Microbial Quality of Popular Locally Processed Meats Sold in Retail Outlets in Trinidad, West Indies

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ABSTRACT

A total of 480 samples of locally produced processed meats, including chicken franks, chicken bologna, and bacon from brands A and B, was collected from 8 supermarkets across the island of Trinidad over a 1-year period and subjected to a range of microbiological analyses. The results showed that 54.2, 0.4, and 1.7% of the samples exceeded recommended limits for aerobic bacteria, *Escherichia coli* and *Staphylococcus aureus*, respectively, *Listeria* spp. were detected in 19.4% of samples, whereas *L. monocytogenes* was present at a prevalence rate of 7.5%. Brand A products had lower microbiological quality, accounting for 100% of samples positive for *L. monocytogenes*, *E. coli*, and *S. aureus*; and 75% for *Listeria* spp. and coliforms. Bacon was the product that most frequently exceeded microbiological limits, and accounted for 100% of samples positive for *E. coli*, 83.3% for *L. monocytogenes*, 72% for *Listeria* spp., 62.5% for *S. aureus*, and 61.9% for coliforms.

Processed meat products are a convenient, easy-to-prepare and inexpensive source of nutrition worldwide; however, they are one of the most frequent vehicles for the transmission of foodborne pathogens to humans (42). Meat contains water, amino acids, nucleotides, peptides, and sugars (22), and serves as an ideal substrate for the growth and proliferation of certain species of bacteria, such as *Staphylococcus* spp. and *Listeria* spp. (31).

Many pathogenic bacteria are known to be associated with processed meat products, including *Escherichia coli* O157, *Staphylococcus aureus*, and *Salmonella* spp. These microorganisms can cause serious foodborne illnesses with symptoms, such as severe vomiting and chronic diarrhea, which can lead to dehydration and, in some instances, death (10, 16, 29). Of particular importance is *Listeria monocytogenes*, a species of bacteria for which the U.S. Food and Drug Administration has set a “zero tolerance” limit in ready-to-eat (RTE) foods (37). The presence of this pathogen in foods is potentially hazardous, especially for high-risk sectors of the population, including children, the elderly, and immuno-compromised individuals (38). Infections of *L. monocytogenes* can result in septicemia and meningitis in the immunocompromised, as well as septic abortions and stillbirths in pregnant women (42).

The prevalence of contaminated processed meat products is a worldwide problem. Recent outbreaks of foodborne illnesses have occurred in the United States and France due to *L. monocytogenes*-contaminated hot dogs and pork tongue, respectively (42). Contamination of RTE meats with *L. monocytogenes*, *S. aureus*, *E. coli*, *Salmonella* spp., and unacceptable levels of aerobic bacteria also has been reported in other countries, including Lebanon, Argentina, and Nigeria (17, 27, 32).

In Trinidad, RTE products have been found to contain various species of pathogens and fecal indicator organisms. Adesiyun (1) reported the presence of a range of RTE foods in the island contaminated with bacteria, including *S. aureus*, *E. coli*, and *Salmonella* spp. Other reports have indicated the presence of pathogenic or fecal indicator bacteria in popular street foods, including black pudding, a sausage-like food of animal origin (2), and “doubles,” a sandwich-like food consisting of curried chickpeas between two fried breads (25). In addition to these, the prevalence of processed meat products contaminated by *Listeria* spp. was documented following a massive recall from a large meat processing plant in the island in 2003 (14).

Processed meats in Trinidad have shown increasing potential to pose health risks to consumers. However, there is a dearth of information on the potential risks to consumers of these products. This study, therefore, aims to investigate the prevalence of pathogenic and fecal indicator species of bacteria in retail processed meat products sold at commercial retail outlets in Trinidad, West Indies.

MATERIALS AND METHODS

Information on the sale of processed meat products at retail outlets was obtained from a previously completed island-wide survey (34). The two most popular brands (coded as A and B) and the three most popular products (chicken franks, chicken bologna, and bacon) were chosen for the detailed microbiological study.

