**Animal Board Invited review: Comparing conventional and organic livestock production systems on different aspects of sustainability**

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**Supplementary Table S6:** Reviewed studies comparing antibiotic resistance in organic and conventional livestock production

| Reference | Bacteria investigated | Antibiotic panel | Study country | Sample point | Sample type | # units/samples: conventional (organic) | Significantly higher ADR or MDR | Explanation observed differences |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| *Dairy cattle* |  |  |  |  |  |  |  |  |
| Bennedsgaard *et al.* (2006) | *Staphylococcus aureus* | Penicillin | Denmark | farm | quarter milk | 20 (18) farms, 493 (391) cows | no difference between prevalence | not mentioned |
| Berge *et al.* (2010) | *Escherichia coli* | Amikacin, amoxicillin–clavulanic acid, ampicillin, cefazolin, ceftiofur, chloramphenicol, gentamicin, nalidixic acid, streptomycin, sulfisoxazole, tetracycline, trimethoprim-sulfamethoxazole | USA (California, Oregon, Washington) | farm | fecal | 11 (7) farms, 607 (345) isolates | MDR conventional odds ratio 2.58 (p=0.02) | use of antimicrobials, genetically linked resistance to more antimicrobials |
| Bombyk *et al.* (2008) | *Staphylococcus* | Erythromycin, penicillin, pirlimycin, tetracycline | USA (Minnesota) | farm | milk from teat | 8 (8) farms, 339 (501) cows | conventional: less susceptible for pirlimycin, tetracycline (p<0.044) | mechanisms behind difference remains unclear (management practices) |
| Cho *et al.* (2006) | *Escherichia coli* O157 | Amikacin, amoxicillin–clavulanic acid, ampicillin, cefazolin, cefoxitin, ceftiofur, cephalothin, chloramphenicol, enrofloxacin, gentamicin, imipenem, orbifloxacin, spectinomycin, sulfadimethoxine, tetracycline, ticarcillin, ticarcillin–clavulanic acid, trimethoprim-sulfamethoxazole | USA (Minnesota) | farm | fecal | 18 (8) farms, 271 (166) fecal samples | no differences in resistance profiles of isolates | use of antimicrobials |
| Cho *et al.* (2007) | Shiga Toxigenic *Escherichia coli* | Amikacin, amoxicillin–clavulanic acid, ampicillin, cefazolin, cefoxitin, ceftiofur, cephalothin, chloramphenicol, enrofloxacin, gentamicin, imipenem, orbifloxacin, spectinomycin, sulfadimethoxine, tetracycline, ticarcillin, ticarcillin–clavulanic acid, trimethoprim-sulfamethoxazole | USA (Minnesota) | farm | rectal fecal, milk filter | 20 (8) farms, 29 (23) isolates | conventional (spectomycin) (p<0.05)MDR no difference | unable to compare use of antimicrobials due to too few isolates |
| Cicconi-Hogan *et al.* (2014) | coagulase-negative staphylococci | Methicillin | USA (New York, Wisconsin, Oregon) | farm | bulk milk tank | 100 (192) farms, 100 (192) samples | no difference in farm prevalence | use of antimicrobials |
| Dolejska *et al.* (2011) | ESBL-producing *Escherichia coli* |  | Czech Republic | farm | rectal swap, milk filter | 1 (1) farms, 309 (154) rectal swaps, 2 (2) milk filters | Conventional: prevalence rectal swaps 39% (<1%) conventional 1 positive milk filter (0) | use of antimicrobials, farm management practices |
| Garmo *et al.* (2010) | *Staphylococcus aureus*, coagulase-negative staphylococci | Penicillin | Norway | farm | quarter milk | 25 (24) herds, 523 (487) cows | no difference between prevalence | late indoor season higher prevalence |
| Halbert *et al.* (2006a) | *Campylobacter* spp. | Azithromycin, chloramphenicol, ciprofloxacin, clindamycin, erythromycin, gentamicin, nalidixic acid, tetracycline | USA (Michigan, Minnesota, New York, Wisconsin) | farm | fecal, bulk milk tank, milk line, water source, feed bunks, housing | total 128 farms, 912 (304) isolates | conventional: more tetracycline resistant isolates (p<0.01) | no clear relation between use of antimicrobials and resistance patterns, contact with wildlife |
