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ABSTRACT

Abstract

The consumption of foodborne pathogens contaminated in food is one of the major causes of diarrheal diseases in Thailand. The objective of this study was to evaluate the prevalence and types of contaminating bacteria in retailed foods sold in Thailand. Food from four categories (137 samples total), including meat (51 samples), vegetables (38 samples), fish or seafood (37 samples), and fermented food (11 samples), was purchased randomly from seven different open-markets and seven supermarkets in Thailand from August 2010 to March 2011. Seven types of major foodborne pathogens were identified using conventional culture methods. Approximately 80% of meat samples tested was contaminated with Salmonella spp. In contrast, the Salmonella spp. contamination rate of vegetable (5%) or fermented food (9%) samples was comparatively low. Six strains of Cronobacter sakazakii and two strains of Yersinia enterocolitica were also isolated. A substantially higher rate of contamination by Bacillus cereus was observed in fermented food (82%) than in samples of meat (2%) and fish or seafood (5%). Seven Listeria spp. isolates were obtained from meat and fish or seafood samples. Approximately 39% of samples tested were found to be contaminated with Staphylococcus spp. (54 isolates). The rate of bacterial contamination of meat did not depend on the type of market. However, the contamination rate of Staphylococcus spp. in vegetables was higher in open markets than in supermarkets, and the contamination rate of Salmonella spp. and Staphylococcus spp. in fish or seafood samples purchased in open markets was likewise higher than in those purchased in supermarkets. Therefore, improvement of hygienic practices throughout the food chain may be required to reduce the risk of food poisoning.

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Prevalence of Foodborne Pathogens in Retailed Foods in Thailand

Chiraporn Ananchaipattana,1,3 Yukie Hosotani,1 Susumu Kawasaki,1 Sirikae Pongsawat,1 Bari Md. Latiful,4 Seiichiro Isobe,1,2 and Yasuhiro Inatsu1

Abstract

The consumption of foodborne pathogens contaminated in food is one of the major causes of diarrheal diseases in Thailand. The objective of this study was to evaluate the prevalence and types of contaminating bacteria in retailed foodstuffs in Thailand. Food from four categories (137 samples total), including meat (51 samples), vegetables (38 samples), fish or seafood (37 samples), and fermented food (11 samples), was purchased randomly from seven different open-markets and seven supermarkets in Thailand from August 2010 to March 2011. Seven types of major foodborne pathogens were identified using conventional culture methods. Approximately 80% of meat samples tested was contaminated with Salmonella spp. In contrast, the Salmonella spp. contamination rate of vegetable (5%) or fermented food (9%) samples was comparatively low. Six strains of Cronobacter sakazakii and two strains of Yersinia enterocolitica were also isolated. A substantially higher rate of contamination by Bacillus cereus was observed in fermented food (82%) than in samples of meat (2%) and fish or seafood (5%). Seven Listeria spp. isolates were obtained from meat and fish or seafood samples. Approximately 39% of samples tested were found to be contaminated with Staphylococcus spp. (54 isolates). The rate of bacterial contamination of meat did not depend on the type of market. However, the contamination rate of Staphylococcus spp. in vegetables was higher in open markets than in supermarkets, and the contamination rate of Salmonella spp. and Staphylococcus spp. in fish or seafood samples purchased in open markets was likewise higher than in those purchased in supermarkets. Therefore, improvement of hygienic practices throughout the food chain may be required to reduce the risk of food poisoning.

Introduction

Production and processing of foods is now making an important contribution to development of countries. In the case of Thailand, the government has clearly emphasized food security and safety by promoting "safe food products" for both domestic and international markets. In addition, the Thai government has established a policy to develop Thailand as the "Kitchen of the World." It may be needless to say that conducting hygienic food practices in food chain increases the quality of not only exported foods but also domestic foods. However, various kinds of foodborne pathogens have been found in Thai food, and they may be a major cause of diarrheal diseases in this country (Boonmar et al., 2003; Indrawattana et al., 2011; Minami et al., 2010; Padungtod and Kanene, 2006; Suthienkul et al., 1990; Vindigni et al., 2007; Vuddhakul et al., 2000).

