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REVIEW

Antimicrobial-resistant bacterial infections from foods of animal origin: understanding and effectively communicating to consumersG. Donald Ritter,¹ Gary R. Acuff,² Gilles Bergeron,³ Megan W. Bourassa,³ Benjamin J. Chapman,⁴ James S. Dickson,⁵ Kenneth Opengart,⁶ Matthew Jude Salois,⁷ Randall S. Singer,⁸ and Carina Storrs⁹

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Consumers are increasingly interested in the attributes of the food they consume. This includes what is in the food and how it was raised; and at least some consumers are willing to pay a premium for products with specific attributes. However, the current plethora of labels on the market does not adequately address this issue; rather than providing actionable information, most labels add to the consumer confusion. In addition, there is a tendency toward “absence labels” that can contribute to a negative consumer perception of conventional products that may or may not include the attribute in question. Communication with consumers about the complex and highly technical issue of antimicrobial resistance (AMR) is challenging, and experiences from communication efforts about food safety–related issues demonstrate exactly how challenging this is to communicate clearly. General lessons learned from the science of risk communication can help guide efforts to communicate about the challenging issue of AMR. There are efforts underway to chart out a new approach. A new labeled animal production certification program is under development to provide choice for consumers, while reducing consumer confusion, which mandates antibiotic stewardship practices.

Keywords: antibiotics; antimicrobial resistance; food animals; no antibiotics ever

Introduction

A major concern with the use of antibiotics in animal agriculture is that it could increase the risk of antibiotic-resistant bacterial infections in the human general population through several pathways.¹ For antimicrobial resistance (AMR) to spread from farms to consumers via handling or consuming foods of animal origin, numerous sequential events must occur, and for many of these events, the risk is uncertain. Various other public health risks associated with antimicrobial use in animal agriculture that are not foodborne include direct contact with farm animals, environ-

mental spread of antibiotic-resistant bacteria from the farm or some other mechanism, such as secondary human-to-human transfer of farm-acquired resistant bacteria in the community.

In order to conduct risk assessments for early stages in the spread of AMR through food products derived from animals, it is possible to use available data regarding the presence of AMR bacteria on food animal farms and in foods of animal origin after processing, in addition to data from surveys conducted farther downstream in the supply chain, primarily in retail meat. Consumer handling of foods of animal origin is an additional important

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component of a farm-to-fork risk assessment. As examples, practicing proper food handling procedures, hand washing, and cooking meat to the appropriate temperature will reduce the risk of foodborne infection, yet these data are less frequently collected.

There have been numerous attempts to influence consumer purchasing via food labels. Consumers face an onslaught of labels on packages of foods of animal origin in retail markets. Government-mandated labels are directed at food safety, while other voluntary labels target actual or perceived quality attributes related to specific animal production practices. All voluntary production label claims on meat and poultry products require approval from USDA-FSIS, while similar claims on milk and egg products are regulated by the Food and Drug Administration (FDA). Many of these voluntary label claims indicate the absence of antibiotics or hormones in the farming practice or the food product, and they are often more prominently displayed than labels regarding the contents of the package. Research suggests that there is widespread confusion and frustration among consumers surrounding such negative labeling. A survey completed by ORC International found that 73% of consumers believe that antibiotics are present in most chicken meat despite federal regulations prohibiting unsafe levels of antibiotic residues from being present in any meat sold in the United States.^{2,3}

From a food safety and public health perspective, mandatory government product labels serve as the cornerstone to communicating information with consumers that may impact safe food handling practices.⁴ Providing consumers with accurate food safety information is important because they have ultimate control over food preparation in their homes and can potentially reduce the risk of illness through their actions.⁵ Yang *et al.* reported that approximately 51% of respondents stated they had observed the presence of safe handling labels on meat packaging.⁶ Of those who had seen the label, 79% reported reading it; slightly more than a third of participants self-reported they altered their behavior as a result of the information presented on these labels. While participants reported the labels altered their preparation practices, the labels did not successfully prevent them from engaging in risky food handling behaviors. Overall, the authors concluded that labels were a reasonable method for disseminat-

ing food safety information to consumers, but additional measures were needed to motivate consumers to alter unsafe food handling behaviors.⁶

Although some surveys indicate that a growing number of consumers say they want to know more details about how their food is produced and are worried about issues such as antibiotic use in animal agriculture, other research suggests that when it comes to actually buying meat, the majority of consumers decide based only on price, taste, and freshness.⁷ Only a small subset of consumers seek voluntary label claims, such as “no antibiotics ever” on packaging; it is this group that may change their behavior based on marketing campaigns, and in turn, may influence other consumers in their communities to follow them.

