Incidence of *Salmonella*, *Campylobacter jejuni*, *Campylobacter coli*, and *Listeria monocytogenes* in Poultry Carcasses and Different Types of Poultry Products for Sale on the Belgian Retail Market

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ABSTRACT

From January 1997 to May 1998, 772 samples of poultry carcasses and poultry products for sale on the retail market in Belgium were analyzed for the presence of *Salmonella* spp., *Salmonella* Enteritidis, *Campylobacter jejuni*, *C. coli*, and *Listeria monocytogenes* per 100 cm2 or 25 g. Poultry samples were contaminated with *Salmonella* (36.5%), *C. jejuni* and *C. coli* (28.5%), and *L. monocytogenes* (38.2%). In about 12.3% of the poultry samples, the *L. monocytogenes* contamination level exceeded 1 CFU per g or cm2. Significant differences in pathogen contamination rates of poultry products were noticed between the poultry products originating from Belgian, French, and U.K. abattoirs. Poultry products derived from broiler chickens running free in pine woods until slaughtering age (12 to 13 weeks) had a significantly (P < 0.05) lower contamination rate of *Salmonella* than poultry products from enclosed broilers slaughtered at the age of 6 to 8 weeks. A significantly (P < 0.05) lower pathogen contamination rate was noted for *Salmonella*, *C. jejuni*, and *C. coli* for poultry cuts with skin compared to poultry cuts with skin on. An increase in pathogen contamination rate was noticed during cutting and further processing. To diminish *C. jejuni*, *C. coli*, *Salmonella*, and *L. monocytogenes* contamination rates, hygienic rules of slaughter and meat processing must be rigorously observed. At the moment, zero tolerance for these pathogens is not feasible, and there is a need to establish criteria allowing these pathogens to be present at reasonable levels in the examined poultry samples.

Risk assessment is a tool used to evaluate the safety of food. Among classes of hazards associated with food, microbial contamination of the food supply is among the most important. Risk assessment, however, is limited by a lack of data on the incidence of pathogens in foods (13).

Poultry and poultry products are a common vehicle of foodborne illness. Microbial risks associated with raw poultry products include *Salmonella* spp., *Campylobacter jejuni*, *C. coli*, and *Listeria monocytogenes*. Outbreaks involving large numbers of people are usually caused by *Salmonella*. Campylobacteriosis occurs as sporadic cases of illness instead of outbreaks. *Campylobacter* infections are increasing in Europe and other parts of the world (22, 27) and are the most common cause of human diarrhea in England and Wales (24, 28) and the United States (29). Eating undercooked chicken is one risk factor associated with sporadic campylobacteriosis (22). Worldwide, salmonellae and campylobacters are by far the most important pathogens associated with poultry products (7). Case–control studies, however, suggest that undercooking raw poultry is involved in human listeriosis among individuals susceptible to the condition (14). Although sufficient heating will eliminate the above-mentioned pathogens, cross-contamination can occur as a result of manipulation of raw poultry in the kitchen.

Information on contamination rates of poultry products for the above-mentioned pathogens is needed to characterize exposure in health risk assessment. This study was conducted to estimate the incidence of *Salmonella*, *C. jejuni*, *C. coli*, and *L. monocytogenes* on poultry carcasses and poultry products distributed on the Belgian retail market.

MATERIALS AND METHODS

Sample collection. From January 1997 to May 1998, 772 samples of poultry carcasses and poultry products were analyzed for the presence of *Salmonella*, *Salmonella* Enteritidis, *C. jejuni*, *C. coli*, and *L. monocytogenes*. Samples were taken monthly at the depot of a large chain of supermarkets in Belgium. At the central depot, chilled poultry carcasses and products were arriving from several abattoirs in Belgium (10 sites), France (16 sites), and occasionally the United Kingdom (2 sites), The Netherlands (1 site), or Italy (1 site). From the central depot on, the chilled carcasses and products were distributed to individual supermarkets of the chain serving Belgian consumers. Neither at the central depot nor at the individual supermarkets was there any processing of the poultry products. Samples were collected at the central depot because this enabled gathering of samples from a large number of abattoirs at one point. In addition, the sampling plan represented what is offered for consumption in the Belgian super-
market. Samples collected in the screening included (i) poultry carcasses of broiler chicken (industrial breeding, 6 to 8 weeks old), free-range chicken (12 to 13 weeks old), broiling hen (≤2 years old), spring chicken (4 to 6 weeks old), and guinea fowl (≤13 weeks old); (ii) poultry cuts, including leg, wing, breast, and fillets of broiler chickens and turkeys; (iii) processed poultry in general products for barbecue, such as sausages and hamburgers made of chicken or turkey meat, sliced poultry meat mounted on a skewer, and chicken wings coated with spices. Processed poultry was investigated only in the summer (May to September).

