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Food Safety and Organic Meats

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Abstract

The organic meat industry in the United States has grown substantially in the past decade in response to consumer demand for nonconventionally produced products. Consumers are often not aware that the United States Department of Agriculture (USDA) organic standards are based only on the methods used for production and processing of the product and not on the product's safety. Food safety hazards associated with organic meats remain unclear because of the limited research conducted to determine the safety of organic meat from farm-to-fork. The objective of this review is to provide an overview of the published results on the microbiological safety of organic meats. In addition, antimicrobial resistance of microbes in organic food animal production is addressed. Determining the food safety risks associated with organic meat production requires systematic longitudinal studies that quantify the risks of microbial and nonmicrobial hazards from farm-to-fork.

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INTRODUCTION

The U.S. organic food industry has grown substantially in popularity. According to the Organic Trade Association's Organic Industry Survey (2011), total organic food sales accounted for $6.1 billion in 2000 and more than quadrupled in the past 10 years to $26.7 billion in 2010. Organic meat sales in 2010 were $470 million and include poultry (63%), beef (22%), sausages/deli meat (11%), pork (3%), and lamb (1%) (OTA 2011) (**Figure 1**). The United States Department of Agriculture (USDA) Economic Research Service (ERS) reported a major increase in the total number of United States–grown organic livestock between 2000 and 2008, with an increase for cows, hogs, pigs, sheep, and lamb from 56,028 in 2000 to 475,829 in 2008; and for poultry (layer hens, broilers, turkey, and other) from 3,159,050 in 2000 to 15,518,075 in 2008 (USDA-ERS 2010).

In order to label a food product as organic in the United States, there are specific regulations that must be followed. These regulations, as defined by the USDA National Organic Program, can be found in **Table 1** and are much more extensive than those for products labelled as "natural" and "naturally raised" or "free-range," "free-roaming," and "pasture." These types of livestock production are often referred to as "organic" by consumers and occasionally appear in the scientific

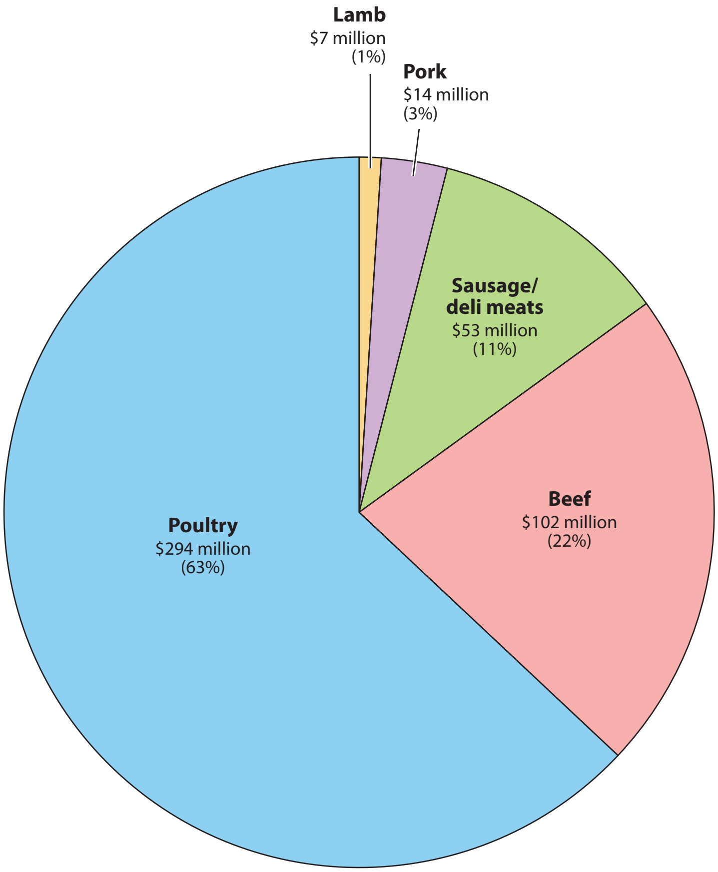

Figure 1

Organic meat sales in 2010 by subcategory (adapted from OTA 2011).

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Table 1 Key requirements for natural, naturally raised, free-range, and organically raised livestock and poultry or foods according to the United States Department of Agriculture (USDA) (FSIS 2011; USDA-AMS 2009a,b; USDA-NOP 2010)

USDA organic standard	Naturally raised	USDA natural foods	Free-range
■ Only fed 100% organic feed ■ Federal Drug Administration–approved trace minerals and vitamins allowed (not exceeding amount needed for nutrition and health) ■ Vaccines allowed to keep animal healthy ■ Prebiotics/probiotics allowed ■ No animal byproducts ■ No hormones, no growth promotants ■ No antibiotics ■ No drugs ■ No routine use of synthetic parasiticides ■ No withholding of treatment of sick or injured animal to keep organic status ■ No keeping animals in cages ■ Access to outdoors	■ No growth promotants ■ No antibiotics (except for ionophores used as coccidiostats for parasite control) ■ Not fed animal (mammalian, avian, and aquatic) byproducts derived from the slaughter/harvest processes, including meat and fat, animal waste materials (e.g., manure and litter), and aquatic byproducts (e.g., fishmeal and fish oil)	■ No artificial ingredients ■ No added colorings ■ Minimally processed	■ Access to outside

literature. For example, meat products marketed as "natural" are only required to not contain artificial ingredients or added colors and be minimally processed (FSIS 2011). The "naturally raised" label refers to livestock used for the production of meat and meat products that have been raised entirely without growth promotants or antibiotics (except for ionophores used as coccidiostats for parasite control), and have never been fed animal (mammalian, avian, or aquatic) byproducts derived from the slaughter/harvest processes, including meat and fat, animal waste materials (e.g., manure and litter), and aquatic byproducts (e.g., fishmeal and fish oil) (USDA-AMS 2009a, 2009b). Finally, "free-range," "free-roaming," and "pasture" can be used as labels for meat products that come from animals with outdoor access (FSIS 2011).

Consumers often have the perception that organic foods are safer and healthier than conventionally grown foods, and this is the primary reason for organic food and organic meat purchases (Van Loo et al. 2010, FMI & AMI 2010). Consumers are willing to pay premium prices for these products (Van Loo et al. 2011). However, most of the research conducted on organic-based foods has concluded that there is no evidence that organic food is safer, healthier, or more nutritious (Williams 2002, Magkos et al. 2003). Therefore, a food product produced organically is not necessarily indicative of it being safer. Consumers are often not aware that the organic standards are only based on production and processing practices and not on the final quality or safety of the product (Brennan et al. 2003). There are no stricter food safety standards for organic foods; organic foods are required to meet the same food safety standards as nonorganic foods. Food safety hazards associated with organic meats remain unclear because the results of studies comparing conventionally and organically produced meat are often contradictory. With increasing popularity in consumption of organic, free-range, and natural meat, it is becoming more urgent to address the associated impacts on food safety and to further evaluate if the consumer perception of organic meat being safer than conventionally produced meat is warranted. In addition, if there are particular food safety hazards more closely associated with organic food production and/or processing practices, these need to be identified.