| Halbert *et al.* (2006b) | *Campylobacter* spp. | Amoxicillin-clavulanic acid, ampicillin, azithromycin, ceftiofur, ceftriaxone, cephalothin, chloramphenicol, ciprofloxacin, clindamycin, erythromycin, florfenicol, gentamicin, kanamycin, nalidixic acid, streptomycin, sulfamethoxazole, tetracycline, trimethoprim-sulfamethoxazole | USA (Michigan, Minnesota, New York, Wisconsin) | farm | fecal, bulk milk tank, milk line, water source, feed bunks, housing | total 128 farms, 1 570 (460) isolates | conventional: more tetracycline resistant isolates (p=0.007) | use of antimicrobials |
| Johnston (2002) | bacteria | Penicillin g | USA (Minnesota) | farm | fecal | 5 (5) farms, 30 (30) samples, 90 (90) isolates | no difference in minimum inhibitory concentration (p=0.147) | no difference, because different bacterial isolates and large standard deviation in MIC |
| McKinney *et al.* (2010) | genes (tet(O), tet(W), sul (I), sul(II)) | Tetracycline, sulfonamide | USA (west) | farm | manure lagoon | 2 (1) farms, 63 (87) samples | conventional: 4 concentration in water solubles higher (p<0.0212), 3 concentrations in settles solids higher (p<0.0236), sul(II) no difference | use of antimicrobials |
| Miranda *et al.* (2009a) | *Escherichia coli*, *Staphylococcus aureus* | Ampicillin, aztreonam, cephalotin, chloramphenicol, cyprofloxacin, doxycycline, fosfomycin, gentamicin, nitrofurantoin, streptomycin, sulfisoxazole | Spain | retail | Arzua-Ulloa pasteurized milk-cheese | 67 (60) samples | conventional: *E. coli*: ampicillin, streptomycin (p<0.05); *S. aureus*: cephalotin, fosfomycin, gentamicin, streptomycin (p<0.05)organic: *E. coli*: doxycycline (p<0.05); *S. aureus*: ampicillin, doxycycline, sulfisoxazole (p<0.05)MDR: no difference in resistance patterns | use of antimicrobials, contamination by environment and meat handlers |
| Ray *et al.* (2006) | *Salmonella* spp. | Amoxicillin-clavulanic acid, ampicillin, ceftriaxone, ceftiofur, cephalothin, chloramphenicol, ciprofloxacin, gentamicin, kanamycin, nalidixic acid, streptomycin, sulfamethoxazole, tetracycline, trimethoprim-sulfamethoxazole | USA (Michigan, Minnesota, New York, Wisconsin) | farm | bulk milk tank, fecal, floors, feed bunk, manure storage, bird droppings | 69 (26) farms | conventional: at least 1 streptomycin resistant isolate (odds ratio 7.5, p<0.05), conventional more isolates resistant to streptomycin (OR 5.4) and sulfamethoxazole (OR 4.2) (p<0.05) | use of antimicrobials, previous use before conversion to organic, cross-resistance, biocide use, movement of animals, people, vehicles, wildlife between herds; herd size |
| Roesch *et al.* (2006) | *Staphylococcus aureus*, nonaureus staphylococcus spp., *Streptococcus uberis*, *Streptococcus dysgalactiae* | Amoxicillin-clavulanic acid (2:1), ceftiofur, chloramphenicol, clindamycin, enrofloxacin, eryhtromycin, gentamicin, oxacillin, penicillin, quinupristin-dalfopristin, tertracycline, vancomycin | Switzerland | farm | quarter milk | 60 (60) farms, 487 (483) cows | no difference between prevalenceMDR no difference | no explanation why no difference |
| Sato *et al.* (2004a) | *Campylobacter* | Cyprofloxacin, gentamicin, eryhtromycin, tertracylcine | USA (Wisconsin) | farm | fecal | 30 (30) farms, 300 (300) samples | No evidence for difference in resistance | no evidence for use of antimicrobials as a reason |
| Sato *et al.* (2004b) | *Staphylococcus aureus* | Bacitracin, cephapirin, chloramphenicol, ciprofloxacin, erythromycin, gentamicin, kanamycin, oxacillin, penicillin, streptomycin, sulphamethoxazole, quinupristin/dalfopristin, tetracycline, trimethoprim, vancomycin | USA (Wisconsin) | farm | bulk milk tank | USA: 30 (30) neighbouring farms, 152 (179) isolates | conventional: higher probability reduced susceptibility ciprofloxacin (OR=3.33, p<0.05) | use of antimicrobials, conventional: relatively small farm size, many organic farms in neighbourhood could have changed their philosophy regarding antimicrobials use |
| Sato *et al.* (2004b) | *Staphylococcus aureus* | Avilamycin, bacitracin, cephapirin, chloramphenicol, ciprofloxacin, erythromycin, gentamicin, kanamycin, oxacillin, penicillin, streptomycin, sulphamethoxazole, quinupristin/dalfopristin, tetracycline, trimethoprim, vancomycin | Denmark | farm | bulk milk tank | Denmark 20 (20) farms, 77 (75) isolates | organic: higher probability reduced susceptibility avilamycin (OR=0.15, p<0.05) | use of antimicrobials |