This article will describe the risk of AMR infection from farm use of antibiotics, how to effectively communicate this to consumers, and new steps that are being taken to clarify voluntary labeling of foods of animal origin. This article is primarily based on the presentations and discussions of the integrated discussion group meeting “Minimizing the Risk of Antimicrobial Resistance From Food Animal Production,” hosted by the New York Academy of Sciences on May 8 and 9, 2018.

Risk of antibiotic-resistant infections from food

The risk to consumers of acquiring an AMR infection attributed to on farm use of antibiotics is dependent on the occurrence of a series of events: (1) bacteria or resistance genes emerge on the farm in response to antibiotic use; (2) bacteria or resistance genes spread to human population; (3) person acquires infection with the bacteria or associated bacteria that carry the resistance genes; and (4) additional public health costs may be incurred beyond that caused by the infection with the antimicrobial resistant bacteria. In order to perform a risk assessment of AMR infections for consumers from antibiotic use in animal agriculture, it is necessary to assess the risk of each of these events.

One challenge in assessing the exposure risk to consumers is that several factors need to be accounted for, including consumer and retailer mishandling and lack of proper food preparation practices. Additional factors upstream of these exposures, at the level of food animal processing, need to be considered as well. However, some data

for these factors upstream and downstream from consumers are available. One source of these data is the USDA Food Safety and Inspection Service (FSIS) that routinely samples meat and poultry. Data can be downloaded from the FSIS website that date back several years regarding the presence of the following bacteria in animal products from numerous large-scale producers across the United States: *Salmonella* and *Campylobacter* in broiler chicken and turkey carcasses; *Salmonella* and *Listeria* in egg products; *Salmonella* and *Escherichia coli* O157:H7 in raw ground beef; *Salmonella* and *Listeria* in poultry and ready-to-eat meat.⁸ Notably, these datasets only report whether samples were positive or negative for the target bacteria and do not report bacterial load, and *Salmonella* has demonstrated ability to cause illness in humans from very low contamination levels, so nondetection of the bacteria in food does not connote a product safe to handle or consume. The FSIS also determines the antibiotic resistance profiles of the bacteria that are isolated, but these data must be obtained through a FOIA (Freedom of Information Act) request.

Among the other surveillance systems, the FDA National Antimicrobial Resistance Monitoring System (NARMS) tests a range of retail meat products for the presence of some AMR bacteria.⁹ However, it is difficult to make comparisons between data sets because the various surveillance systems (e.g., NARMS and FSIS plant sampling) use different methodologies, such as collecting samples from individual animals or groups of animals and from different parts of animals, such as the skin, colon, and fecal matter. To help address these issues, the World Organization for Animal Health (OIE), Codex, and WHO Advisory Group on Integrated Surveillance of Antimicrobial Resistance (AGISAR) are trying to encourage member countries to develop programs using standard surveillance methodologies, but currently existing programs are reluctant to change their protocols.¹⁰

No antibiotics ever

In recent years, consumer concerns about the use of antibiotics in raising food animals has created increased demand for meat and poultry from animals raised in no antibiotics ever (NAE) programs. For example, the proportion of broiler chickens

that are raised with NAE has climbed from virtually 0% in 2009 to around 5% in 2012, and dramatically increased after 2015 when several large producers, including Tyson, made the switch to NAE.^{11,12} As of May 2018, between 45% and 55% of broilers were raised as NAE, according to Agri Stats data, which means the source animals have never received any antibiotics—including ionophores, in feed, water, or by injection—during their lifetime.¹³