Little has been published on the safety of organic meat and any associated microbiological risks. Although the consumer perceives these products as safer, production methods, such as access to the outdoors, restrictions on therapeutic use of antimicrobials, and the often smaller processing facilities, may contribute to a greater microbiological safety risk (Miranda et al. 2008a). This review provides an overview of the studies on microbiological safety of organic meat. In addition, the risks for development of antimicrobial resistance of microbes associated with organic and conventional livestock production are compared. Antimicrobial-resistant microorganisms present in meat may survive when treated with antimicrobials, presenting a potential food safety risk for consumers. Other production methods in organic production, such as the limited use of chemicals, particularly antibiotics, hormones, and pesticides, are perceived as safer practices and are discussed.

COMPARING FOOD SAFETY HAZARDS IN CONVENTIONAL AND ORGANIC MEAT PRODUCTION

The primary actual and perceived food safety hazards associated with meats and meat products are microbial contamination, chemical residuals of growth hormones and antibiotics, food poisoning toxins, and use of genetically modified ingredients in the production of animal feeds (Krystallis et al. 2006). Krystallis et al. (2006) classified the food safety risks of meat consumption in terms of severity and familiarity. Regarding severity, the primary risks (from the most to the least alarming) are: *Salmonella*, bovine spongiform encephalopathy (BSE), *Escherichia coli*, hormones, antibiotics, and use of genetically modified materials; whereas for familiarity (from the most unknown to the least unknown), the order of risks are genetically modified ingredients, hormones, antibiotics, BSE, and *E. coli*.

Microbiological Contamination

Foods that are microbiologically contaminated may harbor harmful microorganisms, making them potentially risky for human food consumption. Organic meat production has the potential to have higher microbiological safety risks because of the strict restrictions in the use of pharmaceutical agents for therapeutic use (such as antimicrobials or parasiticides), raising the animals outdoors, use of slow-growing breeds and the smaller slaughtering facilities (Engvall 2001, Institute of Food Technologists 2006, Thamsborg 2002). However, with proper management, such risks can be reduced (Bourn & Prescott 2002, Yiridoe et al. 2005, Winter & Davis 2006). Consumers often buy organic meats because they believe they are healthier or safer (O'Donovan & McCarthy 2002). However, this may not be true. The microbial safety of conventional animal production has been widely studied, but organic animal production practices have not been examined to this same degree of depth (Young et al. 2009). This needs to change if the market demand for organic meats continues to increase, as microbiological safety may emerge as a greater risk when not only more of the human population consumes these products but the range of host susceptibility increases with changes in the demographics of the consumer.

The ability for animals to be raised free range is important in organic farming, but by the very nature of this type of environment, this production system has the potential for greater food safety risks. With free-range practices, there is a greater risk of transfer of zoonosis from wildlife to farm animals via greater exposure to pathogens carried by parasites, rats, mice, birds, and pathogens in soil. Because of extended exposure to outdoor conditions, organically raised farm animals may

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more likely be infected by *Salmonella* and *Campylobacter* (Lund 2006, Hansen et al. 2002). In addition, organic farming stresses the importance of nonchemical disease prevention rather than conventional drug-based treatment; hence the use of antibiotics is prohibited in organic livestock production. This could lead to greater foodborne pathogen levels and concomitant increases in microbiological safety risks. Conversely, food safety risks could be reduced because of the lower animal stocking rates typically associated with organic production (Hansen et al. 2002).

Although rationale can be provided for both pro and con on the potential for food safety risks in organic meat animal production, actual data to support either scenario remain elusive. This stems from two issues. Not only are there limited data on the microbiological safety of organic meat production practices, but more importantly, there is a lack of definitive research because of the much more difficult task of conducting truly direct comparative studies between conventional and organic systems where confounding factors can be either removed or at least taken into account. Consequently, the research findings that are available regarding the microbiological safety of organic livestock production are not consistent. A few studies have been conducted to compare the prevalence of pathogens in organically and conventionally raised animals. Although the results of most studies revealed that pathogens are more or equally prevalent in organically raised and conventionally raised animals, results of some studies indicate the opposite (**Tables 2–4**).

Many factors, such as location, season, time before processing, and detection/isolation methods, influence the prevalence of foodborne pathogens in livestock (Sato et al. 2004). Variability among these factors makes it difficult to compare the results of different studies; however, comparisons of some conventionally and organically or naturally raised livestock studies are possible, and these studies revealed some potentially important differences.

Poultry. Multiple studies have compared the prevalence of *Salmonella* in conventional and organic poultry at production, processing, and retail (**Table 2**). Some on-farm studies have compared *Salmonella* prevalence between organic- or pasture-raised broiler birds and conventionally raised birds (Siemon et al. 2007, Alali et al. 2010), whereas other studies have determined *Salmonella* prevalence at organic- or pasture-raised farms without a comparison group (Esteban et al. 2008, Hoogenboom et al. 2008, Melendez et al. 2010). Siemon et al. (2007) and Alali et al. (2010) determined there was a significantly lower prevalence of *Salmonella* in poultry at pasture-raised and USDA-certified organic poultry farms, respectively, compared with conventional poultry farms. Three other studies revealed varying results for pasture-raised poultry farms with no *Salmonella* detected (Hoogenboom et al. 2008) or a low prevalence of 2.9% (Esteban et al. 2008), compared with a relatively high prevalence of 25% for conventional poultry farms (Melendez et al. 2010). These prevalence determinations usually vary between studies because of seasonal effects and differences in hatchery sources, feed composition, vaccination programs, and flock-disease status.

At the processing stage, Griggs et al. (2006) determined that 18.7% of carcasses of chickens raised without antibiotics were positive for *Salmonella*, whereas Lund et al. (2003) determined that 1.7% of intestinal samples from birds fed an organic or pasture diet were positive for *Salmonella*. Retail comparisons between *Salmonella* prevalence on meat of organically and conventionally reared broilers have yielded conflicting results with some studies reporting higher *Salmonella* contamination on organic and free-range poultry meat compared with conventional poultry meat (Bailey & Cosby 2005, Cui et al. 2005) and other studies (Lestari et al. 2009) reporting lower *Salmonella* prevalence on organic poultry meat compared with conventional poultry meat. It was not clear in the two studies (Cui et al. 2005, Lestari et al. 2009) whether organic chicken carcasses were from USDA-certified organic birds, pasture-raised birds, or free-range birds. Bailey & Cosby (2005) suggested that the greater prevalence of *Salmonella* on organically raised chickens is due to the birds' access to the outdoors, where they are exposed to wild birds, insects,

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Table 2 Prevalence of foodborne pathogens in poultry produced under organic and conventional conditions