| Sato *et al.* (2005) | *Escherichia coli* | Ampicillin, amoxicillin–clavulanic acid, cephalotin, cefoxitin, ceftiofur, ceftriaxone, streptomycin, kanamycin, gentamicin, apramycin, amikacin, chloramphenicol, tetracycline, sulfamethoxazole, trimethoprim-sulfamethoxazole, nalidixic acid, cyprofloxacin | USA (Wisconsin) | farm | rectal fecal | 30 (30) farms, 595 (596) samples | conventional: ampicillin (p<0.001), streptomycin (p=0.002), kanamycin (p<0.001), gentamicin (p=0.008), chloramphenicol (p=0.003), tetracycline (p<0.001), sulfamethoxazole (p=0.021)MDR cows no difference (p=0.434)MDR calves conventional (p<0.001) | use of antimicrobials, preservation of resistant strains for many years |
| Tikofsky *et al.* (2003) | *Staphylococcus aureus* | Ampicillin, cephalothin, erythromycin, novobiocin, oxacillin, penicillin, penicillin-novobiocin, pirlimycin, tetracycline, vancomycin | USA (New York, Vermont) | farm | milk from teat | 16 (22) farms, 117 (144) isolates | conventional: lower susceptibility ampicillin (p=0.0007), penicillin (p=0.0106), tetracycline (p=0.00003) | use of antimicrobials (little selection pressure), mechanisms of resistance in pathogens, population of pathogens, susceptibility of a strain |
| Walk *et al.* (2007) | *Escherichia coli* | Ampicillin, amoxicillin-clavulanic acid, cephalothin, cefoxitin, ceftiofur, ceftriaxone, streptomycin, kanamycin, gentamicin, apramycin, amikacin, tetracycline, sulfamethoxazole, trimethoprim-sulfamethoxazole, nalidixic acid, ciprofloxacin | USA (Wisconsin) | farm | fecal | 30 (30) matched farms, 300 (300) samples | MDR conventional: higher | use of antimicrobials |
|  |  |  |  |  |  |  |  |  |
| *Beef cattle* |  |  |  |  |  |  |  |  |
| Guarddon *et al.* (2014) | mesophillic aerobic bacteria, *Enterobacteriaceae* | Tetracycline | Spain | retail | chicken thighs | 30 (30) beef steaks | no difference in total tetracycline-resistant bacteria counts and bacteria harbouring tet(A), tet(B) or tet(A)+tet(B) | use of antimicrobials, higher than expected in organic production |
| Miranda *et al.* (2009b) | *Escherichia coli* | Ampicillin, aztreonam, cephalotin, chloramphenicol, doxycycline, ciprofloxacin, fosfomycin, gentamycin, nitrofurantoin, streptomycin, sulfisoxazole | ? Spain | retail | pre-packaged beef steaks | 75 (75) beef steaks | conventional: ampicillin 44.8% (36.6%) (p=0.0028), doxycycline 28.7% (17.2%) (p=0.0049), gentamycin 2.3% (1.1%) (p=0.0278), sulfisoxazole 62.1% (41.9%) (p=0.034)organic ciprofloxacin 7.5% (1.1%) (p=0.0382) | use of antimicrobials |
| Miranda *et al.* (2009b) | *Staphylococcus aureus* | Chloramphenicol, clindamycin, ciprofloxacin, doxycycline, erythromycin, gentamycin, penicillin, oxacillin, nitrofurantoin, rifampin, sulfisoxazole | ? Spain | retail | pre-packaged beef steaks | 75 (75) beef steaks | conventional: ciprofloxacin 20.8% (10.7%) (p=0.0014), doxycycline 16.7% (4.8%) (p=0.0093)organic: gentamycin 7.1% (0.0%) (p=0.0237) | use of antimicrobials |
| Miranda *et al.* (2009b) | *Listeria monocytogenes* | Cephalotin, chloramphenicol, doxycycline, enrofloxacin, erythromycin, gentamycin, rifampin, sulfisoxazole, vancomycin | ? Spain | retail | pre-packaged beef steaks | 75 (75) beef steaks | no difference | external factors as environment or (meat) handlers in chain |
|  |  |  |  |  |  |  |  |  |
| *Pigs* |  |  |  |  |  |  |  |  |
| Garcia-Migura *et al.* (2005) | vancomycin-resistant *Enterococcus faecium* | Nitrofurantoin, penicillin, tetracycline, erythromycin, ciprofloxacin, gentamicin, streptomycin, kanamycin, quinupristin-dalfospristin, vancomycin, teicoplanin, chloramphenicol, florfenicol, bacitracin, flavomycin, salinomycin | England, Wales | farm | fecal | 7 (5) farms | MDR: traits did not appear to be specific to individual farms or sample types | use of antimicrobials, insufficient cleaning and disinfection could have allowed for persistence of VREF, new contaminated stocks, environment (domestic or wild animals, feed, litter, water) |