**Determination of sample size.** A total of 480 retailed processed meat products was analyzed. This number was
determined based on the formula: \( n_0 = z^2 (P) (1 - P)/d^2 \), where \( d \) (acceptable level of precision) = 0.04, \( z \) (confidence coefficient) = 2, and \( P \) is the prevalence rate (20). For this study, a prevalence rate of 19.8% was used based on estimates from previous studies (3, 8, 14). Eight supermarkets that carried both brands of all three products were chosen for the survey based on size and administrative regions in the island (Fig. 1). Of these, three were chain stores (more than one outlet), one was large (more than seven cashiers), two were medium (three to seven cashiers), and two were small (fewer than three cashiers). The numbers of the different sized supermarkets were roughly proportional to those of all supermarkets in the survey (42 of 60) that sold the two brands and three product types (34). The supermarkets in each size category were selected randomly from five major regions of the island: North-West Coast, East-West Corridor, South-East Coast, Central, and South.

In each supermarket, 60 samples were taken for bacteriological analysis, comprising 30 samples each from brands A and B. Samples from each brand consisted of 10 chicken franks, 10 chicken bologna, and 10 bacon products. All samples were collected over a 12-month period from October 2005 to November 2006. Supermarkets were sampled on a rotation basis and no more than six samples (one of each brand and product type) were collected in a single day.

The total number of samples taken from each supermarket size was 120 for small, 120 for medium, 60 for large, and 180 for chain supermarkets.

**Collection and preparation of retail samples.** Retail packages of the meat products were collected from supermarkets and transported on ice to the laboratory. The samples were stored on ice and processed within 24 h of collection. The external package of the retail sample was sanitized by swabbing with 70% ethanol, and after drying, a sterile scalpel blade was used to open the pack along the vacuum seals. Sterile pairs of scissors and forks were used to cut and macerate the product into smaller portions, which were weighed on an electronic balance (Ohaus Scout Pro Balance, Ohaus Corporation, Parsippany, NJ). Portions (25 g) of each meat product then were added aseptically into sterile stomacher bags.

**Methods for the detection of bacteria.** Total coliforms, *E. coli*, *E. coli* O157, *S. aureus*, and total aerobic bacteria were enumerated using spread plating techniques on selective agar media. *Listeria* spp. and *Salmonella* spp. were detected qualitatively on selective agar media after enrichment in broths. This not only allowed for the resuscitation of potentially injured bacteria, but also increased the possibility that low numbers of pathogens in samples could be detected (5, 19).

To 25 g of each macerated meat product in stomacher bags, 225 ml lactose broth was added and then homogenized using a stomacher (Seward Stomacher 400 Lab System, Seward Company, Worthington, West Sussex, UK) for 2 minutes at high speed. Portions (0.1 ml) of the homogenized mixture were then spread plated on selective media for different bacteria being enumerated: eosin methylene blue for the detection of *E. coli* (4, 12, 15, 36), sorbitol MacConkey agar for *E. coli* O157 (4, 26, 36), MacConkey agar for coliforms (4, 36), mannitol salt agar for *S. aureus* (11, 36), and plate count agar for the detection of aerobic bacteria (30, 36).

For each homogenized sample, a further 0.1 ml of the lactose broth mixture was added to 9.9 ml sterile saline to obtain a 100-fold dilution and mixed using a vortex mixer. The plate count agar plates were inoculated with 0.1 ml and spread using a sterile spreader. All agar plates then were incubated aerobically (Thermo Fisher Scientific, Inc., Waltham, MA) at 37°C for 24 h, following which characteristic colonies were enumerated using a Quebec Darkfield colony counter (Cambridge Instruments, Inc., Pine Brook, NJ). The dilutions used for plating were selected for high likelihood of obtaining 30 to 300 colonies based on preliminary optimization studies. However, to cater for the occurrence of some samples having bacterial levels exceeding the typical range, the highest dilutions were stored immediately in a refrigerator (Jordon...
TABLE 1. Frequency of products positive for microorganisms under evaluation by location of supermarkets\(^a\)