Author	Country	Key findings	Bacteria investigated	Sample point and type of sample
Alali et al. (2010)	United States	*Salmonella* prevalence in fecal samples was 5.6% (10/180) and 38.8% (93/240) from USDA organic and conventional farms, respectively.	*Salmonella*	Farm (fecal)
		Salmonella prevalence in feed samples was 5.0% (3/60) and 27.5% (22/80) from USDA organic and conventional farms, respectively.	*Salmonella*	Farm (feed)
		Salmonella prevalence in water samples was 0% (0/60 and 0/80) from USDA organic and conventional farms, respectively.	*Salmonella*	Farm (drinking water)
Avrain et al. (2003)	France	*Campylobacter* was isolated from 57% (221/390) of conventional broilers, 51% (77/150) of export broilers and 80% (48/60) of free-range broilers.	*Campylobacter*	Slaughter (cecal samples)
Bailey & Cosby (2005)	United States	31% (42/135) of free-range and 25% (13/53) of all-natural chickens were *Salmonella*-positive.	*Salmonella*	Producer, retail (carcass)
Colles et al. (2008)	United Kingdom	Chickens from 64 flocks had a *Campylobacter* shedding rate of 90.4% (881/975).	*Campylobacter*	Farm
Cui et al. (2005)	United States	61% (121/198) of organic and 44% (27/61) of conventionally produced chickens were *Salmonella*-positive. Most organic (76%, 150/198) and conventionally produced (74%, 45/61) chickens were *Campylobacter*-positive.	*Salmonella and Campylobacter*	Retail
Esteban et al. (2008)	Spain	70.6% of 34 free-range poultry farms were *Campylobacter*-positive, followed by *Listeria monocytogenes* (26.5%) and *Salmonella* (2.9%).	*Salmonella, Campylobacter, L. monocytogenes*	Farm (fecal sample)
Griggs et al. (2006)	United States	Carcasses of 299 chickens raised without antibiotics were 18.7% *Salmonella*-positive and 96% *Campylobacter*-positive.	*Salmonella and Campylobacter*	Processing plant (carcass)
Hanning et al. (2010)	United States	*Campylobacter* prevalence was 30% (53/178), 75% (36/48), and 100% (16/16) for pasture-raised poultry at farms, on retail carcasses, and at a processing facility, respectively.	*Campylobacter*	Farm (pens, feed, water, insects), retail (carcass), and processing
Heuer et al. (2001)	Denmark	*Campylobacter* contaminated all of 22 organically raised broiler flocks compared to only 37% (29/79) of conventionally raised broiler flocks, and 49% (29/59) of extensive indoor-raised broiler flocks.	*Campylobacter*	Slaughter (cloacal swabs)
Hoogenboom et al. (2008)	The Netherlands	No *Salmonella* was detected in feces of organically raised broilers at nine farms. *Campylobacter* was detected at all organic broiler farms.	*Salmonella and Campylobacter*	Farm (feces)
Lestari et al. (2009)	United States	*Salmonella* was isolated from 22% (31/141) of conventionally and 20.8% (11/53) of organically raised chickens.	*Salmonella*	Retail (carcass)

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Luangtongkum et al. (2006)	United States	*Campylobacter* spp. prevalence in conventionally raised broilers and turkeys was 66% (227/345) and 83% (299/360), respectively, whereas *Campylobacter* prevalence in USDA organically raised broilers and turkeys was 89% (317/355) and 87% (201/230), respectively.	*Campylobacter*	Processing plant (intestinal sample)
Luangtongkum et al. (2008)	United States	In the first two weeks of organic broiler production, no *Campylobacter* was recovered from the environment and feces of chickens (0/15), whereas from 3 to 10 weeks, the *Campylobacter* prevalence in feces and the environment ranged from 61% (11/18) to 88% (21/24), respectively. At the end of production, *Campylobacter* was isolated from the intestinal tracts of all 30 broilers sampled.	*Campylobacter*	Farm (fecal and environmental samples, including feed, water, litter, grass), slaughter (intestinal sample)
Lund et al. (2003)	United States	No *Campylobacter* contamination was detected in viscera or feed from four different groups (n = 456): (*a*) free-range, organic feed; (*b*) free-range, traditional feed; (*c*) pastured pen, organic feed; and (*d*) pastured pen, traditional feed. There was no significant difference in *Salmonella* prevalence among the different treatment groups.	*Salmonella and Campylobacter*	Slaughter
Melendez et al. (2010)	United States	*Salmonella* was detected in 50% (18/36) of retail broiler carcasses and 25% (41/164) of on-farm samples of pasture-raised poultry.	*Salmonella*	Farm (pens, feed, water, insects), retail
Miranda et al. (2008a)	Spain	Mean counts of Enterobacteriaceae from organically raised chickens were significantly higher than those from conventionally raised chickens.		Retail (carcass)
Miranda et al. (2008c)	Spain	The prevalence of *Escherichia coli* was significantly higher on meat of organically raised poultry compared with that of conventionally raised poultry, i.e., 82% (45/55) and 62% (38/61), respectively. No significant differences were observed in the prevalence of *Staphylococcus aureus* (67% and 57%), respectively, and *L. monocytogenes* (49 and 41%), respectively.		Retail (carcass)
Miranda et al. (2007)	Spain	*Enterococcus* mean counts were significantly higher on meat of organically raised chickens (3.18 log CFU g^{-1}) than meat of conventionally raised chickens (2.06 log CFU g^{-1}) or meat of conventionally raised turkeys (1.23 log CFU g^{-1}).	*Enterococcus*	Retail (carcass)
Siemon et al. (2007)	United States	*Salmonella* prevalence on conventionally reared broilers was significantly higher (30%, 125/419) than for those raised on pasture (16%, 83/512).	*Salmonella*	Farm (fecal sample)
Soonthornchaikul et al. (2006)	United Kingdom	*Campylobacter* was detected on 80% (n = 30) of prepackaged European Union–regulated organically reared chickens, 83% (n = 30) of prepackaged intensively reared chickens, and 100% (n = 30) of butchered but unpackaged, intensively reared chickens.	*Campylobacter*	Retail (carcass)

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Table 3 Prevalence of foodborne pathogens in organically and conventionally raised swine during production

Author	Country	Key findings	Bacteria investigated	Sample point and type of sample
Gebreyes et al. (2006)	United States	*Salmonella* prevalence was significantly higher among antimicrobial-free-raised swine (15.2%, n = 414) than conventionally raised swine (4.2%, n = 475) at the farm level. At slaughter, antimicrobial-free-raised swine had a higher *Salmonella* prevalence (15%, n = 362) than conventionally raised swine (6.8%, n = 381).	*Salmonella*	Farm (feces) and slaughter (carcass)
Gebreyes et al. (2008)	United States	Antimicrobial-free swine raised outdoors had a significantly higher seroprevalence of *Salmonella* (54%, 176/324, versus 39%, 115/292) and *Toxoplasma* (7%, 22/324, versus 1%, 3/292) than swine raised under conventional, intensive indoor conditions. In addition, two pigs (0.34%, 2/324) from the alternative production system were seropositive for *Trichinella* versus none (0/292) of the conventionally raised pigs.	*Salmonella*, *Toxoplasma*, *Trichinella*	Farm (serum)
Hoogenboom et al. (2008)	The Netherlands	*Salmonella* and *Campylobacter* were present in 27% and 56%, respectively, of swine feces samples obtained from 30 organic farms.	*Salmonella*, *Campylobacter*	Farm (feces)
Jensen et al. (2006)	Denmark	All swine grown under organic conditions (n = 47) shed *Campylobacter* spp. during sampling of three consecutive trials. *Campylobacter jejuni* was detected in 29.8% (n = 47) and 10% (n = 144) in environmental samples. *Campylobacter coli* was detected in 100% (n = 47) and 29% (n = 144) in environmental samples.	*Campylobacter*	Farm (feces, wildlife, paddock environment, including surface soil and water)
Jensen et al. (2004)	Denmark	Seroprevalence of *Salmonella* in swine (n = 56) raised outdoors under organic conditions was greater than *Salmonella* seroprevalence in swine grown indoors under conventional conditions.	*Salmonella*	Farm (feces, wildlife, environment)