| Guarddon *et al.* (2014) | mesophillic aerobic bacteria, *Enterobacteriaceae* | Tetracycline | Spain | retail | pork steaks | 40 (40) samples | no difference in total tetracycline-resistant bacteria countsconventional total count of bacteria harbouring tet(B) 3.2 log CFU/g (2.7) (p<0.05) | use of antimicrobials, higher than expected in organic production |
| Hoogenboom *et al.* (2008) | *Escherichia Coli, Enterococcus faecium, Campylobacter* spp. | Amoxicillin, cefotaxim, ciprofloxacin, chloramphenicol, gentamicin, neomycin, tertracycline, sulfamethooxazole, trimethoprim, nalidixic acid, florfenicol, linezolid, doxycycline, erythromycin, vancomycin, flavomycin, salinomycin, synercid, streptomycin, metronidazole, trimethoprim-sulfamethoxazole | Netherlands | farm | fecal | national data (31) farms, (155) samples | conventional: much higher incidence of antibiotic resistant bacteria | use of antimicrobials |
| Miranda *et al.* (2008a) | *Escherichia coli* | Ampicillin, cephalotin, chloramphenicol, doxycycline, enrofloxacin, gentamicin, nitrofurantoin, streptomycin, sulfisoxazole | Spain | retail | loin meat | 67 (54) samples | conventional: ampicillin (p<0.0001), oxycycline (p<0.0001), sulfisoxazole (p<0.0001)MDR conventional: resistance to ≥ two agents higher (p<0.0001) | use of antimicrobials |
| Nulsen *et al.* (2008) | *Escherichia coli* | Ampicillin, gentamicin, streptomycin, tetracycline, ciprofl oxacin, cotrimoxazole, neomycin | New Zealand (North Island) | farm | fecal | 3 (1) farms | ampicillin conventional 3%, organic 0%; ciprfloxacin conventional 0%, organic 0%; co-trimoxazole conventional 11%, organic 0%; Gentamicin conventional 1%, organic 0%; neomycin conventional 1%, organic 1%; streptomiycin conventional 25%, organic 3%; tetracycline conventional 60%, organic 5% | use of antimicrobials, introduction of breeding stock with antimicrobial use history |
| Nulsen *et al.* (2008) | *Enterococcus* spp. | Ampicillin, gentamicin, streptomycin, tetracycline, vancomycin, erythromycin, virginiamycin | New Zealand (North Island) | farm | fecal | 3 (1) farms | ampicillin conventional 0%, organic 0%; erythromycin conventional 69%, organic 1%; Gentamicin conventional 0%, organic 0%; streptomiycin conventional 54%, organic 0%; tetracycline conventional 67%, organic 5%; vancomycin conventional 0%, organic 0%; virginiamycin conventional 50%, organic 0% | use of antimicrobials, introduction of breeding stock with antimicrobial use history |
|  |  |  |  |  |  |  |  |  |
| *Broilers* |  |  |  |  |  |  |  |  |
| Alali *et al.* (2010) | *Salmonella* | Ampicillin, amoxicillin/clavulanic acid, amikacin, cefoxitin, ceftriaxone, ceftiofur, cephalothin, chloramphenicol, ciprofloxacin, gentamicin, kanamycin, nalidixic acid, streptomycin, sulfamethoxazole, tetracycline, trimethoprim/sulfamethoxazole | USA (North Carolina) | farm | fecal, feed, water | 4 (3) farms from same company, 240 (180) fecal samples, 80 (60) feed samples, 80 (60) water samples | conventional: Cefoxitin 55.2% of isolates resistant (8.3%) (p=0.004), Ceftiofur 53.5% (8.3%) (p=0.004), Streptomycin 91.4% (58.3%) (p=0.01), Sulfisoxazole 25.0% (1.72%) (p=0.014)organic: tetracycline 33.3% (6.9%) (p=0.025)MDR conventional ≥ two antibiotics 62% (41% organic), single antibiotic 36.2% (33.3%), pan susceptible 1.7% (25%) | use of antimicrobials |
| Álvarez-Fernández *et al.* (2013) | *Escherichia coli* | Gentamicin, ampicillin, amoxicillin-clavulanic acid, piperacillin-tazobactam, cefotaxime, sulphamethoxazole-trimethoprim, chloramphenicol, tetracycline, nalidixic acid, ciprofloxacin, fosfomycin, nitrofurantoin | Spain | retail | chicken carcasses | 30 (30) carcasses | conventional: resistance prevalence gentamicin 40.0% (org. 0.0%), ampicillin 100% (53.3%), amoxicillin-clavulanic acid 73.3% (20.0%), nalidixic acid 100.0% (40.0%)MDR conventional: average number of resistances per strain 5.20 (2.53) (p<0.05)ciprofloxacin 73.3% (26.7%) | use of antimicrobials, co-selection for resistance, exchange resistance genes between bacteria |