<table>
<thead>
<tr>
<th>Microbial parameter</th>
<th>East-West Corridor</th>
<th>North-West Coast</th>
<th>South-East Coast</th>
<th>Central</th>
<th>South</th>
<th>(P) value</th>
</tr>
</thead>
<tbody>
<tr>
<td>TAPC</td>
<td>131 (54.6)</td>
<td>19 (31.7)</td>
<td>36 (60.0)</td>
<td>41 (68.3)</td>
<td>33 (55.0)</td>
<td>0.001</td>
</tr>
<tr>
<td>S. aureus</td>
<td>2 (0.8)</td>
<td>3 (5.0)</td>
<td>3 (5.0)</td>
<td>0 (0.0)</td>
<td>0 (0.0)</td>
<td>0.025</td>
</tr>
<tr>
<td>E. coli</td>
<td>7 (2.9)</td>
<td>0 (0.0)</td>
<td>0 (0.0)</td>
<td>0 (0.0)</td>
<td>0 (0.0)</td>
<td>&gt;0.05</td>
</tr>
<tr>
<td>Total coliforms</td>
<td>38 (15.8)</td>
<td>3 (5.0)</td>
<td>6 (10.0)</td>
<td>11 (18.3)</td>
<td>5 (8.3)</td>
<td>&gt;0.05</td>
</tr>
<tr>
<td>Listeria spp.</td>
<td>46 (19.2)</td>
<td>12 (20.0)</td>
<td>12 (20.0)</td>
<td>13 (21.7)</td>
<td>10 (16.7)</td>
<td>&gt;0.05</td>
</tr>
<tr>
<td>L. monocytogenes</td>
<td>16 (6.7)</td>
<td>4 (6.7)</td>
<td>6 (10.0)</td>
<td>8 (13.3)</td>
<td>2 (3.3)</td>
<td></td>
</tr>
</tbody>
</table>

\(^a\) \(n = 240\) for East-West Corridor and 60 each for the other zones.

\(^b\) Acceptable limits: TAPC, \(10^5\) CFU/g; S. aureus, \(10^4\) CFU/g; E. coli, \(10^5\) CFU/g; L. monocytogenes, not detected in 25 g (7, 13, 15, 18).

Statistical analysis. Analysis of the resultant bacterial counts was done using nonparametric Kruskal-Wallis and \(\chi^2\) tests (Statistical Package for Social Sciences, SPSS version 17.0, SPSS, Inc., Chicago, IL) (28).

RESULTS

Total aerobic plate count. Aerobic bacteria were detected (detection limit >10 CFU/g) in 83.5% (401 of 480) of products with 260 (54.2%) of the samples exceeding the acceptable limit of \(10^5\) CFU/g for total aerobic plate count (TAPC) (7, 13, 15, 18). Of these, 45% (117 of 260) were brand A and 55% (143 of 260) brand B products, and bacon (41.5%) contributed the largest proportion, followed by franks (35.4%) and bologna (23.1%, \(P = 0.001\)).

Bacon, regardless of the brand, was the product type that most frequently exceeded acceptable limits. Of the brand A products that exceeded the TAPC limit, 43.6% were bacon, 41.9% franks, and 14.5% bologna (\(P < 0.001\)). Likewise, 39.9% of brand B products that exceeded the limit were bacon, 30.1% franks, and 30.1% bologna (\(P > 0.05\)).