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Kijlstra et al. (2004)	The Netherlands	None of 621 swine on 30 conventional farms were *Toxoplasma gondii*–positive compared with 3% (38/1295) of swine raised on an animal-friendly swine farm (13 farms of which 39% were positive).	*T. gondii*	Slaughter (blood)
Meerburg et al. (2006)	The Netherlands	Approximately 3% (85/2796) of organically raised swine were *T. gondii*–positive. 54% (22/41) of the organic farms were contaminated.	*T. gondii*	Slaughter
Miranda et al. (2008b)	Spain	The prevalence of *Escherichia coli* on pork (47.8%, 33/67) from pigs conventionally raised was significantly less than on pork (64.8%, 35/54) from pigs organically raised.	*E. coli*	Retail (carcass)
Nowak et al. (2006)	Germany	*Yersinia enterocolitica* contamination was significantly higher in conventionally raised swine (n = 210) compared to alternative (organically) raised swine (n = 200), with *Y. enterocolitica* detected in tonsils (22% versus 11%), cecum (11% versus 5%), and lymph nodes (7% versus 2%).	*Y. enterocolitica*	Slaughter (tonsils, caecum, cecal lymph node)
Thakur & Gebreyes (2005)	United States	*C. coli* prevalence was significantly higher in swine at antimicrobial-free pig nursery farms (77.3%, n = 120) than in swine raised at conventional farms (27.6%, n = 90). At swine finishing farms, there was no significant difference in the prevalence of *C. coli* (53%, n = 240, for antimicrobial-free farms and 55.8%, n = 180, for conventional farms).	*C. coli*	Farm (feces) and slaughter (carcass)
Van der Giessen et al. (2007)	The Netherlands	*T. gondii* infection rates varied from 0.38% (1/265) for intensively raised swine, to 2.7% (11/402) for organically and 5.6% (10/178) for free-range-raised pigs. At the farm level, only 4% (1/24) of the intensive farm-raised swine were infected compared with 25% (10/40) and 33% (3/9) of those raised in organic and free-range farms, respectively.	*T. gondii*	Slaughter (blood samples)
Zheng et al. (2007)	Denmark	There were no significant differences in *Salmonella*-seropositive swine grown under organic, outdoor (nonorganic) or indoor conditions on farms (total farms = 34).	*Salmonella*	Slaughter (meat samples)

Table 4 Foodborne pathogen prevalence in organically and conventionally raised beef during production

Author	Country	Key findings	Bacteria investigated	Sample point and (type of sample)
Miranda et al. (2009)	Spain	There were no significant differences in the prevalence of *Escherichia coli* (43%, 32/75 versus 48%, 36/75), *Staphylococcus aureus* (55%, 41/75 versus 51%, 38/75), *Listeria monocytogenes* (29%, 22/75 versus 36%, 27/75) and *Salmonella* spp. (0/75 versus 0/75) between conventionally (n = 75) and certified organic–raised beef cattle (n = 75).	*E. coli*, *S. aureus*, *L. monocytogenes*, *Salmonella* spp.	Retail (steak)
Reinstein et al. (2009)	United States	*E. coli* O157:H7 prevalence in USDA-certified organic- and naturally raised cattle was 14.8% (n = 553) and 14.2% (n = 506), respectively, and was similar to the prevalence of *E. coli* O157:H7 in conventionally raised cattle (11.2%, n = 322).	*E. coli*	Slaughter (fecal samples and rectoanal mucosal swabs)

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rodent droppings, and other potential carriers of *Salmonella*. Consequently, consumers should not assume that chickens labelled as organic, free range, or all natural are less contaminated with *Salmonella* than conventionally raised chickens. This is partially due to the fact that chicks raised on organic and pasture/free-range farms are typically purchased from conventional hatcheries. It is well-documented that hatcheries can be one of the main sources for *Salmonella* contamination of newly hatched chicks (Cox et al. 1990; Bailey et al. 1992, 1994; Cox et al. 1997).

The prevalence of *Campylobacter* in organic and conventional poultry production systems has been documented in a number of studies (**Table 2**). On-farm, *Campylobacter* prevalence has been determined at organically raised and pasture-raised poultry farms without a conventional poultry farm as a comparison group (Hoogenboom et al. 2008, Luangtongkum et al. 2008, Esteban et al. 2008, Colles et al. 2008, Hanning et al. 2010). The overall prevalence was high, ranging from 61% to 90.4%, except for the study by Hanning et al. (2010) in which *Campylobacter* prevalence was 30%. Variations in seasons, hatchery sources, feed composition, vaccination programs, flock-disease status, breeds, and intervention strategies may be factors that influenced the variation in *Campylobacter* prevalence.

At the processing stage, *Campylobacter* was isolated at higher frequencies in cecal and intestinal contents from pasture/free-range birds and organically raised birds compared with the respective *Campylobacter* prevalence at the farm. Avrain et al. (2003) determined that 80% of cecal samples collected from free-range birds were positive for *Campylobacter* compared with 57% of conventionally reared birds. Other studies consistently reported high prevalences of *Campylobacter* (100%) in cecal/intestinal contents of pasture-raised birds (Hanning et al. 2010) and cecal/intestinal contents of organically raised birds [89% and 100% by Luangtongkum et al. (2006) and Luangtongkum et al. (2008), respectively]. Furthermore, Heuer et al. (2001) determined that 100% of cloacal swabs of organic broiler flocks and 37% of conventional broiler flocks at the slaughterhouse were contaminated with *Campylobacter*; however, 96% of chicken carcasses rinsed and tested for *Campylobacter* at the processing plant were positive.

At retail, Hanning et al. (2010) determined that 75% of pasture-raised chickens were *Campylobacter*-positive. In the other two studies that compared *Campylobacter* prevalence between organic and conventional broiler carcasses at retail, Cui et al. (2005) reported a slightly higher prevalence on organic (76%) than on conventional (74%) carcasses, whereas Soonthornchaikul et al. (2006) determined 80% of organic chickens were *Campylobacter*-positive. Studies conducted in Spain compared contamination prevalence of other foodborne pathogens and indicator microbes on organically raised and conventionally raised chickens. The contamination percentages of *Enterococcus* (Miranda et al. 2007), *E. coli* (Miranda et al. 2008c) and Enterobacteriaceae (Miranda et al. 2008a) were higher on organic chickens, but no difference in contamination was detected for *Staphylococcus aureus* and *Listeria monocytogenes* (Miranda et al. 2008c).

Pork. Results of studies on organically raised swine are similar to those for organically raised poultry. Organic swine often have either a higher prevalence of the different pathogens or no differences compared with conventional swine (**Table 3**). Thakur & Gebreyes (2005) reported a significantly higher prevalence of *Campylobacter coli* in pigs grown under antimicrobial-free conditions than in conventionally grown pigs at nursery farms (77% versus 28%). However, no significant differences were detected at the finishing farms (53% versus 56%), which may indicate that the absence of antimicrobials does not influence the final *Campylobacter* contamination. However, pigs raised organically also have outdoor access, which may present a higher risk for pathogen contamination. Another study of *Campylobacter* in swine on organic farms revealed *Campylobacter jejuni* in 29% of the pigs for three consecutive trials. However, *C. coli* was present in levels ranging from 0.3% to 46% (Jensen et al. 2006). Environmental samples from this study revealed contamination levels of 10% *C. jejuni* and 29% *C. coli*. Miranda et al. (2008b) observed a significantly higher prevalence of *E. coli* on organic (65%) than on conventional pork (48%) at retail. *Yersinia enterocolitica* contamination was also reported to be lower for pigs grown in alternative housing systems than for conventionally raised pigs (Nowak et al. 2006).