| Cohen Stuart *et al.* (2012) | ESBL producing bacteria |  | Netherlands | retail | chicken breast | 12 stores, 60 (38) samples | conventional: prevalence 100% (84% organic) (p<0.001); mean load 80 (20) (p=0.001); Co-resistance rate tetracycline 73% (46%) (p<0.001) | use of antimicrobials, colonized 1-day-old chicks, cross-contamination from conventional to organic during rearing or slaughter, or from environment (soil, surface water) |
| Cui *et al.* (2005) | *Campylobacter* spp. | Chloramphnicol, ciprofloxacin, erythrmycin, tertracycline | USA (Maryland) | retail | chicken carcasses | 3 (3) stores, 61 (198) carcasses | conventional: ciprofloxacin 20% (5%) (p<0.05) | not mentioned |
| Cui *et al.* (2005) | *Salmonella* spp. | Amikacin, amoxicillin-clavulanic acid, ampicillin, apramycin, ceftiofur, ceftriaxone, cephalothin, chloramphenicol, ciprofloxacin, florfenicol, gentamicin, kanamycin, nalidixic acid, streptomycin, sulfamethoxazole, tetracycline, trimethoprim-sulfamethoxazole | USA (Maryland) | retail | chicken carcasses | 3 (3) stores, 61 (198) carcasses | MDR conventional: S. Typhimurium 100% isolates resistant 5-7 antibiotics, organic 79% isolates susceptible to all antibiotics | not mentioned |
| Garcia-Migura *et al.* (2005) | vancomycin-resistant *Enterococcus faecium* | Nitrofurantoin, penicillin, tetracycline, erythromycin, ciprofloxacin, gentamicin, streptomycin, kanamycin, quinupristin-dalfospristin, vancomycin, teicoplanin, chloramphenicol, florfenicol, bacitracin, flavomycin, salinomycin | England, Wales | farm | fecal | 6 (7) farms | MDR: traits did not appear to be specific to individual farms or sample types | use of antimicrobials, insufficient cleaning and disinfection could have allowed for persistence of VREF, new contaminated stocks, environment (domestic or wild animals, feed, litter, water) |
| Guarddon *et al.* (2014) | mesophilic aerobic bacteria, *Enterobacteriaceae* | Tetracycline | Spain | retail | chicken thighs | 30 (30) thighs | no difference in total tetracycline-resistant bacteria countconventional: total count of bacteria harbouring tet(B) 2.8 log CFU/g (1.8) p<0.05) and tet(A)+tet(B) 3.3 log CFU/g (2.8) | use of antimicrobials |
| Han *et al.* (2009) | *Campylobacter* spp. | Ciprofloxacin, erythromycin, gentamicin, tetracycline | USA (Louisiana) | retail | chicken carcasses | 26 (1) stores, 141 (53) carcasses | conventional: ciprofloxacin (8.5% (0.0%) (p<0.05), erythromycin 23.9% (10.4%) (p<0.05) | use of antimicrobial, geographic region, chicken producer, environment |
| Heuer *et al.* (2001) | *Campylobacter* spp. | Tetracycline, ampicillin, erythromycin, enrofloxacin, streptomycin | Denmark | processing | cloacal swap | 79 (22) flocks, 790 (220) samples | antibiotic resistance scarce among isolates from all rearing systems | not established |
| Heuer *et al.* (2002) | vancomycin-resistant Enterococci | Vancomycin | Denmark | processing | cloacal swap | 24 (12) farms, 140 (22) flocks | conventional: 74.3% flock prevalence (9.1%) (p<0.0001) | use of antimicrobials, persistence in environment |
| Hoogenboom *et al.* (2008) | *Escherichia Coli, Enterococcus faecium, Campylobacter* spp. | Amoxicillin, cefotaxim, ciprofloxacin, chloramphenicol, gentamicin, neomycin, tertracycline, sulfamethooxazole, trimethoprim, nalidixic acid, florfenicol, linezolid, doxycycline, erythromycin, vancomycin, flavomycin, salinomycin, synercid, streptomycin, metronidazole, trimethoprim-sulfamethoxazole | Netherlands | farm | fecal | national data (9) farms, (45) samples | conventional: much higher incidence of antibiotic resistant E. coli and E. faeciumno difference Campylobacter | absence of selection pressure in organic animals (no use of antimicrobials) |
| Kola *et al.* (2012) | ESBL |  | Germany | retail | chicken breast and leg | 9 supermarkets, (4 organic food stores), 1 butcher | no difference | use of antimicrobials, colonized 1-day-old chicks, cross-contamination from conventional to organic during rearing or slaughter, or from environment |