There are two types of retail markets in Thailand: supermarkets and open markets. Supermarkets are indoors, often air conditioned, typically offer controlled-temperature environments, and have displays of prepackaged products under refrigeration. In contrast, open markets are traditional open-air markets where foodstuffs are sold by individual vendors or farmers and are usually displayed unwrapped and at ambient temperature. Same categories of foods (such as vegetables, raw meats, fishes) tend to be sold by each vendor in the open markets. These markets naturally have multiple sources of potential contamination (rodents, insects, sewage, and water). The state of the prevalence of foodborne pathogens in retailed foodstuffs sold in these markets is not clear.

The objective of this study, therefore, was to evaluate the contamination rate and types of foodborne pathogens including Escherichia (E.) coli, Salmonella spp., Cronobacter (C.) sakazakii, Yersinia spp., Listeria spp., Staphylococcus spp., and...
Bacillus (B.) cereus in four categories of retailed food (meat, vegetables, fish or seafood, and fermented food) in two kinds of Thai markets.

**Methods**

**Collection of Thai food samples**

Raw food samples (137 total) from four categories including meat (51 samples include of 23 pork samples, 17 chicken samples, 11 beef samples), leafy vegetables (38 samples), fish or seafood (37 samples) and fermented meat/fish food (11 samples) were purchased randomly from geographically different seven open-markets and seven supermarkets in the Bangkok and Pathum Thani areas from August 2010 to March 2011. All samples were transported to the laboratory at Rajamangala University of Technology Thanyaburi in an insulated box with ice to maintain the temperature at 4-6°C.

**Escherichia coli**

A 25-g sample was homogenized with 225 mL of sterile mEC enrichment broth (Eiken Co., Ltd., Tokyo, Japan), and the mixture was incubated at 42°C for 24 h. Following incubation, one loopful of broth was streaked onto Rainbow Agar (O157; Biolog Inc., Hayward, CA), Chrom Agar O26-O157 (ISEL, Kanto Chemical Co. Inc, Tokyo, Japan), XMEHEC agar (Nissui Co., Ltd., Tokyo, Japan), and CT-MacConkey Sorbitol agar (Nissui Co., Ltd.) and incubated at 35°C for 24 h. Typical E. coli serotype O26, O157, or O111 suspected colonies were picked and confirmed by their biochemical characteristics in TSI/LIM tubes (Nissui Co., Ltd.) and API 20E (BioMérieux, Marcy l'Etoile, France) diagnostic kits. The possibility of production of Shiga-like toxin (stx) 1 and Shiga-like toxin (stx) 2 was assayed by NH Immunochromatost VTI/1 (Cosmo Bio Co., Carlsbad, CA) and O-157 VTI/1 PCR Typing Set Plus (Takara Biotechnology Co., Ltd., Osaka, Japan).

**Salmonella spp.**

A 25-g sample was homogenized with 225 mL of sterile EEM enrichment broth (Nissui Co., Ltd.) and incubated at 35°C for 24 h. After incubation, 0.5- and 1.0-mL portions of the EEM-enriched sample were transferred to 10 mL of Rappaport-Vassiliadis (RV) broth and Hjurna tetraethionate (TD) broth (Eiken Co., Ltd., Tokyo, Japan), respectively. The RV broth was incubated at 42°C for 24 h, and the TD broth was incubated at 35°C for 24 h. Following incubation, both cultures were streaked on DHL agar (Nissui Co., Ltd.), bismuth sulfide agar (Difco Lab., Detroit, MI), and MLCB agar (Nissui Co., Ltd.) and incubated at 35°C for 24 h. Suspected colonies were picked and subjected to biochemical testing with TSI/LIM tubes and with the Sintromell LA “Seiken” latex-agglutination test kit (Denka Seiken Co., Ltd., Tokyo, Japan). Positive isolates were confirmed as API 20E diagnostic kits.

**Yersinia spp.**

A 25-g sample was homogenized in 225 mL of phosphate-buffered saline (PBS, pH 7.0) and incubated at 10°C for 7 days. After enrichment, a loopful of culture was streaked onto Yersinia selective agar (Oxoid Ltd., Basingstoke, UK) with Yersinia selective supplement SR0109 (Oxoid Ltd.) and incubated at 30°C for 24 h. Following incubation, colonies were isolated and confirmed using an API 20E (BioMérieux) diagnostic kit. Positive Y. enterocolitica strains were isolated and confirmed by 16S ribosomal DNA sequencing.