Some studies revealed differences in *Salmonella* prevalence in swine between production systems. For example, Gebreyes et al. (2006) reported significantly higher prevalence of *Salmonella* in swine grown under antimicrobial-free conditions than in conventionally raised swine both at the farm as well as at the slaughter plant (15% versus 4% at the farm and 15% versus 7% at slaughter). Similarly, Jensen et al. (2004) reported a higher *Salmonella* seroprevalence in pigs raised outdoors. Likewise, Gebreyes et al. (2008) reported a seroprevalence of 54% in pigs raised outdoors in antimicrobial-free conditions compared with 39% in pigs reared conventionally indoors. Other studies, however, have revealed no differences in *Salmonella* prevalence based on production systems. In a study from the Netherlands, the *Salmonella* prevalence in swine grown on organic farms was 27%, which was concluded to be similar to that in swine grown on conventional farms (Hoogenboom et al. 2008). Zheng et al. (2007) determined no significant differences in *Salmonella* prevalence in swine grown under organic, outdoor-nonorganic, and indoor conditions.

There are different potential risk factors for *Salmonella* infections in organic and conventional production systems (Zheng et al. 2007). An initial factor is the introduction of *Salmonella* to the herd. This might be as a result of the purchase of a pig infected with *Salmonella* that is introduced into the herd, stress caused by transportation resulting in increased *Salmonella* shedding rates, or contact with the environment (contamined equipment, direct contact with rodents, wild birds, or cats, or fecal contamination). A second risk factor is horizontal transmission of *Salmonella* among pigs, which could be influenced by the floor type, bedding material, pen separation, herd size, stocking density, water supply, mixing of pigs resulting in increased stress, cleaning of the pens, disinfection of pens, and presence of foodborne pathogens on caretaker boots. A third factor is the survival and proliferation of *Salmonella* in a pig's gastrointestinal system. Although pigs with outdoor access have a higher exposure to the environment, Zheng et al. (2007) reported that the risk for acquiring *Salmonella* infections from outdoor exposure may be counteracted by differences

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in feeding practices, hygiene, and management. In their study, the risk for acquiring *Salmonella* infections was mostly attributed to the introduction of *Salmonella* by purchasing infected pigs that were added to the herd and by transporting the pigs, which causes stress and can induce higher rates of *Salmonella* shedding.

Another microbial safety hazard for animals raised with outdoor access is the greater potential for parasitic infections due to contact with the environment compared with animals raised in confinement. Parasitic infections caused by *Toxoplasma* (Gebreyes et al. 2008, Meerburg et al. 2006, Kijlstra et al. 2004) and *Trichinella* (Gebreyes et al. 2008, van der Giessen et al. 2007) in organic pig production have been addressed from a food safety perspective. *Toxoplasma* can cause toxoplasmosis, one of the leading causes of death due to foodborne illnesses in the United States (Centers for Disease Control 2010a). Meerburg et al. (2006) reported that 3% of the organic pigs were infected with *Toxoplasma gondii* and that the risk for *T. gondii* infections in organic pigs can be reduced by applying good agricultural practices during production, including limiting the number of cats on the farm because they serve as hosts for *T. gondii*. In a comparative study between pigs raised in intensive conventional, organic, and free-range housing systems, 0.38%, 2.7%, and 5.6%, respectively, of the pigs were infected with *T. gondii*, indicating that outdoor farming results in greater opportunities for parasitic infections (van der Giessen et al. 2007). Similarly, Kijlstra et al. (2004) determined that all of the 621 conventionally indoor-raised pigs were free of *T. gondii*, whereas 3% of 1,295 alternatively raised pigs were infected. Gebreyes et al. (2008) also reported significant differences, with 7% of pigs raised outdoors and antimicrobial free being *Toxoplasma* seropositive and only 1% of the pigs raised intensively indoors were *Toxoplasma*-positive. The two pigs seropositive for *Trichinella* were from the outdoor, antimicrobial-free farm (Gebreyes et al. 2008). Although the infection levels are small, it shows that pigs raised with outdoor access have a potentially higher prevalence of parasitic infections. However, pigs raised organically on many of the farms were not infected, which illustrates that it is possible to control parasitic infections at the farm level, even for pigs raised with outdoor access.

Beef. Results of studies on the prevalence of foodborne pathogens in organically and naturally raised cattle are presented in **Table 4**. There are only limited data on the prevalence of pathogens in cattle raised under organic or natural conditions for meat. Reinstein et al. (2009) reported *E. coli* contamination at slaughter in USDA-certified organically (14.8%) and naturally raised (14.2%) cattle similar to those previously reported for conventionally raised cattle (11.2%). Likewise, Miranda et al. (2009) did not detect any significant differences of *E. coli* prevalence in conventionally (43%) and organically (48%) raised beef at retail. Miranda et al. (2009) also found no significant differences in *S. aureus* (55% versus 51%), *L. monocytogenes* (29% versus 36%) and *Salmonella* spp. (0% for both) contamination on organically and conventionally raised beef. Given the lack of data comparing food safety issues in conventional and alternative beef production, results from more studies are needed before definitive conclusions can be made regarding food safety in organic beef.

Antimicrobial Resistance of Bacterial Pathogens

Antibiotic resistance of bacterial pathogens, as well as commensal bacteria, is an issue that has become the subject of ongoing debate in public forums. A key comparison is conventional versus organic in which organic production systems represent the potential baseline for animal systems where antimicrobial agents that are considered to be banned are not used. Hence, antimicrobial resistance data from organic systems are useful for assessing the potential impact of antimicrobial removal in conventional systems. Therefore, in this section, the prevalence of antimicrobial-resistant organisms in organic and conventional meat production systems is compared. Different

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terms are used with respect to antimicrobials, and the terminology used here is based on definitions from the Centers for Disease Control and Prevention (Centers for Disease Control 2010b). An antimicrobial agent is defined as "a general term for the drugs, chemicals, or other substances that either kill or slow the growth of microbes" (Centers for Disease Control 2010c). An antibiotic is defined as "a type of antimicrobial agent made from a mold or a bacterium that kills, or slows, the growth of other microbes, specifically bacteria" (Centers for Disease Control 2010c). From these definitions, it is clear that all antibiotics are antimicrobials but not all antimicrobials are antibiotics. In this section, the term antibiotics is used when appropriate to specify a particular group of antimicrobial agents.

The major concern with the use of antimicrobial agents for food animals is not so much the possibility of residues in the food products but the potential for the emergence, development, and spread of drug-resistant commensals and pathogens to humans. Antibiotics in livestock production can be used for different reasons. When administered at subtherapeutic (low) levels, they can be used as (*a*) growth promoters to enhance performance and weight gain and (*b*) preventative therapeutic agents, where antimicrobial agents are supplemented in feed given to healthy animals to prevent disease. This subtherapeutic antimicrobial use in livestock production accounts for 90% of the total antibiotics for animals (Tikofsky et al. 2003). In addition, antibiotics at higher levels (i.e., therapeutic level) are used to treat diseased animals. An estimated 28.8 million pounds of antimicrobial agents were sold/distributed for nontherapeutic and therapeutic purposes in the United States (Food and Drug Administration 2009).