| Lestari *et al.* (2009) | *Salmonella* spp. | Amikacin, amoxicillin–clavulanic acid, ampicillin, cefoxitin, ceftiofur, ceftriaxone, chloramphenicol, ciprofloxacin, gentamicin, kanamycin, nalidixic acid, streptomycin, sulfisoxazole, tetracycline, trimethoprim-sulfamethoxazole | USA (Louisiana) | retail | chicken carcasses | 26 (1) stores, 141 (53) carcasses | conventional: amoxicillin-clavulanic acid 19.4% (9.1%) (p<0.05), cefoxitin 19.4% (9.1%) (p<0.05)organic: streptomycin 66.7% (46.2%) (p<0.05), tetracycline 63.6% (41.9%) (p<0.05)MDR conventional 48.2% (33.3%) isolates susceptible to all antibiotics | transfer of resistant genes to other serovars |
| Luangtongkum *et al.* (2006) | *Campylobacter* spp. | Ampicillin, tetracycline, gentamicin, kanamycin, clindamycin, erythromycin, ciprofloxacin, norfloxacin, nalidixic acid | USA (Ohio) | processing | intestinal tracts | 10 (5) farms, 345 (355) tracts, 167 (165) isolates | conventional: tetracycline, ciprofloxacin, norfloxacin, nalidixic acid (p<0.05)organic: erythromycin (p<0.05)MDR no difference (p>0.05) | use of antimicrobials, transmission of resistant isolates without selection pressure |
| Mazengia *et al.* (2014) | *Salmonella* spp. | Amoxicillin–clavulanic acid, ampicillin, cefoxitin, ceftriaxone, chloramphenicol, ciprofloxacin, gentamicin, kanamycin, nalidixic acid, tetracycline, trimethoprim-sulfamethoxazole | USA (Washington state) | retail | raw chicken packages | total 18 stores, 1 094 (228) packages | conventional: significantly higher resistant rates than organicMDR conventional: all isolates resistant to ≥ two antibiotics from conventional | antibiotic treatment of animals |
| Miranda *et al.* (2007) | *Enterococcus* spp. | Ampicillin, chloramphenicol, doxycycline, ciprofloxacin, erythromycin, gentamicin, nitrofurantoin, vancomycin | Spain | retail | skin-on drum stick | 30 (30) samples | conventional: higher resistance ampicillin (p=0.0067), chloramphenicol (p=0.0154), doxycycline (p=0.0277), ciprofloxacin (p=0.0024), erythromycin (p=0.0028), vancomycin (p=0.0241)MDR conventional 33.3% (11.67%) (p=0.0021) | use of antimicrobials |
| Miranda *et al.* (2008b) | *Escherichia coli* | Ampicillin, cephalothin, chloramphenicol, doxycycline, ciprofloxacin, fosfomycin, gentamicin, nitrofurantoin, streptomycin, sulfisoxazole | Spain | retail | drum sticks | 61 (55) drum sticks | conventional: ampicillin 53.9% (21.9%) (p<0.0001), cephalothin 34.8% (4.8%) (p<0.0001), ciprofloxacin 27.8% (9.5%) (p=0.0026), doxycycline 47.8% (25.7%) (p<0.0001), gentamicin 9.6% (1%) (p<0.0001), streptomycin 46.1% (23.8%) (p<0.0001), sulfisoxazole 36.5% (21.9%) (p=0.0021)conventional MDR 76.5% (34.3%) (p<0.0001) | use of antimicrobials |
| Miranda *et al.* (2008b) | *Staphylococcus aureus* | Chloramphenicol, doxycycline, ciprofloxacin, clindamycin, erythromycin, gentamicin, nitrofurantoin, oxacillin, sulfisoxazole | Spain | retail | drum sticks | 61 (55) drum sticks | conventional: Doxycycline 58.4% (34.1%) (p=0.0001); organic: Clindamycin 83.5% (67.3%) (p=0.0239)MDR no difference (p=0.0826) | not mentioned |
| Miranda *et al.* (2008b) | *Listeria monocytogenes* | Chloramphenicol, doxycycline, erythromycin, gentamicin, sulfisoxazole, vancomycin | Spain | retail | drum sticks | 61 (55) drum sticks | conventional: doxycycline 18.8% (2.6%) (p=0.0446)MDR no difference (p=0.2409) | not mentioned |
| Miranda *et al.* (2008c) | Enterobacteriaceae | Ampicillin, cephalothin, chloramphenicol, doxycycline, ciprofloxacin, gentamicin, nitrofurantoin, sulfisoxazole | Spain | retail | skin-on drum stick | 30 (30) samples | conventional: higher resistance ampicillin (p=0.0001), chloramphenicol (p=0.0004), doxycycline (p=0.0013), ciprofloxacin (p=0.0034), gentamicin (p=0.0295) and sulfisoxazole (p=0.0442)MDR conventional 63.3% (organic 41.7%) (p=0.0197) | use of antimicrobials |
| Mollenkopf *et al.* (2014) | bla(CMY-2) *Salmonella* spp. |  | USA (Ohio, Michigan, Pennsylvania) | retail | pre-packaged chicken breasts | total 99 stores, 95 (40) packages | no difference  | not mentioned |