In the U.S. poultry industry, the price premium paid to chicken processors for boneless skinless breast meat with the NAE label appears to be decreasing as the market becomes saturated. As an example, in 2013, the premium was 60–80 cents per pound for boneless skinless breast meat, but this dropped to about 30 cents per pound by 2017.¹¹ There is less demand for NAE with other cuts of chicken, especially dark meat cuts; in fact, there now is a negative premium on NAE wings (this is due to NAE birds being generally smaller and the U.S. market preferring jumbo size wings). Retail chicken production for the NAE market represents nearly 50% of the total volume of all chicken produced, yet retail sales of NAE chicken account for less than 10% of the total volume.¹⁴ Additionally, premium prices are typically charged for prime cuts like boneless breast meat, which make other nonprime cuts more expensive without having the corresponding higher market. Both of these factors make production of NAE economically unsustainable at current levels. Despite the eroding premiums for producers, NAE poultry costs consumers 50–200% more than conventional poultry due to variable price premiums added by food retailers, who are getting more margin on top of the additional cost charged by chicken suppliers.

Motivations for raising NAE animals

To understand the motivations for shifting toward an NAE system, a private research team conducted an anonymous online survey of 565 food animal producers and veterinarians working within the broiler, turkey, swine, beef, and dairy industries predominantly in the United States in late 2017.¹⁵ Over 95% of respondents were located in the United States. Just over half of the respondents currently work with or have previously worked with animals being raised without antibiotics (NAE respondents) and thus have direct experience with NAE

production. Comments from this survey will be limited to responses from this NAE producers' group. The survey revealed that the decision to use an NAE system was market driven. Across all the commodity groups, the majority of NAE respondents selected "to fulfill a client/customer request" as a contributing factor for going NAE. Other common reasons were "to increase the sale price of animals/product" and "to gain market entry into a retail program."

The NAE respondents believed that demand for products would "slightly increase" or "significantly increase" if they were labeled NAE while at the same time indicated that NAE would slightly or significantly increase the cost of production.¹⁵ This raises questions about whether NAE respondents actually see higher returns on their investment, and agrees with other reports that NAE increases production costs, but does not always add value (e.g., in the case of chicken wings).¹⁶

Over 80% of producers and veterinarian survey respondents with NAE production experience said they thought NAE production would either slightly or significantly worsen animal health and welfare.¹⁵ However, the same respondents agreed that the perception of customers, specifically retailers, restaurants, and food services, was that NAE slightly or significantly improved animal health and welfare, revealing a major disconnect between NAE producers and buyers. A disconcerting finding from the survey of producers and veterinarians was that they somewhat or strongly agreed that maintaining an NAE label took priority over animal health and welfare at times, based on the experience of NAE respondents.¹⁵ Producers who have invested in an NAE system face various pressures, including those from marketing departments within their companies, not to treat sick animals and lose the value of the NAE label.

Impacts of NAE on animals and the environment

Animals raised under NAE production systems are at risk of increased morbidity and mortality. Monthly mortality among NAE broiler chickens was 25–50% higher in 2017 compared with conventionally raised chickens in the United States. From October 2017 to May 2018, mortality rates of broilers raised without antibiotics averaged about 4.2%, while conventionally raised chickens had an average

mortality rate of about 2.9% (more than 40% lower), according to Agri Stats data.¹¹ After falling steadily from 18% mortality to approximately 5% between 1925 and 2013, there has been an uptick in mortality coinciding with the surge in NAE production (Fig. 1).¹⁷

Trends in morbidity with increased occurrence of specific health conditions, such as necrotic enteritis and bacterial osteomyelitis for the poultry industry, corroborate mortality trends indicating that NAE systems could jeopardize animal welfare. Presumably, the increase in these conditions among NAE broilers is due to the increase in the potential for intestinal infections, which in turn leads to more urine and diarrhea, and thus more moisture and ammonia in the poultry litter. Indeed, NAE flocks are at 3.5-fold greater risk of ammonia burns in the eye, have 1.4-fold greater risk of having foot lesions, and 1.5-fold greater risk of having air sacculitis compared with conventionally raised flocks.¹⁸ NAE birds at increased risk of enteric health problems have reduced daily weight gain when compared with conventionally raised animals.¹⁹