Regarding the frequencies of samples exceeding the acceptable TAPC limits (Tables 1 and 2), there were significant differences among locations and size of supermarkets (\(P = 0.001\) for both). In general, the South-East Coast (60%) and Central (68.3%) had higher proportions of samples exceeding acceptable limits compared with the other locations (31.7 to 55%). Samples taken from the small outlets (39.2%) also had

TABLE 2. Frequency of products positive for microorganisms under evaluation by size of grocery\(^a\)

<table>
<thead>
<tr>
<th>Microbial parameter</th>
<th>Small</th>
<th>Medium</th>
<th>Large</th>
<th>Chain</th>
<th>(P) value</th>
</tr>
</thead>
<tbody>
<tr>
<td>TAPC</td>
<td>47 (39.2)</td>
<td>71 (59.2)</td>
<td>32 (53.3)</td>
<td>110 (61.1)</td>
<td>0.001</td>
</tr>
<tr>
<td>S. aureus</td>
<td>3 (2.5)</td>
<td>2 (1.7)</td>
<td>0 (0.0)</td>
<td>3 (1.7)</td>
<td>&gt;0.05</td>
</tr>
<tr>
<td>E. coli</td>
<td>0 (0.0)</td>
<td>5 (4.2)</td>
<td>2 (3.3)</td>
<td>0 (0.0)</td>
<td>0.007</td>
</tr>
<tr>
<td>Total coliforms</td>
<td>13 (10.8)</td>
<td>16 (13.3)</td>
<td>12 (20.0)</td>
<td>22 (12.2)</td>
<td>&gt;0.05</td>
</tr>
<tr>
<td>Listeria spp.</td>
<td>19 (15.8)</td>
<td>24 (20.0)</td>
<td>15 (25.0)</td>
<td>35 (19.4)</td>
<td>&gt;0.05</td>
</tr>
<tr>
<td>L. monocytogenes</td>
<td>9 (7.5)</td>
<td>7 (5.8)</td>
<td>4 (6.7)</td>
<td>16 (8.9)</td>
<td>&gt;0.05</td>
</tr>
</tbody>
</table>

\(^a\) \(n = 120\) for small and medium, 60 for large, and 180 for chain supermarkets.

\(^b\) Acceptable limits: TAPC, \(10^5\) CFU/g; S. aureus, \(10^4\) CFU/g; E. coli, \(10^5\) CFU/g; L. monocytogenes, not detected in 25 g (7, 13, 15, 18).
lower proportions that exceeded the limit in comparison to the medium-sized (59.2%), large (53.3%), and chain (61.1%) supermarkets.

Significant differences in TAPC were also observed among locations (P < 0.001) and size (P = 0.001, Table 3). Median values based on location and size of groceries followed a similar trend to the frequencies of samples that exceeded recommended limits. The highest median values were from Central (9.0 × 10⁶ CFU/g) and South-East Coast (1.4 × 10⁸), while the lowest was from the North-West Coast (1.2 × 10⁴). Median TAPCs increased progressively with size of grocery values, with values of 4.4 × 10³, 4.4 × 10⁵, 5.2 × 10⁵, and 2.0 × 10⁶ for small, medium, large, and chain supermarkets, respectively.

**Coliforms.** Coliforms were detected in 63 (13.1%) of 480 of samples, 47 (75%) of which were brand A and 16 (25%) brand B products (P < 0.001). The majority (61.9%) of the coliform-positive samples were bacon (39 of 63), while 20 (31.7%) were franks and 4 (6.3%) were bologna (P < 0.001). A further breakdown of positive products from brand A showed that most (61.9%) were bacon (31 of 47), followed by franks (31.9%, 15 of 47), and bologna (21.1%, 1 of 47; P < 0.001). Likewise, brand B products showed a similar trend with 50% (8 of 16) bacon samples positive for coliforms, followed by 5 franks (31.3%) and 3 bologna samples (18.8%) (P > 0.05).

Supermarkets at all locations, and of all sizes, carried meat products that were positive for coliforms; however, there were no significant differences in their distribution (P > 0.05, Tables 1 and 2). Likewise, analysis of the quantitative data did not show significant differences (P > 0.05) based on location (P > 0.05) and size (P > 0.05) of groceries, with medium and mode values being zero (data not shown).