Samples were taken in an aseptic manner (using sterilized utensils under a laminar flow hood). For poultry carcasses and cuts with skin on (e.g., chicken wings, chicken legs, and turkey legs), 300 cm² (approximately 75 g) of skin was excised from two chicken carcasses or multiple chicken cuts from the same lot. Samples of poultry carcasses consisted of skin of the wing, leg, breast, and part of the cloacal region. For poultry samples without skin (e.g., fillets) and processed poultry, 75 g of meat was taken. The samples were put in a 500-ml sterile bottle and made up to 300 ml with a saline and peptone solution consisting of 8.4 g of NaCl per liter (Vel, Leuven, Belgium) and 3 g of tryptone per liter (Oxoid, Hampshire, Basingstoke, UK). Samples were taken at the central depot of the chain of supermarkets and transported under refrigeration to the laboratory for analyses.

Microbiological analyses. In the laboratory, the 300-ml saline and peptone sample suspension was transferred under a laminar flow hood to a sterile stomacher bag and homogenized using a Colworth stomacher (Seward Laboratory, London, UK).

Next, three times 100 ml of the saline and peptone food homogenate was transferred to a new stomacher bag and supplemented with 100 ml each of double-concentrated buffered peptone water, double-concentrated Preston medium, or double-concentrated demi-Fraser medium (all from Oxoid) to look for Salmonella, C. jejuni, C. coli, and L. monocytogenes per 100 cm² or 25 g. For L. monocytogenes, detection per cm² or per g was also performed. In Europe, a microbiological criterion for L. monocytogenes of <100 CFU per g or per cm² on the sell-buy is generally accepted (15). At this low level of contamination, pasteurization (heating to a core temperature of 71°C) is sufficient to inactivate L. monocytogenes (18). In view of a food safety objective of <100 CFU per cm² or per g at the ultimate date of consumption and taking into account a maximum 2-log outgrowth of the pathogen under refrigeration temperatures during the storage period of poultry, L. monocytogenes should be absent per square centimeter or gram on the day of distribution to the retail market (day of sampling in the present study). Detection of L. monocytogenes per square centimeter was performed (if poultry carcasses or poultry samples with skin on were sampled) by means of transfer of 1 ml of the 300-ml saline and peptone food homogenate to 9 ml of Fraser broth was incubated for 24 h at 30°C. Typical colonies were confirmed as L. monocytogenes by incubation in a jar under microaerophilic atmosphere in nutrient broth (Preston medium, Oxoid) supplemented with growth and selective supplement (Preston medium, Oxoid) but without blood (31). After incubation for 24 and 48 h, Campylobacter blood-free selective medium (Oxoid) was inoculated by streaking. The plates were searched for typical colonies (small gray droplike or gray slimy colonies) after 48 h of incubation. Typical colonies were confirmed as C. jejuni or C. coli using microscopic analyses, a catalase test, oxidase test, and sensitivity to cephalothin and nalidixic acid (31). Detection of C. jejuni and C. coli. The microbiological technique for the investigation of C. jejuni and C. coli consisted of incubation in a jar under microaerophilic atmosphere in nutrient broth (Preston medium, Oxoid) supplemented with growth and selective supplement (Preston medium, Oxoid) but without blood (31). After incubation for 24 and 48 h, Campylobacter blood-free selective medium (Oxoid) was inoculated by streaking. The plates were searched for typical colonies (small gray droplike or gray slimy colonies) after 48 h of incubation. Typical colonies were confirmed as C. jejuni or C. coli using microscopic analyses, a catalase test, oxidase test, and sensitivity to cephalothin and nalidixic acid (31).

Detection of L. monocytogenes. Detection of L. monocytogenes was performed as described elsewhere (1). In short, demi-Fraser broth was incubated for 24 h at 30°C and streaked on Oxford medium. Next, 0.1 ml of demi-Fraser broth was transferred to 10 ml of Fraser broth (Oxoid) incubated for 24 and 48 h at 37°C, and streaked on Oxford medium (Oxoid). The Oxford medium was incubated for 48 h, and typical colonies (maximum five) were purified on tryptone soy agar (Oxoid) and identified by motility testing, fermentation of rhamnose, xylose, and mannitol, β-hemolysis, and a CAMP test (1).

