base.

THE ROLE OF EXTENSION IN PREVENTING ANIMAL DISEASE INTRODUCTION

Although extension personnel should be aware of and assist state and federal disease control programs where appropriate, it is at the farm level where extension programming has potential for great impact. Biosecurity procedures implemented by specific farms are important to animal health and well-being. The introduction of infectious diseases against which existing animals have little or no immunity through either exposure or vaccination has the potential to cause significant illness, production losses, and animal suffering, in addition to increased production costs due to treatments and death losses.

A wealth of publications that address biosecurity have been authored and distributed by extension services, universities, state departments of agriculture, and livestock commodity groups. A recent review of these publications outlines recommendations made through 111 publications from university cooperative extension services and state departments of agriculture, as well as recommendations from the major livestock commodity groups (Moore et al., 2008). The majority of these publications focused on general livestock, dairy, beef, and poultry operations. Recommendations that were commonly expressed over the variety of publications included use of foot baths or disposable boots, control of visitor access, control of vehicle access, vector control, equipment and tool disinfection, and management or limitation of new incoming animal additions to farms. Discrepancies among recommendations were not uncommon in this review. For example, recommended isolation time for new animals entering dairy operations varied from 14 to 30 d, whereas similar recommendations for beef operations varied from 14 to 60 d. Among the publications, there were wide differences in the extent of recommendations and the inclusion or exclusion of certain biosecurity procedures. In addition, the recommendations varied substantially in their depth, with some being specific and others general in nature (Moore et al., 2008).

Vaccination programs were frequently included in the list of biosecurity procedures that are appropriate to implement on the farm level (Moore et al., 2008).

Whereas proper vaccination programs are essential to ensure an optimal level of resistance against infectious diseases, it should be understood that only a handful of vaccines currently approved for use in animal populations have achieved a label designation that indicates prevention of infection. The typical animal vaccine is approved as an aid in disease prevention. In other words, most current animal vaccines have only demonstrated an ability to help diminish the severity of clinical signs caused by disease agents that have already entered a population of animals. With rare exceptions, they do not prevent the entry of an infectious agent into an individual animal or, therefore, onto a farm. So, although important to animal health, vaccine programs do not fit the definition of a true biosecurity procedure that prevents the entry of disease agents onto a farm. It is possible that animal caretakers may get a false sense of security through vaccine programs at the expense of other more effective, albeit more difficult, biosecurity procedures.

When taking into consideration the sheer numbers and wide variety of published recommendations, it is conceivable that many producers may become discouraged when trying to account for these differences. This may result in "cherry-picking" procedures that are most convenient for them or avoiding them entirely, resulting in incomplete biosecurity programs.

Infectious disease agents such as porcine reproductive and respiratory syndrome (**PRRS**) virus infection of pigs, Johne's disease in cattle, or EHV infections in horses immediately come to the mind of producers, veterinarians, and educators as the most important threats to animal health. However, as educators, we could also make the case that, considering the overwhelming number and often vague nature of biosecurity recommendations, threats to animal health could also come in the form of educational failures. Biosecurity recommendations that are too general to be useful, are long laundry lists, are "one size fits all," are in conflict with each other, are impractical to implement, are poorly connected to science, or are not connected to a compelling reason for their use are all threats that could undermine the likelihood that an animal caretaker will effectively implement effective and efficient biosecurity procedures for their animals.

There are many means of entry for infectious disease agents onto a farm, including newly purchased breeding stock, feeder animals, wildlife, vehicles, boots and clothing of visitors or workers, equipment, insects, and rodent pests. This variety of potential sources can make biosecurity practices seem quite daunting if the goal is to prevent all sources of disease entry all the time. Perhaps the entry routes most likely to result in disease introduction should become the initial focus of biosecurity.