| Mollenkopf *et al.* (2014) | bla(CMY-2), bla(CTX-M), quinolone-resistant determining regions *E. coli* |  | USA (Ohio, Michigan, Pennsylvania) | retail | pre-packaged chicken breasts | total 99 stores, 95 (40) packages | conventional: QRDR 18% (0% organic), bla(CMY-2), bla(CTX-M) no difference | not mentioned |
| Mollenkopf *et al.* (2014) | *Campylobacter* spp. | Cirpofloxacin, clindamycin, erythromycin, florfenicol, gentamicin, naladixic acid, telithromycin, tertracycline | USA (Ohio, Michigan, Pennsylvania) | retail | pre-packaged chicken breasts | total 99 stores, 95 (40) packages | no difference in proportion with increased resistance | not mentioned |
| Mollenkopf *et al.* (2014) | *Salmonella* spp. | Amoxicillin/clavulanic acid, ampicillin, azithromycin, ceftoxitin, ceftiofur, ceftriaxone, chloramphenicol, ciprofloxacin, gentamicin, kanamycin, naladixic acid, streptomycin, sulfisoxazole, tertracycline, trimethoprim-sulfamethoxazole | USA (Ohio, Michigan, Pennsylvania) | retail | pre-packaged chicken breasts | total 99 stores, 95 (40) packages | no difference in proportion with increased resistance | not mentioned |
| Mollenkopf *et al.* (2014) | *Escherichia coli* | Amoxicillin/clavulanic acid, ampicillin, azithromycin, ceftoxitin, ceftiofur, ceftriaxone, chloramphenicol, ciprofloxacin, gentamicin, kanamycin, naladixic acid, streptomycin, sulfisoxazole, tertracycline, trimethoprim-sulfamethoxazole | USA (Ohio, Michigan, Pennsylvania) | retail | pre-packaged chicken breasts | total 99 stores, 95 (40) packages | no difference in proportion with increased resistance | not mentioned |
| Sapkota *et al.* (2014) | *Salmonella* Kentucky | Amikacin, amoxicillin-clavulanate, ampicillin, cefoxitin, ceftiofur, ceftriaxone, chloramphenicol, cyprofloxacin, gentamicin, kanamycin, nalidixic acid, streptomycin, sulfisoxazole, tetracycline, sulfamethoxazole | USA (Mid-Atlantic) | farm | litter, water, feed | 5 (5) farms, 10 (10) houses, 30 (30) litter samples, 20 (20) water samples, 10 (10) feed samples | conventional isolates: amoxicillin–clavulanate (p=0.049), ampicillin (p=0.042), cefoxitin (p=0.042), ceftiofur (p=0.043), ceftriaxone (p=0.042)MDR conventional 44% (6% organic) (p=0.015) | antibiotic selective pressure, multiple and complex factors in environment (e.g. horizontal gene transfer, changed bacterial physiology) |
| Sapkota *et al.* (2011) | *Enterococcus faecalis* | Chloramphenicol, ciprofloxacin, daptomycin, erythromycin, flavomycin, gentamicin, kanamycin, lincomycin, linezolid, nitrofurantoin, penicillin, streptomycin, quinupristin/dalfopristin, tetracycline, tigecycline, tylosin, vancomycin | USA (Mid-Atlantic) | farm | litter, water, feed | 5 (5) farms, 10 (10) houses, 30 (30) litter samples, 20 (20) water samples, 10 (10) feed samples, 133 (126) isolates | conventional: Erythromycin (p=0.004), tigecycline (p=0.004)MDR conventional 42% (10%) (p=0.02) | use of antimicrobials, hatcheries/parent stocks use antibiotics, antibiotic-resistant bacteria contaminated feed and water |
| Sapkota *et al.* (2011) | *Enterococcus faecium* | Chloramphenicol, ciprofloxacin, daptomycin, erythromycin, flavomycin, gentamicin, kanamycin, lincomycin, linezolid, nitrofurantoin, penicillin, streptomycin, quinupristin/dalfopristin, tetracycline, tigecycline, tylosin, vancomycin | USA (Mid-Atlantic) | farm | litter, water, feed | 5 (5) farms, 10 (10) houses, 30 (30) litter samples, 20 (20) water samples, 10 (10) feed samples, 133 (126) isolates | conventional: ciprofloxacin (p=0.01), gentamicin (p=0.047), nitrofurantoin (p=0.02), penicillin (p<0.001), tetracycline (p<0.001)MDR conventional 84% (17%) (p<0.001) | use of antimicrobials, hatcheries/parent stocks use antibiotics, antibiotic-resistant bacteria contaminated feed and water |
|  |  |  |  |  |  |  |  |  |
| *Laying hens* |  |  |  |  |  |  |  |  |