Statistical analysis. Data were subjected to statistical analysis (logistic regression model) using SPSS for Windows, release 7.5 (SPSS, Inc., Chicago, Ill.).

RESULTS

Poultry products for sale in the retail market in Belgium were contaminated with Salmonella (36.5%), C. jejuni or C. coli (28.5%), and L. monocytogenes (38.2%) (Table 1). Table 1 shows that Salmonella Enteritidis was not the predominant Salmonella serotype in the poultry samples. Salmonella Enteritidis was isolated from 5.4% of the poultry samples, whereas 36.5% of the samples were contaminated with Salmonella spp. Salmonella, C. jejuni, and C. coli are well-known pathogens associated with poultry. L. monocytogenes is rarely cited as an important pathogen for poultry products, although the results from the present study showed that incidence of L. monocytogenes in poultry products was as high as for Salmonella. In about 12.3% of the poultry samples, the contamination level of L. monocytogenes exceeded 1 CFU per g or per cm². Because L. monocytogenes is a psychrotrophic pathogen, having the ability to multiply during storage at refrigeration temperatures, there is a risk that in these samples the pathogen...
TABLE 1. Incidence of Salmonella, Campylobacter jejuni, C. coli, and Listeria monocytogenes in poultry products for sale on the Belgian retail market according to country of origin

<table>
<thead>
<tr>
<th>Country of origin</th>
<th>Salmonella Enteritidis (&gt;1 CFU/100 cm² or 25 g)</th>
<th>Other spp. (&gt;1 CFU/100 cm² or 25 g)</th>
<th>Campylobacter (&gt;1 CFU/100 cm² or 25 g)</th>
<th>L. monocytogenes (&gt;1 CFU/cm² or 25 g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Belgium</td>
<td>32/279 (11.5) A</td>
<td>121/279 (43.4) AD</td>
<td>54/247 (21.9) AE</td>
<td>44/279 (15.7) A</td>
</tr>
<tr>
<td>France</td>
<td>3/434 (0.7) B</td>
<td>143/434 (32.9) BD</td>
<td>129/427 (30.2) BD</td>
<td>45/434 (10.4) B</td>
</tr>
<tr>
<td>Italy</td>
<td>0/13 (0.0)</td>
<td>4/13 (30.8)</td>
<td>2/13 (15.4)</td>
<td>0/13 (0.0)</td>
</tr>
<tr>
<td>The Netherlands</td>
<td>0/2 (0.0)</td>
<td>0/2 (0.0)</td>
<td>0/2 (0.0)</td>
<td>0/2 (0.0)</td>
</tr>
<tr>
<td>United Kingdom</td>
<td>7/44 (15.9) A</td>
<td>14/44 (31.8) BD</td>
<td>24/44 (54.5) CE</td>
<td>6/44 (13.6) A</td>
</tr>
<tr>
<td>Total</td>
<td>42/772 (5.4)</td>
<td>282/772 (36.5) D</td>
<td>209/733 (28.5) E</td>
<td>95/772 (12.3)</td>
</tr>
</tbody>
</table>

*Values are numbers of samples per total number of samples. Values in parentheses are percentages of positive samples.*

*Incidence levels within columns followed by different letters (A, B, or C) differ significantly (P < 0.05).* (Because of the low number of samples from Italy and The Netherlands, these were not included in the statistical analyses.) Incidence levels within rows followed by different letters (p or e) differ significantly (P < 0.05). (Only contamination levels of Salmonella spp., C. jejuni, C. coli, and L. monocytogenes [>1 CFU/100 cm² or 25 g] were compared.)

exceeds the accepted (European) level of contamination before the end of shelf life.

Significant (P < 0.05) differences in the pathogen contamination rates of poultry products were noticed between the different countries of origin (Table 1). Contamination with Salmonella was highest in products from Belgian abattoirs (10 sites), whereas C. jejuni and C. coli contamination was best controlled at these sites. Products from the United Kingdom (2 sites) had significantly (P < 0.05) higher contamination rates of Salmonella Enteritidis compared to those from France for sale on the Belgian retail market.