Along with the challenge of addressing possible multiple routes of infectious disease entry, another challenge relative to biosecurity recommendations regards consideration of the most up-to-date scientific information to guide those recommendations. For example, a high percentage of published documents recommended the use of foot baths for personnel entering animal locations. Experimental data indicate that, in the manner foot baths are used currently in most swine units, they are not effective in decreasing the number of bacteria on boots or shoes, and may in fact serve as a vehicle for bacterial spread. Unless organic matter, such as manure, is kept from contaminating the foot baths, the disinfectant will soon become inactivated. Foot baths can be an effective way of disinfecting footwear if manure and other organic matter can be removed first (Amass et al., 2003).

Another challenge faced by educators in trying to help producers implement biosecurity recommendations is the wide variety of needs faced by different operations. The strict biosecurity requirements of a boar stud housing valuable animals with the goal of producing PRRS-free semen (e.g., air filtration, extended quarantine, comprehensive testing of incoming animals) are vastly different from a commercial cow-calf operation, for example. Even within species groups, wide varieties of needs exist: a beef seedstock producer producing semen or embryos vs. a grass-fed cattle operator producing market-weight cattle, for example.

Relatively few of the published recommendations mentioned specific risk assessments for individual farms. Assessing where the risks of disease introduction lie for an individual farm allows one to prioritize interventions and will also serve to identify practices that can be practically and easily implemented. None of the published recommendations reviewed mentioned anything about prioritizing biosecurity measures; for example, is it more important to isolate incoming animals or to limit visitor access? There is little doubt that some measures listed in certain publications are more important than others for the situation on a given farm. Therefore, an individual, farm-specific approach to biosecurity is more desirable than dependence on general recommendations. Tools are available to extension personnel for conducting individual risk assessments, in concert with herd veterinarians, regarding infection control practices. Comprehensive materials for beef, dairy, and equine facility risk assessment are available through the Center for Food Security and Public Health at Iowa State University (Iowa State University Center for Food Security and Public Health, 2006). This website can be accessed to produce an initial questionnaire based on the species and type of operation. Answers from this questionnaire then are input into the website, resulting in a short list of possible interventions for that farm to consider. Consultation between the producer and the extension educator or veterinarian can then produce a plan that prioritizes practical interventions for the farm.

In prioritizing biosecurity interventions, educators should consider the difference between biological sources and mechanical sources of disease agent entry. Examples of biological sources of disease entry would be animals that are actively infected and shedding infectious agents or bacteria (e.g., *Salmonella*) that proliferates in contaminated environments (e.g., a trailer for hauling animals). Mechanical sources are objects that physically move an infectious agent from one place to another, such as contaminated boots, coveralls, or vehicle tires. Because the number and viability of organisms is substantially greater with biological sources, prioritization of biosecurity measures that prevent their entry should in most cases be considered first. Examples of such interventions include isolation and targeted disease testing of incoming new animals.

Extension personnel have a unique role in educating youth about biosecurity measures. As one example, animal exhibitions present ideal opportunities to emphasize infection control practices and proper management of animal movements to prevent novel disease back at home. Specific practices that can be highlighted include maintaining a clean animal environment at the fair or exhibition, and avoidance of shared equipment between animals. Following animal exhibition events, isolation of returning animals upon their return to the farm is of importance in preventing any potential disease entry. Although recent National Animal Health Monitoring System data indicate that 53.6% of animal exhibitors routinely isolate animals after coming home, 33.1% never do (USDA-APHIS, 2009), indicating room for improvement.

Assisting producers and educating youth in development of biosecurity plans is an appropriate function of extension personnel. To help ensure that these recommendations are adopted, educators should strive to prioritize interventions, make recommendations farm-specific, and seek out science behind recommendations, involving veterinarians and veterinary diagnostic laboratories whenever possible. Tools are available to help extension personnel, along with veterinarians, formulate specific, useful recommendations for farms and ranches.