**E. coli.** Seven (1.5%) of 480 samples were positive for *E. coli*, and all of them exceeded acceptable limits (≥10² CFU/g) (7, 13, 15, 18). All samples were brand A bacon products obtained from large and medium-sized supermarkets located in the East-West Corridor. Regarding the frequencies of samples exceeding the acceptable TAPC limits (Tables 1 and 2), there were significant differences among the different sizes of supermarkets (P < 0.05), but not for location (P > 0.05).

Likewise, significant differences were detected among the microbial counts of all 480 samples according to grocery size (P < 0.05), but not for location (P > 0.05). However, median and mode values were zero.

None of the samples were positive for *E. coli* O157.

**S. aureus.** Of 480 samples 48 (10.0%) were positive for *S. aureus*, including 8 (16.7%) with counts of *S. aureus* that exceeded acceptable limits (≥10⁴ CFU/g) (7, 13, 15, 18) and all originated from brand A. These were mostly bacon at 62.5% (5 of 8), followed by bologna at 25.0% (2 of 8), and franks at 12.5% (1 of 8). However, the difference was not statistically significant (P > 0.05).

No significant differences in the distribution of samples exceeding acceptable limits were observed among supermarket sizes (P > 0.05); however, there were significant differences among locations (P = 0.025, Tables 1 and 2). The North-West Coast (5%) and South-East Coast (5%) had greater proportions of samples exceeding limits for *S. aureus* compared with the other zones (0 to 0.8%).

Similarly, significant differences were detected for quantitative levels according to grocery location (P < 0.003), but not for size (P > 0.05). However, median and mode values were zero (data not shown).

**Listeria spp.** The overall prevalence of *Listeria* spp. was 19.4% (93 of 480). Of the *Listeria*-positive products, 67 (72.0%) were bacon, while 23.7% (22 of 93) were franks, and 4.3% (4 of 93) were bologna (P < 0.001). The vast majority (70 of 93) of *Listeria*-positive samples were from brand A products compared with brand B (23 of 93, P < 0.001).

Bacon was the product with the highest frequency of *Listeria*-positive samples compared with the other products in both brands (P < 0.001). *Listeria*-positive brand A products consisted of 50 (71.4%) bacon, 17 (24.3%) franks, and 3 (4.3%) bologna samples. *Listeria*-positive brand B items consisted of 17 (73.9%) bacon, 5 (21.7%) franks, and 1 (4.3%) bologna samples. There was no significant difference among locations or size of supermarkets (P > 0.05) for the distribution of *Listeria*-positive samples (Tables 1 and 2).

**L. monocytogenes.** Of the 93 isolates identified as *Listeria* spp., 36 (38.7%) were confirmed as *L. monocytogenes*. The overall prevalence of *L. monocytogenes* was

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**TABLE 3. Median (range) total aerobic plate counts of processed meat samples by location and size of supermarkets**

<table>
<thead>
<tr>
<th>Location</th>
<th>Median TAPC (CFU/g)</th>
<th>Range TAPC (CFU/g)</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>East-West Corridor</td>
<td>4.0 × 10⁵ (0.0–8.6 × 10⁶)</td>
<td>1.2 × 10⁴ (0.0–4.4 × 10⁵)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>North-West Coast</td>
<td>1.4 × 10⁶ (0.0–5.4 × 10⁵)</td>
<td>9.0 × 10⁶ (0.0–3.8 × 10⁶)</td>
<td></td>
</tr>
<tr>
<td>South-East Coast</td>
<td>2.1 × 10⁵ (0.0–5.0 × 10⁵)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Central</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>South</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Size</th>
<th>Median TAPC (CFU/g)</th>
<th>Range TAPC (CFU/g)</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Small</td>
<td>4.4 × 10³ (0.0–8.0 × 10⁶)</td>
<td>4.4 × 10⁵ (0.0–8.6 × 10⁵)</td>
<td>0.001</td>
</tr>
<tr>
<td>Medium</td>
<td>5.2 × 10⁵ (0.0–4.7 × 10⁶)</td>
<td>2.0 × 10⁶ (0.0–5.0 × 10⁶)</td>
<td></td>
</tr>
<tr>
<td>Large</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chain</td>
<td></td>
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</tbody>
</table>
7.5% (36 of 480) based on biochemical and serological analysis. The differences in the frequency of isolation of *L. monocytogenes* from meat products by location and size of supermarkets were not statistically significant (*P > 0.05*, Tables 1 and 2). However, *L. monocytogenes* was detected only in brand A products and the frequency of positive bacon samples (30 of 36) was significantly (*P < 0.001*) higher than those of franks (4 of 36) and bologna (2 of 36).