The increase in mortality among chickens raised NAE, along with the lower stocking density usually required for NAE flocks, the higher feed conversion ratio and increased time required to grow the birds and the increased downtime in houses between flocks, result in a greater negative environmental impact compared with chickens raised in conventional programs. Researchers estimate that if all producers in the United States switched to NAE systems, they would need between 680 and 880 million more birds annually to maintain the current level of supply.^{20,21} To raise these additional animals would require 5.4–7.2 million more tons of feed and 1.9–3.0 billion more gallons of water each year, and produce 4.6–6.1 million more tons of manure.^{20,21} This estimate was based on national averages for key parameters, including stocking density and mortality, and was designed to assess the environmental implications and compare conventional and NAE production systems. To better assess more system-wide environmental impacts that can more broadly account for all positive and negative impacts, a full life-cycle assessment analysis, a tool used to calculate the total environmental costs attributed to an animal production system that compares NAE to conventional broiler production, is warranted.

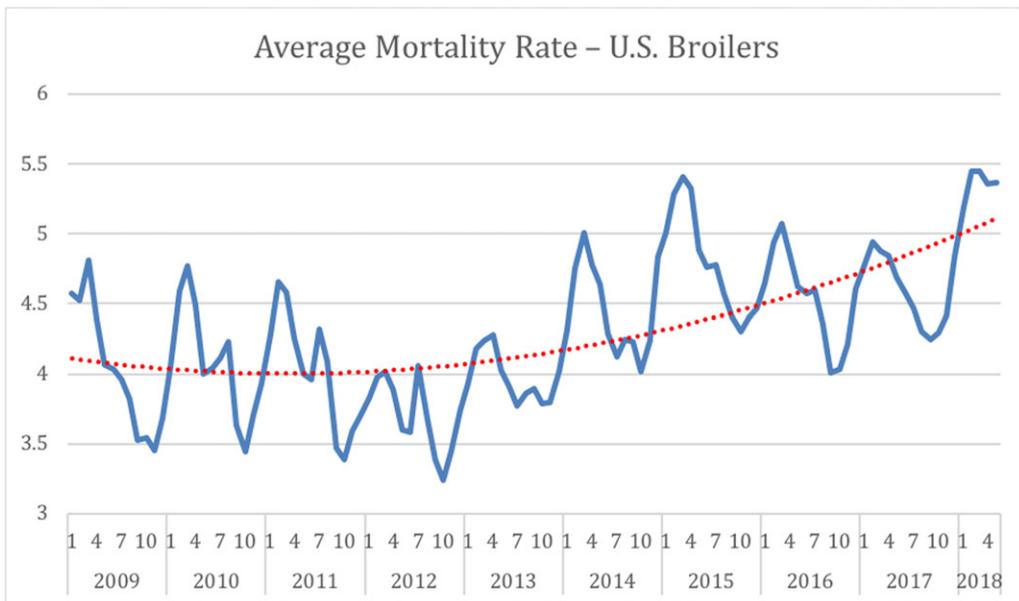


Figure 1. Monthly mortality of U.S. broiler chickens from 2009 to 2018. Adapted from Agri Stats.

Antibiotic use claims and labeling on meat packaging

Abundance of absence food labeling

In 2002, the FAO advocated for a comprehensive food system in which the dynamic interaction of all players is crucial to secure food safety and quality. Government authorities, producers, processors, marketers and distributors, and consumers, along with organizations or institutions specialized in scientific and technological research, education and information, all have independent functions within the system. However, the system functions best through partnership—coordination and cohesiveness of actions, interactions, communication, and collaboration—and, for this to happen, participants must:

- function in an open and transparent process;
- have clear delineation of responsibility and the authority to make decisions for meeting their responsibilities; and
- have, or be given, the resources to participate and work together effectively.

The FAO states that the system must be science based, with clarity on roles and responsibilities of all stakeholders to ensure promotion, coordination, and planning related to prevention, intervention,

control, response, and communication throughout the whole food system.