ROLE OF EXTENSION IN ADDRESSING CONTEMPORARY ISSUES IN FOOD ANIMAL PRODUCTION

Meeting the food security needs of the 2050 global population will require development of new technologies that result in increased efficiency of production (FAO, 2006). Currently, less than 2% of the US population is actively involved in production agriculture. Fewer are involved in food animal production. At the same time, over the past decade, 14 states have changed livestock care and use regulations through referendum or other forms of legislative action (Table 3). Therefore, it is reasonable to predict that the general public will continue to be called upon to determine which technologies developed to increase efficiency are acceptable or unacceptable. Without appropriately communicating why and how these technologies will be used, there is a risk that a misinformed public will reject safe technologies that could effectively increase agricultural production and alleviate food insecurity. Technologies that aim to increase food animal production are especially at risk given the increased perception of animals as companions.

Many of these technologies continue to be developed at Land Grant universities entirely or in partnership with allied industries. Therefore, the Cooperative Extension Service may be uniquely positioned to create and implement educational programs that can appropriately introduce these technologies to nonagricultural audiences that may affect food animal production, be it through policy development or simply by voting. However, these are often nontraditional audiences. Many are unaware of extension education programs and may not respond to traditional means of extension.

Purdue University has recently developed 2 programs focused on contemporary issues in food animal production and targeted to nontraditional audiences. In both cases, the programs have the simple goal of providing individuals with the information they need to make informed decisions on how this sector of agriculture affects their lives and communities. Importantly, each program uses several very easy assessment tools to measure efficacy and impact of the different engagement programs.

PURDUE UNIVERSITY CONCENTRATED ANIMAL FEEDING OPERATIONS TEAM

Over the past 10 yr, Indiana has seen significant growth in livestock production. Much of this growth has come in the form of larger farms regulated by the Indiana Department of Environment Management (**IDEM**) as either confined feeding operations or larger concentrated animal feeding operations (**CAFO**) that required the National Pollutant Discharge Elimination System permit through the US Environmental Protection Agency. The IDEM currently regulates approximately 2,000 livestock facilities in Indiana, which has decreased by approximately 215 farms in the past years due to local and global economic factors (IDEM, 2011).

In some cases, the expansion of the livestock industry has met considerable opposition. In Indiana, planning commissions are charged with approving construction of a new livestock operation at the county level. By state statute, planning commissions contain a representa-

Table 3. States that have changed livestock care standards or regulations through ballot initiative, referendum, or other legislative action

State	Action
Florida	Banned gestation crates
Oregon	Banned gestation stalls (swine)
Arizona	Banned gestation stalls (swine) and veal crates
Colorado	Banned gestation stalls (swine) and veal crates
California	Banned gestation stalls (swine), battery cages (layers), and veal crates
Utah	Established an Agricultural Advisory Board to establish livestock care standards
Maine	Banned gestation stalls (swine) and veal crates
Oklahoma	Restricted local regulation, orders, and ordinances regarding agriculture production
Ohio	Established a Livestock Care and Standards Board
Indiana	Established a Livestock Standards Board
Michigan	Banned gestation stalls (swine), battery cages (layers), and veal crates
West Virginia	Established a Livestock Care Standards Board
South Carolina	Established that local laws regarding the regulation of livestock are superseded by those of the State General Assembly
Georgia	Restricted regulation of agriculture production by local governments

tive from Purdue University Extension (Slack and Cain, 2008). As the county-level permitting agency, the planning commissions can be bombarded with both questions and conflicting information, especially when the construction of a new facility meets significant opposition.

After requests by planning commission members for credible and accessible information regarding the CAFO, Purdue University developed the Purdue University CAFO team. The team consisted of animal scientists, microbiologists, agriculture economists, public health experts, agronomists, and extension specialists. The team was charged with identifying issues related to CAFO and summarizing available research on each issue. In doing so, the team was able to identify gaps in research and develop programs to address those gaps. Topics for research were divided into social/economic issues, environmental issues, public health issues, and general information on CAFO. To date, the team has produced 25 articles on topics ranging from the fiscal impact of CAFO on county budgets to the fate of antimicrobials that are unabsorbed and excreted after administration to livestock.