**Cronobacter sakazakii**

Samples were homogenized in Moseel-Bouillon enrichment medium (Merck, Darmstadt, Germany) and followed by incubation at 35°C for 24 h. Pre-enrichment cultures were used for isolation of C. sakazakii on Chromocult Enterobacter sakazakii agar (Merck). Colonies were subjected to further characterization using an API 20E kit and 16S ribosomal DNA sequencing for C. sakazakii.

**Listeria spp.**

A 25-g food sample was homogenized in 225 mL of Listeria enrichment broth (Oxoid Ltd.) with Listeria selective enrichment supplement SR014IE (Oxoid Ltd.) and incubated for 48 h at 30°C. After incubation, a loopful of culture was streaked onto Listeria selective agar (Oxoid Ltd.) supplemented with SR014IE (Oxoid Ltd.) and incubated at 30°C for 48 h. Suspected colonies were restreaked on TSA agar with 0.6% yeast extract, and their identity was confirmed using an API Listeria (BioMérieux) diagnostic kit. Confirmation tests were performed with an NH Immunochromatost Listeria kit (Cosmo Bio Co.) or by 16S ribosomal DNA sequencing.

**Bacillus spp.**

A 25-g sample was homogenized in 225 mL of buffered peptone water (Merck) and incubated at 30°C for 24 h. This pre-enrichment culture was streaked on NGKG agar (Nissui Co., Ltd.) with 20% egg yolk and incubated at 30°C for 24 h. Suspected colonies were isolated, identified by microscopic examination, and confirmed using an API 50CH with API CHB (BioMérieux) diagnostic kit. Production of diarreal enterotoxin was determined with a CRET-RPLA Kit (Denka Seiken Co., Ltd.). A PCR Detection kit (Takara Bio Inc., Tokyo, Japan) was used to amplify the ceruleide synthetic enzyme (Crs) gene.

**Staphylococcus spp.**

One loopful of pre-enrichment culture used for the isolation of Bacillus spp. was streaked on mannitol salt agar (Nissui Co., Ltd.) with 20% egg yolk and incubated at 30°C for 24 h. Suspected colonies were isolated and identified by microscopic examination and confirmed using an API Staph (BioMérieux) diagnostic kit and 16S ribosomal DNA sequencing. Enterotoxin-producing S. aureus strains were isolated and confirmed using a PA Lister (Eiken Chemical Co., Ltd.) immuno-lateagglutination test kit.

**Statistical analysis**

One-way analysis of variance (ANOVA) was used to evaluate differences in the number of positive samples per food group. A statistically significant deviation of the contamination rate of each of the tested pathogens among the four categories of tested food samples was detected by chi square test. Differences between the two types of market were evaluated using Fisher's exact probability test. Microsoft EXCEL 2007 (Microsoft, Redmond, WA) was used for the data analysis.
### TABLE 1. Contamination Rate of Pathogens in 137 Retail Foods in Thailand

#### Gram-negative pathogens

<table>
<thead>
<tr>
<th>Categories of foods</th>
<th>Total Numbers of tested samples</th>
<th>Contaminated samples</th>
<th>Contaminated samples</th>
<th>Contaminated samples</th>
<th>Contaminated samples</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Number (%)</td>
<td>Number (%)</td>
<td>Number (%)</td>
<td>Number (%)</td>
<td>Number (%)</td>
</tr>
<tr>
<td>Meat</td>
<td>51</td>
<td>42 (82)</td>
<td>41 (80)</td>
<td>1 (2)</td>
<td>1 (2)</td>
</tr>
<tr>
<td>Fish or seafood</td>
<td>37</td>
<td>22 (59)</td>
<td>13 (35)</td>
<td>2 (5)</td>
<td>1 (3)</td>
</tr>
<tr>
<td>Vegetable</td>
<td>36</td>
<td>11 (29)</td>
<td>2 (5)</td>
<td>0 (0)</td>
<td>4 (11)</td>
</tr>
<tr>
<td>Fermented pork or fish</td>
<td>11</td>
<td>2 (18)</td>
<td>1 (9)</td>
<td>0 (0)</td>
<td>0 (0)</td>
</tr>
<tr>
<td>Total</td>
<td>137</td>
<td>77* (56)</td>
<td>57* (42)</td>
<td>3 (2)</td>
<td>6 (4)</td>
</tr>
</tbody>
</table>

*Total value shows the existence of significant deviation of the rate among four categories of foods. Contamination rates of seven pathogens into four categories of foods were shown.