In France, a label is assigned to poultry products derived from free-range broiler chickens, which run free in pine woods until slaughtering age (12 to 13 weeks). Nonlabeled poultry products are derived from broilers raised in enclosed pens and slaughtered at the age of 6 to 8 weeks. These labeled poultry products have a significantly (P < 0.05) lower Salmonella contamination rate than nonlabeled products (Table 2). Although there was also a trend for lower contamination rates of C. jejuni, C. coli, and L. monocytogenes (>1 CFU per g or per cm²), this decrease was statistically not significant (P > 0.05).

Table 3 shows a significantly (P < 0.05) lower pathogen contamination, except for L. monocytogenes (>1 CFU per cm² or per g), for poultry cuts without skin compared to poultry cuts with skin. However, contamination rates of Salmonella and C. jejuni and C. coli for poultry products without skin are still high (34.6 and 25.0%, respectively). L. monocytogenes contamination (>1 CFU per 100 cm² or per 25 g), on the contrary, is significantly (P < 0.05) higher on poultry cuts without skin, indicating contamination from the environment during processing (utensils, equipment, or personnel).

Table 4 shows that Salmonella Enteritidis was predominantly associated with boiling hen carcasses and never or rarely isolated from turkey products.

An increase in the pathogen contamination rate was noticed during cutting and further processing of the poultry. Chicken carcasses had contamination rates of 29.3 and 41.3% for Salmonella and L. monocytogenes, respectively; chicken cuts, 44.0 and 46.7%, respectively; and processed chicken products, 68.3 and 61.0%, respectively. Although contamination rates for C. jejuni and C. coli similar to those cited for the two above-mentioned pathogens were observed for chicken carcasses (25.6%) and cuts (40.0%), the C. jejuni and C. coli contamination rate observed in processed chicken products was low (6.4%). Campylobacter is a fragile organism and dies off in the presence of air; thus, contamination will be lower the longer the carcass is held after processing. Bostan et al. (6) reported a decrease of the number of C. jejuni from 2.8 to 4.3 × 10⁵ CFU per g in the beginning to 1.1 × 10⁴ CFU per g in refrigerated minced meat, 3.8 × 10³ CFU per g in cubed meat, and

TABLE 2. Incidence of Salmonella, Campylobacter jejuni, C. coli, and Listeria monocytogenes in label and nonlabeled poultry products originating from France for sale on the Belgian retail market

<table>
<thead>
<tr>
<th>Poultry sample</th>
<th>Salmonella spp. (&gt;1 CFU/100 cm² or 25 g)</th>
<th>Campylobacter (&gt;1 CFU/100 cm² or 25 g)</th>
<th>L. monocytogenes (&gt;1 CFU/cm² or 25 g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nonlabeled</td>
<td>40/87 (46.0) A</td>
<td>27/87 (31.0) A</td>
<td>13/78 (16.7) A</td>
</tr>
<tr>
<td>Label</td>
<td>12/82 (14.6) B</td>
<td>19/82 (23.2) A</td>
<td>6/82 (7.3) A</td>
</tr>
</tbody>
</table>

*Values are the number of positive samples per total number of samples. Values in parentheses are percentages of positive samples.*

*Incidence levels within columns followed by different letters differ significantly (P < 0.05).*
TABLE 3. Incidence of Salmonella, Campylobacter jejuni, C. coli, and Listeria monocytogenes in poultry cuts with and without skin for sale on the Belgian retail market

<table>
<thead>
<tr>
<th>Poultry cut</th>
<th>Salmonella spp. (&lt;1 CFU/100 cm² or 25 g)</th>
<th>Campylobacter (&lt;1 CFU/100 cm² or 25 g)</th>
<th>L. monocytogenes (&lt;1 CFU/cm² or g)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(&gt;1 CFU/100 cm² or 25 g)</td>
<td>(&gt;1 CFU/100 cm² or 25 g)</td>
<td>(&gt;1 CFU/100 cm² or 25 g)</td>
</tr>
<tr>
<td>With skin</td>
<td>86/183 (47.0) Aᵇ</td>
<td>71/183 (38.8) A</td>
<td>31/183 (16.9) A</td>
</tr>
<tr>
<td>Without skin</td>
<td>63/182 (34.6) B</td>
<td>45/180 (25.0) B</td>
<td>3/182 (1.6) B</td>
</tr>
</tbody>
</table>

Values are the number of positive samples per total number of samples. Values in parentheses are percentages of positive samples. Incidence levels within columns (processed sample) followed by different letters (E or F) differ significantly (P < 0.05).