**Salmonella.** None of the 480 samples were positive for *Salmonella.*

**DISCUSSION**

The current study indicated that popular locally produced processed meats sold in retail outlets in the island of Trinidad, West Indies, may pose a risk to consumers due to the presence of pathogenic microorganisms. Franks and bologna are considered RTE foods in most parts of the world, and this designation also is used for bacon in many countries. Thus, the presence of unacceptable levels of microorganisms in these foods is of major importance to consumers, producers, and regulators. In this study, the levels of several pathogenic or indicator bacteria exceeding internationally accepted microbiological guidelines included *E. coli* (1.5%), *S. aureus* (1.7%), *L. monocytogenes* (7.5%), and total aerobic bacteria (54.2%). Gibbons et al. (14), investigating possible sources of bacterial contamination in one plant in Trinidad that had a voluntary recall of RTE meats in 2003, found that postcooked deli meat products harbored pathogenic or fecal indicator bacteria, such as *Listeria* spp. (20.0%) and *E. coli* (5.6%). Additionally, the products harbored aerobic bacteria at unacceptable levels. The overall prevalence rate of 19.4% for *Listeria* spp. in retail products in this study was similar to what was reported for the processing plant samples by Gibbons et al. (14). However, the present study found a lower prevalence rate for *E. coli* (1.5%). More than half (54.2%) of the meat products in this study also carried microbial loads of aerobic bacteria that exceeded international standards. Thus, the presence of pathogenic and fecal indicator bacteria in locally produced processed meats remains a problem due to the potential risk of foodborne illness to consumers.

The prevalence of *S. aureus* was 10.0% and this was similar to the prevalence of 11.1% reported for ready-for-sale smoked hams sold in Germany and the 7.1% for processed meats in South Africa (3, 39). Such values for precooked processed meats generally tend to be lower than their uncooked counterparts. *S. aureus* was isolated from 65.8% of raw chicken meats in one study in Japan (21) and from 23.4% ground beef samples in South Africa (39).

For *Listeria* spp., the prevalence (19.4%) in processed meats manufactured in the two Trinidad plants was lower compared with retail processed pork products in the United States, where 53.1% tested positive (8). In the current study, *L. monocytogenes* was found in 7.5% of samples, a prevalence rate comparably lower than that reported for RTE sausages and processed pork products in Eastern European countries, such as Russia (31.8%), and Latvia and Lithuania (38.0%) (6, 9). Similarly, a prevalence of 27.1% was reported for *L. monocytogenes* in prepacked processed pork products in the United States (8).

The detection of *L. monocytogenes* in meats processed and sold in Trinidad is of significant importance considering that it is a zero-tolerance species of bacteria. This pathogen has the potential to cause grave illnesses in humans, including septic abortions, meningitis, and other severe gastrointestinal symptoms (15, 41).

*Salmonella* was not detected in retail processed meat products sampled in this study. This finding is in agreement with a similar 0.0% prevalence reported for RTE meats in the earlier study in Trinidad (14). However, the prevalence rate is considerably lower than those in reports from other countries, including prepackaged processed pork products manufactured in the United States and RTE foods in Lebanon, where the prevalence of *Salmonella* was 12.5 and 47.5%, respectively (8, 17). Therefore, deli meats in Trinidad appear to pose low risks of salmonellosis to consumers. Similarly, in this study, *E. coli* O157 was not detected in any sample. This was in contrast with the report by Gibbons et al. (14), who found a prevalence rate of 9.1% for this indicator organism in samples of deli meats in Trinidad. This indicates that meat processors in the island may have improved quality control systems to eliminate this organism from their products.