#### Gram-positive pathogens

<table>
<thead>
<tr>
<th>Categories of foods</th>
<th>Total Numbers of tested samples</th>
<th>Contaminated samples</th>
<th>Contaminated samples</th>
<th>Contaminated samples</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Number (%)</td>
<td>Number (%)</td>
<td>Number (%)</td>
<td>Number (%)</td>
</tr>
<tr>
<td>Meat</td>
<td>51</td>
<td>6 (12)</td>
<td>1 (2)</td>
<td>29 (57)</td>
</tr>
<tr>
<td>Fish or seafood</td>
<td>37</td>
<td>1 (3)</td>
<td>2 (5)</td>
<td>8 (22)</td>
</tr>
<tr>
<td>Vegetable</td>
<td>38</td>
<td>0 (0)</td>
<td>13 (34)</td>
<td>16 (42)</td>
</tr>
<tr>
<td>Fermented pork or fish</td>
<td>11</td>
<td>0 (0)</td>
<td>9 (22)</td>
<td>1 (9)</td>
</tr>
<tr>
<td>Total</td>
<td>137</td>
<td>7 (5)</td>
<td>27* (20)</td>
<td>54* (39)</td>
</tr>
</tbody>
</table>

A total of 137 samples, including meat, vegetables, fish or seafood, and fermented food, were obtained from different open markets and supermarkets.

Forty-two of 137 (31%) food samples were contaminated with several kinds of three tested serotypes (O26, O157, and O111) of _E. coli_; 57% meat samples (29 of 51 meat samples), 22% fish or sea food samples (eight of 37 fish or sea food samples), 11% vegetables (four of 38 vegetables), and 9% fermented pork or fish samples (one of 11 fermented pork or fish samples). A significant (*p* < 0.05) difference in the _E. coli_ contamination rate between open market and supermarket was observed in the case of fish or seafood: open market 76% and supermarket 45%. Similarly, in the case of vegetable samples the following was found: open market 44% and supermarket 15%. In 136 of _E. coli_ O26, O157, and O111 suspected strains isolated from all the tested samples, no strain harbored stx1/2 genes nor did any produce Shiga-like toxins.

A comparably higher rate of contamination was observed for _Salmonella_ spp. (at 80% in the meat samples). However, only 5% of the vegetable samples were contaminated by _Salmonella_ spp. (Table 1). Two vegetable samples were found to be contaminated with _Salmonella_ spp.; one was a morning glory from the supermarket and the other was kale from an open market. The prevalence of _Salmonella_ spp. in meat samples from open markets was found to be 83% (30 of 36 meat samples, including 82% of chicken, 78% of beef, and 88% of pork samples) and from supermarkets was found to be 67% (10 of 15 meat samples, including 50% of chicken, 50% of beef, and 86% of pork samples). No significant difference in prevalence of _Salmonella_ spp. in meat was observed between open-market and supermarket samples (*p* > 0.05) (Table 2). However, a significantly (*p* < 0.05) higher rate of contamination by _Salmonella_ spp. was observed in fish or seafood from open markets (65%) compared to supermarkets (10%; Table 2).

In 137 collected samples, two _Y. enterocolitica_ strains were isolated from one beef sample from an open market (2% of 51 meat samples) and from one shrimp sample from a supermarket (5% of 37 fish or seafood samples). In addition, six _C. sakazakii_ strains were isolated from one meat sample from an open market (2% of 51 meat samples), from one fish sample from an open market (5% of 37 fish or seafood samples), and from four vegetable samples (11% of 38 vegetable samples), including three vegetable samples from open markets and one vegetable sample from a supermarket.