<10 CFU per g in meat ball. Also, the C. jejuni and C. coli contamination rate for processed turkey products was higher, although not significantly (P < 0.05), than that for processed chicken products, whereas the opposite was observed for Salmonella and L. monocytogenes. In general, turkey products were contaminated with Salmonella spp. and L. monocytogenes at lower rates than chicken products (Table 4). Finally, boiling hen carcasses had a significantly (P < 0.05) higher contamination rate for L. monocytogenes: 28% of boiling hen carcasses had a high level of L. monocytogenes contamination (>1 CFU per g or per cm²).

DISCUSSION

Contamination rates for C. jejuni and C. coli in broiler chickens of 36 and 27.9% have been reported in Denmark (23) and Germany (3), respectively, compared to the contamination rate of 25.6% found in the present study. For chicken cuts, contamination rates for C. jejuni and C. coli of 61% have been reported in The Netherlands (12). In Northern Ireland, 38% of chicken pieces were reported to be contaminated (19). In an earlier study in Belgium, 57.5% of samples were found to be positive for C. jejuni and C. coli (32), whereas in the present study, 40.0% were found to be positive. For L. monocytogenes, 25.7% of poultry carcasses derived from one processing plant were reported to be positive (9). Other reports mention 20% positive poultry meat samples (26) or 59% positive poultry products (16). The contamination rate for L. monocytogenes determined in the present study (38.2%) was in this range. The incidence of Salmonella in poultry in this study was 36.5%. The percentage of Salmonella-positive samples reported for poultry products varies enormously (12.8 to 79%) (10).

It is difficult to compare the incidence of these pathogens reported by different authors because of differences in time period, origin and relative age of the samples, sampling plan, sampling techniques, and methodology applied. In the present study, a large number of samples was analyzed (n = 772), and samples were obtained from abattoirs in different regions (and different countries) supplying poultry products (carcasses, cuts, and meat of predominantly broiler chickens and turkeys) to the Belgian retail market. Individual abattoirs will have different pathogen.

TABLE 4. Incidence of Salmonella, Campylobacter jejuni, C. coli, and Listeria monocytogenes in poultry carcasses, poultry cuts, and processed poultry for sale on the Belgian retail market

<table>
<thead>
<tr>
<th>Poultry sample</th>
<th>Salmonella (&lt;1 CFU/100 cm² or 25 g)</th>
<th>Campylobacter (&lt;1 CFU/100 cm² or 25 g)</th>
<th>L. monocytogenes (&lt;1 CFU/cm² or g)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Enteritidis</td>
<td>Other spp.</td>
<td></td>
</tr>
<tr>
<td>Carcassesᵇ</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chicken</td>
<td>6/133 (4.5) A</td>
<td>39/133 (29.3) A</td>
<td>15/133 (11.3) A</td>
</tr>
<tr>
<td>Boiling hen</td>
<td>5/32 (15.6) B</td>
<td>13/32 (40.6) A</td>
<td>9/32 (28.1) B</td>
</tr>
<tr>
<td>Spring chicken</td>
<td>2/48 (4.2) A</td>
<td>13/48 (27.1) A</td>
<td>8/48 (16.7) A</td>
</tr>
<tr>
<td>Guinea fowl</td>
<td>2/32 (6.2) A</td>
<td>6/32 (18.8) A</td>
<td>2/32 (6.2) A</td>
</tr>
<tr>
<td>Cutsᶜ</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chicken</td>
<td>16/225 (7.1) c</td>
<td>99/225 (44.0) c</td>
<td>36/225 (16.0) c</td>
</tr>
<tr>
<td>Turkey</td>
<td>0/164 (0.1) D</td>
<td>60/164 (36.6) c</td>
<td>1/164 (0.6) D</td>
</tr>
<tr>
<td>Spring chicken</td>
<td>3/28 (10.7) c</td>
<td>8/28 (28.6) c</td>
<td>8/28 (28.6) c</td>
</tr>
<tr>
<td>Guinea fowl</td>
<td>0/3 (0.0)</td>
<td>0/3 (0.0)</td>
<td>0/3 (0.0)</td>
</tr>
<tr>
<td>Processedᵈ</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chicken</td>
<td>6/41 (14.6) E</td>
<td>28/41 (68.3) E</td>
<td>14/41 (34.1) E</td>
</tr>
<tr>
<td>Turkey</td>
<td>2/66 (3.0) F</td>
<td>16/66 (24.2) F</td>
<td>2/66 (3.0) F</td>
</tr>
<tr>
<td>Total</td>
<td>41/772 (5.4)</td>
<td>282/772 (36.5)</td>
<td>209/733 (28.5)</td>
</tr>
</tbody>
</table>

Values are the number of positive samples per total number of samples. Values in parentheses are percentages of positive samples. Incidence levels within columns (carcasses sample) followed by different letters (A or B) differ significantly (P < 0.05).