Consumer trust is strongly related to how they perceive the company's level of care and are more trusting of companies with greater concern for public well-being and attention to food safety.²² Latvala *et al.* found that most consumers do trust the food safety system, both food safety authorities and stakeholders alike.²³ De Jonge *et al.* found that food manufactures have the greatest positive impact on consumer confidence in food safety, but that different food chain actors have different levels of impact on the varying trust dimensions, which in turn affects their influence on consumer confidence.²² Trust generally improves consumer optimism and reduces pessimism (worrying about incidents of developments) in food safety, but major food safety scares can significantly lower consumer trust in the food safety system.²⁴

Consumers shopping for meat, eggs, and dairy have a wide range of product options in retail markets. At the least expensive end, there are many store brand products that lack special antibiotic or other voluntary product claims. The intermediary options are products from responsible antibiotic use programs, which have not yet gained much traction in the retail marketplace. At the most expensive end are products that feature specific and

Table 1. List of negative food label examples

Grown without antibiotics
Grown without the use of antibiotics
Humanely raised without antibiotics
Never any antibiotics administered
Never ever administered antibiotics
Never ever given antibiotics
No added antibiotics
No added antibiotics ever
No antibiotics
No antibiotics administered
No antibiotics ever
No antibiotics ever (USDA PVP)
No antibiotics ever administered
No antibiotics important for human medicine
No hormones administered
No human antibiotics
No medically important antibiotics
Raised without added antibiotics
Raised without antibiotics

multiple health and welfare claims, stating the animals were raised on farms that diverge substantially from conventional farming practices, such as NAE, USDA certified organic, and private programs such as the Global Animal Partnership. These products often have not one but multiple labels that address different distinct issues that can add to consumer confusion. Table 1 gives examples of the many absence food labels related to antibiotics that consumers are confronted with.

The label claims on food animal products from programs, such as NAE or hormone free, are known as “absence” labels because they refer to the lack of antibiotic use or hormone administration in the raising of food animals. The use of antibiotics during the raising of animals is often confused by consumers who conflate antibiotic use during animal production with the presence of unsafe antibiotic residue levels remaining in the meat after the animal is harvested.^{25,26} This misunderstanding can alarm consumers who assume that the store brand or unlabeled options contain harmful antibiotic residue or hormones and as a result subsequently purchase a more expensive absence labeled product if they are able to afford it. Consumer-focused research in 2017 revealed that consumers are frustrated by negative labeling and would like more positive labeling of meat products.²⁷ Additionally, interviews of major U.S. meat retailers and wholesalers conducted by

a poultry production company during onsite visits with buyers and marketing leaders of each company found that customers desired a simple logo that would address their numerous concerns when they buy meat from food animal producers. These interviews suggest that customers desire a labeling option that sensibly balances the pressures from animal activist groups and consumers with the needs for a sustainable production practice that is respectful of animal health and welfare.²⁸

Positive labeling and an alternative approach currently in development

Currently, the only USDA–AMS audited antibiotic use certification program available that is not an absence label is through the Certified Responsible Antibiotic Use (CRAU) program, which was developed by School Food Focus and Pew Charitable Trusts. CRAU requirements include using only veterinary-prescribed antibiotics to treat and control illness and not allowing antibiotics with analogs in human medicine to be used for prevention purposes.²⁹ Although it represents an important first step toward creating a positive antibiotic use label alternative for meat products, the CRAU program is limited to a single attribute. The program only applies to poultry and is currently only utilized for institutional sales to school lunch programs. Additionally, CRAU has no retail approved label and its guidelines are difficult to message to consumers thus limiting its current value in the marketplace.

A possible alternative approach to address this important labeling issue is to include responsible antibiotic stewardship practices within a more encompassing multipoint animal production standard that tries to find a balance among different and potentially contradictory characteristics. An attempt to meet the need for positive labeling promoting responsible antibiotic use practices on a broader scale for consumers and customers is currently in development. A coalition of animal production companies, non-governmental organizations (NGOs), and scientific experts is developing a One Health Certified (OHC) animal production certification program based on the principles of One Health: that the health of animals, people, and the planet are all connected. The One Health animal production standard is being developed as an umbrella standard over similar guidelines

created for all commodity groups. OHC is intended to be a public certification program open to all producers who meet program requirements and successfully pass an audit via the USDA–AMS PVP system. Products from companies that meet the certification requirements would bear a simple universal logo representing a program that promotes antibiotic stewardship, animal well-being, and environmental sustainability. OHC and similar programs can be viewed as transforming conventional production practices and moving conventional producers into a transparent and audited animal production system with defined benchmarked requirements. This new program will be structured to be a continuous improvement standard with an oversight committee and planned reviews. In addition, to avoid adding yet another label to a package to create even more consumer confusion, the program will restrict colabeling such that the One Health logo should not be displayed together with most other voluntary label claims.