USDA national organic livestock production prohibits the use of antimicrobial agents (USDA NOP 2010). Multiple alternatives for antibiotics exist, such as wider use of vaccines, probiotics along with improved management practices including strict disease control, good sanitation, and biosecurity (McEwen & Fedorka-Cray 2002). It is known that the extensive use of antibiotics to treat non-life-threatening problems in humans as well as animals has accelerated the evolution of antibiotic-resistant pathogens (Aarestrup 1999). The use of antibiotics can select for resistance among pathogens causing an increased risk of treatment failures (Aarestrup 1999). In addition, the use of antibiotics may select for resistance genes in nonpathogens, which may transfer resistance to pathogens. The restricted use of antibiotics in organic livestock production may reduce the risk of development of antibiotic resistance in bacteria and thus may contribute to the effectiveness of antibiotics for human or animal treatments (Hansen et al. 2002, Aarestrup 1999, Hamer & Gill 2002, Magkos et al. 2006, Mathews et al. 2001, Gold 2008).

Poultry. Although antimicrobial use is prohibited in organic poultry production and limited in pasture poultry production, several studies have revealed that pathogenic and nonpathogenic bacteria harbor drug resistance traits (Alali et al. 2010, Avrain et al. 2003, Cui et al. 2005, Heuer et al. 2001, Lestari et al. 2009, Luangtongkum et al. 2006, Miranda et al. 2007, Miranda et al. 2008a, Miranda et al. 2008c, Siemon et al. 2007, Soonthornchaikul et al. 2006, Han et al. 2009, Melendez et al. 2010). However, the degree of resistance (number of antimicrobial agents to which the microbes were resistant) varied, especially when compared with isolates from conventionally grown poultry (**Table 5**). Some studies reported lower prevalence of antimicrobial-resistant bacteria on meat from organic and pasture-grown poultry (Cui et al. 2005, Lestari et al. 2009, Soonthornchaikul et al. 2006, Han et al. 2009) at processing and on farms (Avrain et al. 2003, Luangtongkum et al. 2006, Alali et al. 2010, Siemon et al. 2007) compared with conventionally grown poultry. However, Heuer et al. (2001) determined there was no significant difference in the prevalence of antimicrobial-resistant *Campylobacter* on meat from either organically or conventionally grown birds. Variations in antimicrobial resistance results by pathogen can be a function of differences in antimicrobial susceptibility testing methods (broth dilution versus disk diffusion), the standards

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Table 5 Antibiotic resistance of bacteria from organically and conventionally raised poultry during production

Author	Country	Key findings
Alali et al. (2010)	United States	Higher prevalence of multidrug resistance in *Salmonella* isolates from conventional broiler farms than isolates from USDA-certified organic farms.
Avrain et al. (2003)	France	More resistance to tetracycline in *Campylobacter* isolates from commercial and export broilers than isolates from poultry raised under free-range conditions.
Cui et al. (2005)	United States	Most (80%) *Salmonella* Typhimurium isolates from organically raised chickens were susceptible to 17 antimicrobials tested, whereas all *Salmonella* Typhimurium isolates from conventional chickens were resistant to at least five antimicrobials. A significant difference in ciprofloxacin resistance was observed in *Campylobacter* isolates from organically (less than 5% was resistant) and conventionally raised chickens (20% was resistant).
Han et al. (2009)	United States	Higher prevalence of *Campylobacter* isolates resistant to erythromycin (8.5%) and ciprofloxacin (23.9%) from conventionally raised chickens than organically raised chickens (0%, and 10.4%, respectively).
Heuer et al. (2001)	Denmark	No difference in antibiotic susceptibility patterns of *Campylobacter* isolates from chickens raised under organic, conventional, or extensive indoor systems. Most *Campylobacter* isolates (>90%) from the organically and conventionally raised flocks, neither of which used antibiotics for growth promotion, were susceptible to antimicrobials.
Lestari et al. (2009)	United States	*Salmonella* Kentucky isolates from organically raised chickens were susceptible to 11 of the antimicrobials tested, whereas those from conventionally raised chickens were only susceptible to four antimicrobials.
Luangtongkum et al. (2006)	United States	Less than 2% of the *Campylobacter* isolates from organically raised poultry were resistant to fluoroquinolones (important antibiotics for human health), in contrast to 46% and 67% of conventionally raised broilers and turkeys, respectively. A greater resistance was observed when erythromycin, clindamycin, kanamycin, or ampicillin was used in conventionally raised turkeys.
Miranda et al. (2007)	Spain	*Enterococcus* isolates from organically raised chickens were less resistant to ampicillin, chloramphenicol, doxycycline, ciprofloxacin, erythromycin, and vancomycin than isolates from conventional chickens. Significantly more multidrug-resistant strains were from conventionally raised chickens and turkeys than organically raised chickens.
Miranda et al. (2008a)	Spain	Enterobacteriaceae isolates from organically raised chickens were less resistant to ampicillin, chloramphenicol, doxycycline, ciprofloxacin, gentamicin, and sulfisoxazole than those from conventionally raised chickens. Multidrug-resistant isolates were present in each group but were higher in conventionally raised turkeys (57%) and chickens (63%) than in organically raised chickens (42%).
Miranda et al. (2008c)	Spain	For 7 of 10 antimicrobials tested, *E. coli* isolates from organically raised poultry were less resistant to antibiotics than those from conventionally raised poultry. *S. aureus* and *L. monocytogenes* isolates from organic poultry were less resistant to doxycycline only.
Siemon et al. (2007)	United States	5% of the *Salmonella* isolates from pasture-reared chickens were resistant to ceftriaxone, whereas none from conventionally raised flocks were ceftriaxone-resistant. Multidrug-resistant (resistance to three or more classes of antimicrobials) *Salmonella* were in 69% of isolates from conventional farms, but only 11% of isolates were from pasture farms in the Southeast.
Soonthornchaikul et al. (2006)	United Kingdom	All *Campylobacter* from prepackaged organically, prepackaged conventionally and unpackaged conventionally raised chickens (at retail) were resistant to erythromycin and nalidixic acid. 27% of *Campylobacter* from unpackaged conventionally raised, 9% from the prepackaged conventionally raised and none from organically raised chickens were resistant to ciprofloxacin.

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(e.g., Clinical and Laboratory Standards Institute, European Union epidemiologic cut-offs) used to interpret the findings of the susceptibility/resistance assays, and the culture methods used for the isolates (bacterial cells may or may not express their resistance genes outside of the host environment). *Enterococcus* (Miranda et al. 2007), Enterobacteriaceae (Miranda et al. 2008a), and *E. coli*, *S. aureus*, and *L. monocytogenes* isolates (Miranda et al. 2008c) from organically raised poultry were less multidrug resistant than those from conventionally raised poultry (**Table 5**).

For sanitation and biosecurity reasons, Fanatico (2008) has suggested limiting visitors to the bird production area, maintaining dry conditions, incorporating a footbath with an approved disinfectant (such as iodine), and no mixing of species or of birds of various ages to reduce the chance of the spread of diseases in organic poultry production.