Incidence levels within columns (cuts sample) followed by different letters (C or D) differ significantly (P < 0.05). (Guinea fowl not included in statistical analysis.)

Incidence levels within columns (processed sample) followed by different letters (E or F) differ significantly (P < 0.05).
contamination rates, and significant ($P < 0.05$) differences were observed between pathogen contamination rates of products originating from Belgium, France, and the United Kingdom. However, a supermarket selling poultry carcasses and products to consumers obtains poultry from different abattoirs and different countries (international trade). By sampling retail packs, a representative figure for the contamination rates of Salmonella spp., Campylobacter jejuni, Campylobacter coli, and Listeria monocytogenes in poultry products offered to the consumer for consumption is obtained. This relates immediately to the exposure of the consumer to these pathogens.

The contamination rate for Salmonella reported in this study (36.5%) was close to that reported in The Netherlands (33.0 to 34.8%) (2). The incidence of C. jejuni and C. coli in this study (28.5%) was close to that reported in Germany (27.9%) (3). These similarities indicate that the data gathered in this study can be used for risk assessment in countries other than Belgium, especially neighboring countries.

The trend of lower contamination rates in labeled poultry products (free-range broilers, slaughtered at 12 to 13 weeks of age) compared to nonlabeled products (broilers raised in enclosed pens, slaughtered at 6 to 8 weeks) suggests that industrial food production and younger relative age at slaughter have a negative effect on the incidence of pathogens. In industrialized production, environmental and hygienic conditions during breeding can be well controlled, but, for example, providing Salmonella-contaminated feed or insufficient cleaning and disinfection of poultry houses has a great impact on the entire flock (10, 20). Also, in general, young hosts are more susceptible to salmonellae than older ones. This fact may be due to insufficient formation of stable intestinal flora (4).

Because of the way chickens are reared and transported, they bring Salmonella into the processing plant on their skins (14). Salmonella cells are initially entrapped in a water film on the skin and then migrate to the skin, where they are entrapped in ridges and crevices that become more pronounced in the skin after immersion in water (17). This could explain the higher Salmonella contamination rates of poultry cuts with skin. Data obtained from a study monitoring the different processing steps in one plant showed that L. monocytogenes infrequently enters the processing plant on live broiler hens (9). The organism appears to take up residence in the plant, leading to cross-contamination during processing (25). This is also indicated by the higher incidence of L. monocytogenes on poultry cuts without skin (>1 CFU per 100 cm² or per 25 g).

The increase in the incidence of Salmonella during cutting and further processing was expected. It has been reported that Salmonella incidence rates increased from 30% in fecal material collected from incoming birds to 60% in air-chilled carcasses, indicating that cross-contamination occurred (8). Cross-contamination is also responsible for an increase in L. monocytogenes, C. jejuni, and C. coli contamination in cuts. The low incidence of C. jejuni and C. coli in processed poultry may be attributed to a combination of exposure to oxygen, decreased humidity, and suppression of the organism by competitive microflora.

To lower C. jejuni, C. coli, Salmonella, and L. monocytogenes contamination rates, hygienic rules of slaughter and meat processing must be rigorously observed. Improved hygiene control has been found to lower the number of Campylobacter on packaged poultry (21). The incidence of L. monocytogenes especially may be reduced by improving abattoir hygiene. For Salmonella, C. jejuni, and C. coli, great emphasis should be put on prevention and control in poultry breeding. However, to succeed, a multifaceted approach must be applied (30). Preharvest food safety programs implementing the rules of the Hazard Analysis and Critical Control Point (HACCP) concept at farm level from breeding to the slaughter house gate should be added to existing HACCP programs from the slaughter house to the retailer (5). At the present moment, zero tolerance for any of the three pathogens cannot realistically be achieved; thus, there is a need to establish criteria allowing these pathogens to be present at reasonable levels in poultry. Consequently, implementation of good cooking techniques and good kitchen and personal hygiene during preparation are necessary. Also, education of food handlers and information to consumers about microbial risks associated with the consumption of poultry products and how to control them (e.g., storage at the proper temperature and adequate cooking) are needed.

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