| Álvarez-Fernández *et al.* (2012) | *Escherichia coli* | Gentamicin, ampicillin-sulbactam, amoxicillin–clavulanic acid, piperacillin-tazobactam, cefotaxime, sulfamethoxazole-trimethoprim, chloramphenicol, ciprofloxacin, nalidixic acid, tetracycline, nitrofurantoin, phosphomycin | Spain | retail | eggs shell | different supermarkets, total 50 samples of 12 eggs, 20 (20) isolates | conventional: amoxicillin–clavulanic acid 90% (20%) (p<0.05), sulfamethoxazole-trimethoprim 85% (15%) (p<0.05), tetracycline 95% (0%) (p<0.05)organic: phosphomycin 50% (0%) (p<0.05)MDR conventional: resistant ≥ 2 antimicrobials 95% (30%) (p<0.05) | use of antimicrobials, animal crowding, poor sanitation |
| Schwaiger *et al.* (2008) | *Escherichia coli* | Amoxicillin/clavulanic acid, ampicillin, mezlocillin, oxazillin, piperacillin, cefaclor, cefepime, cefotaxime, cefoxitin, ceftazidime, ceftiofur, cefuroxime, imipenem, meropenem, chloramphenicol, florfenicol, ciprofloxacin, enrofloxacin, amikacin, apramycin, gentamicin, netilmicin, streptomycin, tobramycin, sulphamethoxazole/trimethoprim, doxycycline, colistin | Germany | farm | cloacal swap | 10 (10) farms, 276 (257) isolates | conventional: resistant to amoxicillin/clavulanic acid 11.2% (3.5%) (p<0.05), ampicillin 21.4% (9.3%) (p<0.05), cefaclor 19.6% (4.3%) (p<0.05), cefuroxime 2.6% (0.0%) (p<0.05), mezlocillin 16.7% (7.8%) (p<0.05), neomycin 5.8% (0.4%) (p<0.05), piperacillin 15.9% (2.7%) (p<0.05)organic: gentamicin 8.6% (1.5%) (p<0.05)MDR conventional: more double resistant isolates 10.1 (5.1 organic) (p<0.05), less susceptible to all agents 44.9% (60.7% organic) p<0.05 | use of antimicrobials, long duration of resistant population |
| Schwaiger *et al.* (2008) | *Campylobacter coli* | Amoxicillin/clavulanic acid, ampicillin, mezlocillin, oxazillin, piperacillin+tazobactam, cefuroxime, imipenem, chloramphenicol, florfenicol, ciprofloxacin, enrofloxacin, moxifloxacin, gentamicin, kanamycin, neomycin, streptomycin high level, erythromycin, tylosin, clindamycin, linezolid, sulphamethoxazole/trimethoprim, doxycycline, fosfomycin, nitrofurantoin | Germany | farm | cloacal swap | 10 (10) farms, 18 (25) isolates | no differenceMDR no statistical analysis due to low power | natural selection of resistant isolates, cross-contamination with other animals and humans, other selectors as heavy metals |
| Schwaiger *et al.* (2008) | *Campylobacter jejuni* | Amoxicillin/clavulanic acid, ampicillin, mezlocillin, oxazillin, piperacillin+tazobactam, cefuroxime, imipenem, chloramphenicol, florfenicol, ciprofloxacin, enrofloxacin, moxifloxacin, gentamicin, kanamycin, neomycin, streptomycin high level, erythromycin, tylosin, clindamycin, linezolid, sulphamethoxazole/trimethoprim, doxycycline, fosfomycin, nitrofurantoin | Germany | farm | cloacal swap | 10 (10) farms, 99 (118) isolates | conventional: resistant to amoxicillin/clavulanic acid 14.1% (4.2%) (p<0.05), imipenem 19.2% (8.5%) (p<0.05)organic: fosfomycin 22.9% (11.1%) (p<0.05)MDR no difference | natural selection of resistant isolates, cross-contamination with other animals and humans, other selectors as heavy metals |
| Schwaiger *et al.* (2010) | *Listeria* spp. | Amoxicillin/clavulanic acid, ampicillin, mezlocillin, oxazillin, imipenem, chloramphenicol, florfenicol, ciprofloxacin, enrofloxacin, moxifloxacin, teicoplanin, vancomycin, gentamicin high level, kanamycin, neomycin, streptomycin high level, erythromycin, tylosin, clindamycin, linezolid, quinupristin/dalfopristin, doxycycline, fosfomycin, nitrofurantoin, rifampicin | Germany | farm | cloacal swap | 10 (10) farms | no difference | not mentioned |
| Schwaiger *et al.* (2010) | *Enterococcus* spp. | Amoxicillin/clavulanic acid, ampicillin, mezlocillin, oxazillin, imipenem, chloramphenicol, florfenicol, ciprofloxacin, enrofloxacin, moxifloxacin, teicoplanin, vancomycin, gentamicin high level, kanamycin, neomycin, streptomycin high level, erythromycin, tylosin, clindamycin, linezolid, quinupristin/dalfopristin, doxycycline, fosfomycin, nitrofurantoin, rifampicin | Germany | farm | cloacal swap | 10 (10) farms, 99 (118) isolates | conventional: resistance rates higher (p<0.05) | use of antimicrobials, coexistence of resistance to antimicrobials and heavy metals on same plasmid, resistance transfer within or between species |

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