Pork. For livestock production other than poultry, similar results for acquisition of antimicrobial resistance have been reported (**Table 6**). Miranda et al. (2008b) used *E. coli* to evaluate the development of antimicrobial resistance because of its high frequency of mutation compared with other microorganisms commonly found in foods. Significantly less antimicrobial-resistant (ampicillin, doxycycline, sulfisoxazole) *E. coli* developed in organically produced pork compared with conventionally produced pork. In addition, no development of antimicrobial resistance was observed for those antimicrobial agents currently banned in the pork industry, which according to Miranda et al. (2008b) supports the theory that the development of antimicrobial resistance is correlated with the use of antibiotics in farming. The study revealed a higher prevalence of *E. coli* in swine grown under organic conditions; however, these isolates were more sensitive to several antimicrobials compared with swine raised under conventional conditions. Bunner et al. (2007) evaluated the

Table 6 Antibiotic resistance of bacteria from organically and conventionally raised swine

Author	Country	Key findings
Bunner et al. (2007)	United States	*Escherichia coli* from farms of conventionally raised pigs had significantly higher levels of resistance to ampicillin, sulfamethoxazole, tetracycline, and chloramphenicol than *E. coli* from farms of antimicrobial-free-raised pigs.
Gebreyes et al. (2006)	United States	Frequency of *Salmonella* resistant to most classes of antimicrobials (except tetracycline) was significantly higher in conventionally raised swine than in swine raised under antimicrobial-free conditions.
Mathews et al. (2001)	United States	*E. coli* isolates from swine herds that were not subject to antibiotics [antibiotic free (AF)] showed lower minimum inhibitory concentrations (MICs) for ampicillin, gentamicin, oxytetracycline, and sulfamethazine than *E. coli* isolates from swine receiving antibiotics (RA). MICs of oxytetracycline and ceftiofur were greater for *Salmonella* from RA herds than AF herds.
Miranda et al. (2008b)	Spain	*E. coli* isolates from pork produced under organic conditions had lower antimicrobial resistance to ampicillin, doxycycline, and sulfisoxazole than *E. coli* isolates from conventionally produced pork. Additionally, *E. coli* isolates from organic pork had significantly less multidrug resistance. In *E. coli* isolates from organically raised swine, 41% (combinations of at least two of these antimicrobials: ampicillin, doxycycline, and sulfisoxazole) were multidrug resistant compared with 90% for conventionally raised swine. There were no significant differences in antimicrobial resistance for antimicrobial agents that are not used in the pork industry.
Thakur & Gebreyes (2005)	United States	*Campylobacter coli* isolates from conventionally raised pigs were more resistant to tetracycline (83.4%) and erythromycin (77%) than pigs grown under antimicrobial-free conditions (56.2% for tetracycline and 34.5% for erythromycin).

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resistance to 14 different antimicrobials and reported significantly higher antimicrobial resistance for ampicillin, sulfamethoxazole, tetracycline, and chloramphenicol in *E. coli* in conventionally grown pigs compared with *E. coli* in swine grown on antimicrobial-free farms. Similarly, Mathews et al. (2001) detected significantly fewer *E. coli* isolates resistant to ampicillin, gentamicin, oxytetracycline, and sulfamethazine as well as significantly lower minimum inhibitory concentrations (MICs) for these four antimicrobials in swine herds not receiving antibiotics compared with swine that had received these agents.

According to Mathews et al. (2001), the differences in antimicrobial resistance between herds raised at antibiotic-free farms and those subjected to antibiotic use is greater for *E. coli* than *Salmonella*. The resistance patterns of *E. coli* appear to be more affected by antibiotic use than the resistance patterns of *Salmonella*. Gebreyes et al. (2006) observed a significantly higher frequency of antimicrobial resistance to most classes of antimicrobials (except tetracycline) for *Salmonella* isolates from swine grown on conventional farms than from swine grown on antimicrobial-free farms. However, antimicrobial resistance patterns, as well as multidrug resistance, were also commonly detected in swine herds raised under antimicrobial-free conditions (Gebreyes et al. 2006). Thakur & Gebreyes (2005) studied *Campylobacter* in swine grown under antimicrobial-free and conventional conditions. A high prevalence of antimicrobial-resistant *C. coli* was detected in swine grown in both systems; however, there were differences in antimicrobial resistance profiles between the two production systems. Of the six antimicrobials (chloramphenicol, ciprofloxacin, erythromycin, gentamicin, nalidixic acid, and tetracycline) tested, there were more *C. coli* isolates resistant to tetracycline and erythromycin grown in conventional (83% for tetracycline and 77% for erythromycin) than antimicrobial-free systems (56% for tetracycline and 35% for erythromycin). *C. coli* isolated from conventional systems (farm and slaughter; 94.8%) exhibited significantly more often single and multidrug resistance compared with isolates from an antimicrobial-free system (67%) (Thakur & Gebreyes 2005).

As illustrated by the studies cited above, exclusion of antibiotics does not eliminate the occurrence of antibiotic-resistant microbes because even in swine grown on antibiotic-free or organic farms, *Campylobacter* isolates are resistant to antimicrobials. Results suggest, however, that restrictions on the use of antibiotics may reduce the occurrence of antibiotic-resistant microbes in swine (**Table 6**). The high prevalence of antimicrobial-resistant isolates in pigs from antimicrobial-free systems reveals that even though direct antimicrobial use plays a role in the development and transmission of resistant microorganisms, environmental factors also have an effect (Thakur & Gebreyes 2005).

Beef. Limited studies comparing the prevalence of antimicrobial resistant microbes in beef grown under conventional and alternative production conditions have been reported (**Table 7**). Reinstein et al. (2009) reported there were "no major differences in antibiotic susceptibility patterns" of *E. coli* isolates among organically, naturally, and conventionally raised cattle. However, MICs for 12 of the 33 antibiotics were significantly different. The MICs of gentamicin and neomycin were higher for conventionally raised cattle and the MICs for nine other antibiotics (amikacin, apramycin, cefoxitin, ceftriaxone, kanamycin, nalidixic acid, penicillin, rifampin, and tetracycline) were lower for conventionally raised cattle than for naturally or organically raised cattle (Reinstein et al. 2009).

Miranda et al. (2009) studied the antimicrobial resistance of *E. coli*, *S. aureus*, and *L. monocytogenes* in beef production. Although no significant differences in prevalence of *E. coli*, *S. aureus*, and *L. monocytogenes* were detected, significant differences were observed in antimicrobial resistance to 5 of the 11 antimicrobials for *E. coli* isolates from conventional beef compared with organic beef. Ampicillin, doxycycline, gentamicin, and sulfisoxazole resistance were significantly higher in

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Table 7 Comparison of antibiotic resistance in organic and conventional cattle production

Author	Country	Key findings
Miranda et al. (2009)	Spain	*Listeria monocytogenes* isolates did not have resistance differences. There were no significant differences in multidrug-resistant isolates from organically and conventionally raised beef: *Escherichia coli* (66% versus 57%), *Staphylococcus aureus* (56% versus 48%) or *L. monocytogenes* (7% versus 2%), respectively.
Reinstein et al. (2009)	United States	For 7 of the 33 antibiotics tested, no *E. coli* isolates from the three different production systems (conventional, natural, organic) were susceptible. For 12 of 33 antibiotics tested, there were significant differences: (*a*) minimum inhibitory concentrations (MICs) of two antibiotics (gentamicin and neomycin) were higher for conventionally raised cattle; (*b*) MICs for nine other antibiotics (amikacin, apramycin, cefoxitin, ceftriaxone, kanamycin, nalidixic acid, penicillin, rifampin, and tetracycline) were lower for conventionally raised cattle than for naturally or organically raised cattle.

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E. coli isolates from conventional beef, whereas ciprofloxacin resistance was significantly higher in *E. coli* from organic beef. Three of the eleven antimicrobials had significant differences in antimicrobial resistance for *S. aureus* isolated from conventional meat. Ciprofloxacin and doxycycline resistance were higher in *E. coli* isolates from conventional beef and gentamicin was higher in *E. coli* from organic beef. For *L. monocytogenes*, no significant differences in antimicrobial resistance for 11 antimicrobials were detected for *E. coli* isolates from conventional and organic beef.