Feedback from U.S. retailers and wholesalers about creation of the One Health Certified program, as well as initial consumer testing, has been positive. In the end, the national food buyers and consumers will determine if OHC or other such more sustainable and balanced programs have value or not and will gain a permanent foothold in the marketplace.

Communicating risk to consumers

Building acceptance for new food labeling

Despite the frustration among consumers around absence labeling, it will almost certainly require large, expensive marketing and communications campaigns for any new labeling concept to be broadly embraced by consumers. For a marketing campaign to be successful, industry members, trade organizations, regulatory bodies, or NGOs need to deliver messaging to consumers through multiple sources, adopting a social marketing approach that could include government websites, such as the USDA, online conversations, radio ads, and celebrity chefs.³⁰ Generally, consumers are viewed as lacking relevant knowledge to be fully aware of food hazards and how an effective risk management system functions.^{31,32} Research has indicated, for example, that consumers perceive that some level of risk is an integral part of food production; they believe in the efficacy of control systems and in the

ability of science to handle emerging dangers in food safety.³³

Data from a 2016 FoodThink survey revealed that 65% of consumers say it is “very” or “somewhat” important to them to know how their food is produced.³⁷ Additionally, about 80% of consumers reported being at least “somewhat” concerned about antibiotic use in animal agriculture when asked specifically about this issue. However, in studies that asked consumers about the factors that influence them when they purchase food, 95% said their decision came down to three factors: price, taste, and nutrition. Only 5% of consumers are amenity buyers who look for food brands and labels, and who take into consideration factors such as the use of antibiotics in food animals when buying meat. It is this smaller subset of consumers that should be targeted with messaging to communicate the risks and trade-offs of antibiotic use.³⁴

In developing an effective message, risk communication researchers suggest that messaging campaigns should provide actionable information on risk to consumers that can be used to make buying decisions, rather than campaigns simply using negative messaging to convince consumers to buy food animal products with absence labeling. Notably, there are many different types of consumers, ranging from those who are very interested in issues such as antibiotic use in animal agriculture, to those who are not at all interested.³⁴ Effective campaigns will reach consumers who not only are interested but who are also thought leaders in their communities, such as in social media networks. By helping those consumers understand the benefits of new labeling such as OHC, they will help other consumers who follow them to understand and potentially change their behaviors.

Social media outlets and the internet are being explored as avenues for disseminating information about products and strengthening brands. This provides an opportunity for stakeholders, policy makers, and producers to engage in dialogue with consumers about food risks and benefits that can help improve trust and credibility of the company or organization.³⁵ A social media strategy should encourage the spread of accurate information by developing a proactive presence and by targeting key informants and social media users.³⁵ The CDC has created a list of strategies for developing a social media communication plan.³⁶

Effective food safety messaging

For any food safety messaging (including that related to AMR), in addition to developing messaging that is relevant to the subset of consumers that is engaged in these issues, there are three components that are critical to communicating food safety information, according to research on risk communication.³⁰

First, the communication must be rapid and timely. When there is a newsworthy event related to food safety, such as an outbreak or the release of a new report, a trustworthy expert should explain the situation and why decisions were made. At the same time, potential negative consequences associated with these decisions, such as the possibility for increased disease and mortality rates associated with eliminating antibiotic use in animal agriculture, should be communicated to consumers, as should uncertainties and data gaps about the situation. Consumer research indicates that consumers can understand downsides and limitations associated with policy changes. It is important that information comes from people familiar with the changes to help consumers keep in perspective any criticisms that might be leveled by various advocacy groups.