Information was provided to stakeholders in the form of short, web-based (http://www.ansc.purdue.edu/cafo), peer-reviewed articles aimed at a nonagricultural audience and a state-of-the-research symposium with county, state, regional, and federal regulatory agency members. The website contains analytical code (i.e., Google analytics) to measure and analyze activity. To date, pages on the website have been viewed over 30,000 times. The team's research is used by county and state regulatory agencies and in more than 200 other educational programs.

We have also employed surveys to determine impact. These are all offered online and are designed to be completed easily to facilitate greater response from survey participants. Again, online surveys are affordable (i.e., free in some cases) and can provide a great deal of information for analysis. We recently surveyed extension specialists/educators to determine the impact of the program on its target audience. Of those respondents aware of the site (i.e., 88% of respondents), 100% reported using the information on the website to learn about issues related to larger livestock operations, and 59% reported using the site several times to very often. A high percentage (i.e., 87%) of respondents reported sharing the information on the site with others who have questions regarding CAFO in Indiana. Importantly, 92% reported using the information on the site to inform decisions that they have made regarding larger livestock operations. All respondents rated web-based delivery of this information as good (33%), very good (47%), or excellent (20%).

PURDUE UNIVERSITY FOOD ANIMAL EDUCATION NETWORK

Recognizing the growing gap between US citizens and the production of their food and the increasing trend of states to regulate livestock production practices via referendum or similar public vote, Purdue Extension created a second education program targeted to consumers and nonconsumers (still voters) of food animal products. Termed the Purdue Food Animal Education Network, this program aimed to provide individuals that have questions or concerns regarding modern food animal production with information they need to make informed decisions. The goal of the program was not to advocate one system over another, or the consumption of food animal products in general, but simply to give individuals with no connection to agriculture an opportunity to see what happens behind what are sometimes closed doors and why.

The Purdue Food Animal Education Network is entirely web-based and uses various media to provide this nontraditional audience the most accessible information possible. The program is anchored by a main website (http://www.purdueFAEN.com), which hosts more than 20 information pages addressing topics such as "why are antimicrobials used in livestock production?" and "what happens to all that manure?" The site also contains analytical code (i.e., Google analytics). Much of the information is presented in short (i.e., less than 2 min) videos hosted on a Purdue Food Animal Education Network YouTube channel (PurdueFAEN). YouTube also offers some limited analytics to gauge the reach of the information. Advertising through social media (e.g., Facebook) is used to help ensure that the information reaches the targeted nonagricultural audience (more than 75% of Facebook participants are less than 24 yr old; New York City is the most represented area).

Although communicating with these different audiences has proved challenging, with as many failures as successes, it is clear that the most effective programs are those that simply show how things are done with less focus on justifications or why things are done, which often can be taken as defensive. In most cases, these individuals have little reference as to what takes place inside of a modern livestock facility or a processing facility. When given the opportunity, most questions are easily answered by giving individuals opportunities to see firsthand, either live or by video, what actually transpires.

SUMMARY AND CONCLUSIONS

It is possible that the United States will face changes in policies regarding the use of antimicrobials in livestock production in the future. The most likely changes would be limits on the use of antimicrobials as feed additives. Including antimicrobials in feeds is an effective way to prevent bacterial infections and banning this use of the drugs will likely lead to increases in mortality and morbidity, at least in the short-term, as was seen in the European Union. Eliminating this important means of disease control will require heightened biosecurity measures that both prevent diseases from entering the farm, but also limit diseases that may be endemic to certain farms or areas.

At the same time, as the global population grows, agricultural scientists will continually be called upon to develop technologies that produce more food, more efficiently. It is likely that the US general public, the vast majority of whom are not connected to agriculture, will also continually be called upon to determine whether these technologies are appropriate. As is the case with the use of antimicrobials in food animal production, it is likely that some segments of the US population will be uncomfortable with technologies that other groups consider safe and effective. Therefore, it is imperative that those technologies that are deemed safe after thorough research be introduced to the general public in a way that demonstrates their efficacy, but also answers their questions about safety. Failure to do so could result in the popular rejection of technologies that could ultimately lead to greater food security throughout the world.

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