Chemical Residues and Additives

Chemical residues ending up in meat products results from these residues being present in animal feeds (synthetic pesticides, herbicides, fertilizers, and fungicides) or by the addition of drugs, antibiotics, or hormones given to the animals (Kouba 2003). In organic livestock production, however, only 100% organic feed is used and the routine use of veterinary drugs is prohibited (USDA-NOP 2010).

Animal feed and human foods. Organically raised animals can only be fed organic feed that has not been treated with pesticides. Without proper control, unsafe pesticide residues in food can create potential health risks. Organic foods are not necessarily free from pesticides and other synthetic chemicals, but they generally have lower levels of agrochemical residues than conventionally produced alternatives, as the use of artificial fertilizers and pesticides is prohibited in organic farming (Kouba 2003, Williamson 2007). Results of most studies have revealed that organic foods have significantly fewer pesticide residues than foods grown under conventional conditions. Winter & Davis (2006) summarized results from different pesticides in food monitoring programs, including the Pesticide Data Program of the USDA (pesticide residues in 73% of conventional and 23% of organic produce), the Marketplace Surveillance Program of the California Department of Pesticide Regulation (pesticide residues in 31% of conventional and 6.5% of organic produce), and private tests by the Consumers Union (pesticide residues in 79% of conventional and 27% of organic produce), an independent testing organization. These results reveal that detectable pesticide residue contamination of organically produced foods is generally less than that in foods produced under conventional conditions.

It is, however, not clear if these differences are significant because the pesticide residue concentration in foods from both production systems is typically very low. The vast majority of detected pesticide residues in both conventionally raised and organically raised foods are at concentrations

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that are considerably less than the acceptable government-defined thresholds for safe consumption. There is no evidence that the permitted levels of agrochemicals used in conventional farming are harmful. Therefore, the typical exposure to pesticide residues in food should not be considered a safety concern for consumers (Magkos et al. 2003, Bourn & Prescott 2002, Gold 2008, Kouba 2003, Williamson 2007). Winter & Davis (2006) concluded that the reduction of exposure to pesticides through food consumption by utilizing more organic foods would not be significant.

However, some issues have been raised regarding safe tolerance levels of pesticide residues in food. First, the Soil Association (2001), the United Kingdom's leading organic food association, is concerned about the accumulative effect of multiple exposures to pesticide residues in human diets. Secondly, it is not clear what the safe threshold levels of pesticide residues are in children and the unborn (Gold 2008). The National Academy of Sciences (National Research Council 1996) concluded that infants and children require special attention because they are probably more sensitive than adults to exposure to pesticide residues in foods.

Environmental pollutants are chemical contaminants, such as polychlorinated biphenyls, chlorinated hydrocarbons, and heavy metals, caused by environmental pollution. Those pollutants are equally present in organically and conventionally produced foods, and concentrations depend mostly on the farm location (Magkos et al. 2003, 2006). Environmental contaminants (pesticide residues, chemicals, heavy metals) may appear in animal feed, which can give rise to food safety hazards in foods of animal origin. For organic livestock, only organically produced feedstuffs are used, causing a potential lower contamination with pesticide residues and other agrochemicals. However, the potential for contamination of the feed with environmental pollutants is the same in both organic and conventional production systems (Magkos et al. 2003).

Drugs. The routine use of chemically synthesized drugs, such as antibiotics, growth hormones, and synthetic amino acids, to control and prevent disease outbreaks or to improve the growth and feed efficiency of animals is banned in organic livestock production but has been widely used in conventional production systems. The use of growth hormones in conventional livestock production is allowed for cattle in the United States. In contrast, the European Union does not allow the use of hormones in any livestock production (Gold 2008).

Vaccines and other therapeutic applications of synthetic medicines are restricted to the minimum possible use in organic livestock production (Food and Agriculture Organization/World Health Organization 2001). As a result of their restricted use, the levels of drug residues are expected to be lower in organically produced animal products (Hansen et al. 2002, Sundrum 2001). However, currently, there are few data available to enable a comparison of chemical residue levels in organic and conventional foods (Winter & Davis 2006). Furthermore, the chance of livestock drug residues remaining in the final food products and causing human illness has not been confirmed (Magkos et al. 2003). However, residues of pencillin that can cause allergies in pencillin-sensitive people have been confirmed in milk (Dewdney & Edwards 1984). In general, the active ingredients in drugs break down rapidly, and the time between the last treatment with the drug and slaughter is specified by the U.S. Food and Drug Administration, which mitigates the risk of contamination (Mathews et al. 2001). Therefore, the occurrence of drug residues in meat products is a minor concern, even in conventionally produced animal production.

Food Safety Issues Associated with the Use of Animal Byproducts in Feed

Bovine spongiform encephalopathy (BSE) (also known as mad cow disease) is an example of an animal disease that can cause Creutzfeldt-Jakob Disease (CJD) in humans. Consumer concerns about BSE have in part stimulated growth of organic meat production (Kouba 2003, Naspetti &

Zanoli 2009, Newton 2004). Animals can become infected with BSE by ingesting livestock feed containing BSE prion–contaminated animal proteins. Because organically produced animals are not fed animal (ruminant)-based proteins (waste animal meat or bone meal), these organic feeding practices offer protection against BSE in cattle and vCJD in humans (Kouba 2003).

CONCLUSION

Although there is increasing consumer interest in organically produced meat, conclusions on food safety benefits associated with organic meat production practices remain elusive. Based on current scientific evidence, the consumer perception that meats produced under organic and natural conditions are safer may not be justified. Additional research is needed to enable direct comparisons of the safety of meat products from the respective production systems. Furthermore, efforts are needed to improve the production practices of organically raised animals, with the specific purpose of reducing the food safety risks associated with the prevalence of foodborne pathogens in organically raised animals. Research should address more effective ways to reduce these risks, and training and implementation plans for livestock producers should be included. Preventing contact between foodborne pathogens and farm animals is more challenging in organic production conditions because the animals have outdoor access and hence are at higher risk for contact with potential sources of pathogens. Under such production conditions, it is not possible to avoid rodent and bird contact with farm animals; however, such exposures should be minimized as much as possible. For example, pest-proofing farm buildings, as well as preventing access to feed, water, and shelter might be beneficial (Meerburg et al. 2006).

Results of multiple studies (**Tables 5**–**7**) on the prevalence and antimicrobial resistance of foodborne pathogens in poultry, swine, and cattle reveal differences in pathogen contamination of these animals based on production conditions. In general, bacteria isolated from conventionally produced livestock or meats may have a higher likelihood of antimicrobial resistance compared with organically raised animals, and the use of antibiotics in food-producing animals may select for resistant bacteria. Theoretically, this may ultimately lead to problems in treatment with antibiotics of animal and human diseases (Aarestrup 1999). It is likely that preventing the development and spread of antimicrobial resistance in microbes associated with livestock and poultry production will increase in importance in the future. Most studies reveal that meat produced under organic conditions is more often contaminated with foodborne pathogens than meat from conventionally produced animals. However, the pathogens on organic meat are generally more sensitive to antimicrobial agents. Organic livestock production may have the advantage of limiting the development and spread of antimicrobial-resistant foodborne pathogens. However, even animals raised under antimicrobial-free conditions have multidrug-resistant pathogens, which may have a high prevalence of resistant contamination, which may indicate that both the use of antimicrobials and the environment play a role in the development and transmission of antimicrobial-resistant bacteria.

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