Second, the experts who communicate the information to the public must be credible and reliable. They should not represent or be connected to companies or entities that could be perceived as benefiting from the messaging. Paradoxically, in today's current climate in the United States, messaging from experts who represent government agencies, such as the CDC, may not be viewed as legitimate, as trust in government officials among many members of the public has greatly deteriorated in recent years. On the other hand, a spokesperson for a consumer advocacy group, or a celebrity chef mentioning food safety tips on a cooking show, could effectively deliver messaging.

Third, it is critical to evaluate campaigns for food labeling information for their effectiveness and revise them if it is found to be poor. Although many companies have special retail labels, it is rare that they follow up to determine whether the labels influence consumer behavior. For example, the USDA has included safe handling instructions on meat packaging since 1993 but has not performed studies to find out whether they influence consumer behavior, such as increasing the use of thermometers to

ensure the meat is cooked to a safe temperature. A recent pilot study of a consumer market in North Carolina found that a large campaign through radio ads and other media sources focusing on increasing awareness about cooking hamburgers to a certain temperature led only to a small increase in consumer understanding. As new labeling is developed, it will be critical to include plans for follow-up assessments, which will invariably increase the cost of the campaigns. However, it is very difficult to collect data on what consumers do, as opposed to what they report they do or know.

In the context of AMR, rapid and accurate communication should be relayed to consumers from a trustworthy and reliable source. Messaging should be designed to inform rather than alarm, and the goal should be to arm consumers with adequate information to address or allay perceived risks. Modeling AMR communication on the success of other campaigns, such as The 4-Day Throw Away campaign, used both traditional and social media methods to increase knowledge and practices related to food safety handling and storage at home.³⁸ The campaign targeted families with young children and was based on the Health Belief Model. The main message was to throw away unused leftovers after 4 days. Traditional media featured magnets and posters to direct people to a website for further info. Social media features were YouTube videos, a Facebook page, and a Twitter account. Both traditional and social media channels increased awareness and behavior change intentions, especially among parents with children 10 and under, showing that mixed media channels can be part of effective interventions to change food safety behaviors.

An additional strategy for AMR risk communication would be to incorporate lessons learned from Gates³⁹ by incorporating risk information about antibiotic use, why and how it is implemented, and the limitations and risk of the practices directly onto recipe websites to increase awareness and understanding of food safety issues related to certain ingredients, such as poultry, beef, eggs, or milk. Food safety and food origin information should be shown near the recipe instructions, and should serve to direct people to websites with additional information.

However, social marketing may only improve food safety behavior temporarily. In a small-scale

targeted intervention that observed and evaluated food safety practices during domestic food preparation, Redmond and Griffith showed that a “halo effect” over other food safety behaviors may result from interventions that target a specific behavior.⁴⁰ The intervention effect was more pronounced right after the intervention compared with 4–6 weeks later; so behavior change does not appear to be sustained over time. The researchers recommended focusing on specific targeted behaviors one at a time instead of general behaviors and using messages from multiple sources.

Conclusions

The spread of AMR from food animal farms to consumers may occur through several known pathways. Downstream events, such as mishandling of raw foods of animal origin by consumers and workers in retail markets and the food service industry, are relevant to the general population and yet also difficult to track. Research groups carry out surveillance to determine the level of AMR on farms and government agencies routinely monitor AMR levels in food processing plants and on products in retail markets. Although it may not be possible to acquire data that reflect consumers’ actual food handling behaviors, efforts are underway at various levels to help consumers better understand how food is produced and what they can do to reduce their risk of acquiring AMR infections from food products.

There is currently a coalition effort across commodity groups to develop a balanced multipoint animal production program label that includes responsible antibiotic use that will provide both consumers and customer groups, which purchase food animal products from the producers for retail markets, an alternative standard that is more balanced and sustainable than the “no antibiotic ever” single attribute label currently available. However, lessons from risk communication research on conveying basic food safety messages to consumers, such as about cooking meat to a certain temperature, reveal that it will require strategic information campaigns for consumers to understand and accept new labeling concepts. These campaigns deliver messaging using multiple platforms, including online announcements and radio ads. However, it is largely unclear the effectiveness of such information campaigns in influencing consumer behav-

ior even about food safety issues. Going forward, it will be critical for marketing about both food safety and voluntary label claims to include follow-up evaluations to determine whether they appear to help consumers make changes that reduce their AMR risk.

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Competing interests

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