A general pattern was observed in this study where the product with the highest frequency of unacceptable microbiological quality generally was found to be bacon, followed by franks and then bologna. Bacon products accounted for as many as 62.5 and 100.0% of the samples that exceeded international standards for *S. aureus* and *E. coli*, respectively. Additionally, bacon accounted for 72% of all products that were contaminated by *Listeria* spp.; 83% of the samples positive for *L. monocytogenes*, 41.5% of samples exceeding international standards for aerobic bacteria, and 61.9% of those positive for coliforms. This clearly illustrates that bacon products may pose a major health risk to consumers. Factors unique to bacon products, such as nutrient content and pH, may have contributed, in part, to its high bacterial counts (31). Bacon is different from the other two product types (franks and bologna) by its animal source (pork) and associated high fat content. Studies have shown that the presence of fat protects various species of bacteria, such as *Listeria* spp. and *Salmonella* spp., in food and contributes to spoilage by lipid oxidation (23, 40). Although the frequency of chicken franks and bologna samples with unacceptable levels of bacteria was lower than bacon, these products also pose a significant threat to consumers, particularly because they are considered RTE.

Generally, there was widespread distribution of the different bacterial groups among the different regions. However, some differences were observed in samples from the North-West, which had relatively lower TAPC than the other zones, and also for *S. aureus*, which was not detected in any samples from Central and South (Table 1). Similarly, *E. coli* was detected only in samples from the East-West Corridor. These results suggested the possibility that factors before the meats reaching the retail outlets may be
contributing to microbiological quality. These factors may include inadequate heat treatment and postprocessing contamination at the plant or during distribution and marketing (14). Syne et al. (35) reported high bacterial levels, including *S. aureus* and aerobic bacteria, in postcooked RTE meats at one processing plant in the island and suggested postcooking contamination as contributing to the poor quality of the products. The presence of *E. coli* and *Listeria* spp. also may signify poor hygienic conditions or inadequate heat treatments, and in the case of *S. aureus*, possible time–temperature abuse and human contact of the product (13, 14). The manufacturers of the meats investigated in this study, particularly the brand A products, must revise their quality assurance programs to reduce risks of foodborne infections to consumers. However, some factors during retail marketing of the products may be contributing to the variations in food quality observed in supermarkets, as was noted for TAPC, *S. aureus*, and *E. coli*.

All grocers included in the survey of this study indicated that they took ample precautions and safety precautions (34). However, factors, such as changing temperature control; irregular maintenance of freezers, cool rooms, and refrigerators; in addition to stock not being rotated could result in unsafe food. Overall, there were no statistically significant differences among the various sizes of supermarkets that harbored products unfit for consumption. The only exception to this was the instance of small supermarkets having the lowest percentage of products with unacceptable levels of aerobic bacteria. This indicated a relatively greater level of loss of control of microorganisms by the larger supermarkets, which, therefore, indicated increased potential risks to consumers of processed meats from these outlets. The relatively lower quality of foods in the larger supermarkets was unexpected. However, these supermarkets are expected to have relatively large numbers of workers, who may be more difficult to train and supervise by management. In small supermarkets, there were fewer employees and owners mostly supervised all activities (such as cashing and stockpiling) themselves (34). Therefore, it is likely that owners would personally ensure that standards are met for the storage and display of goods in an effort to prevent spoilage and maximize profits.

It is evident from this study that the quality of processed meats in Trinidad tends to be frequently compromised, especially bacon products and those that are brand A. Therefore, it is imperative for manufacturers, retailers, and regulators to ensure more effective management systems are introduced to improve the microbial quality of processed meats sold to consumers in the island.

**ACKNOWLEDGMENT**

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