The highest prevalence of _Staphylococcus_ spp. was found in meat samples (57%), while the lowest prevalence was found in fermented food samples (9%). _Staphylococcus_ spp. was present at a greater frequency in vegetables and fish or seafood from open markets (67% and 41%, respectively) than from supermarkets (25% and 5%, respectively; Table 2). A higher rate of contamination by _B. cereus_ was found in fermented food (82%) compared to meat, and fish or seafood (2% and 5%, respectively) (Table 1). There were 27 _B. cereus_ strains isolated, and of those, 18 were found to produce diarrheal enterotoxin, but we were not able to detect the cereolide synthetic enzyme gene in any of the strains (Table 3).

Seven _Listeria_ spp. (including four isolates of _L. innocua_, one isolate of _L. welshimeri_, and two isolates of _L. monocytogenes_) were identified using 16S ribosomal DNA sequencing. Two _L. monocytogenes_ strains were isolated from chicken and ground pork samples from open markets. _L. monocytogenes_
Table 2. Comparison of the Contamination Rate of Foods Sold in Open Markets and Supermarkets

<table>
<thead>
<tr>
<th>Categories of Foods</th>
<th>Pathogens</th>
<th>Open markets</th>
<th></th>
<th>Supermarkets</th>
<th></th>
<th>Fisher's Direct P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Numbers (%)</td>
<td>Numbers (%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Meat</td>
<td>Escherichia coli</td>
<td>30/36 (83)</td>
<td>12/15 (80)</td>
<td></td>
<td></td>
<td>0.76</td>
</tr>
<tr>
<td></td>
<td>Salmonella spp.</td>
<td>30/36 (83)</td>
<td>10/15 (67)</td>
<td></td>
<td></td>
<td>0.95</td>
</tr>
<tr>
<td></td>
<td>Yersinia spp.</td>
<td>1/36 (3)</td>
<td>0/15 (0)</td>
<td></td>
<td></td>
<td>0.71</td>
</tr>
<tr>
<td></td>
<td>Cronobacter sakazakii</td>
<td>1/36 (3)</td>
<td>0/15 (0)</td>
<td></td>
<td></td>
<td>0.71</td>
</tr>
<tr>
<td></td>
<td>Listeria spp.</td>
<td>4/36 (11)</td>
<td>2/15 (13)</td>
<td></td>
<td></td>
<td>0.80</td>
</tr>
<tr>
<td></td>
<td>Bacillus cereus</td>
<td>1/36 (3)</td>
<td>0/15 (0)</td>
<td></td>
<td></td>
<td>0.71</td>
</tr>
<tr>
<td></td>
<td>Staphylococcus spp.</td>
<td>20/36 (56)</td>
<td>9/15 (60)</td>
<td></td>
<td></td>
<td>0.51</td>
</tr>
<tr>
<td>Fish or seafood</td>
<td>Escherichia coli</td>
<td>13/17 (76)</td>
<td>9/20 (45)</td>
<td></td>
<td></td>
<td>0.05</td>
</tr>
<tr>
<td></td>
<td>Salmonella spp.</td>
<td>11/17 (65)</td>
<td>2/20 (10)</td>
<td></td>
<td></td>
<td>0.00</td>
</tr>
<tr>
<td></td>
<td>Yersinia spp.</td>
<td>1/17 (6)</td>
<td>1/20 (5)</td>
<td></td>
<td></td>
<td>0.71</td>
</tr>
<tr>
<td></td>
<td>Cronobacter sakazakii</td>
<td>1/17 (6)</td>
<td>0/20 (0)</td>
<td></td>
<td></td>
<td>0.46</td>
</tr>
<tr>
<td></td>
<td>Listeria spp.</td>
<td>1/17 (6)</td>
<td>0/20 (0)</td>
<td></td>
<td></td>
<td>0.46</td>
</tr>
<tr>
<td></td>
<td>Bacillus cereus</td>
<td>1/17 (6)</td>
<td>1/20 (5)</td>
<td></td>
<td></td>
<td>0.71</td>
</tr>
<tr>
<td></td>
<td>Staphylococcus spp.</td>
<td>7/17 (41)</td>
<td>1/20 (5)</td>
<td></td>
<td></td>
<td>0.01</td>
</tr>
<tr>
<td>Vegetable</td>
<td>Escherichia coli</td>
<td>8/18 (44)</td>
<td>3/20 (15)</td>
<td></td>
<td></td>
<td>0.05</td>
</tr>
<tr>
<td></td>
<td>Salmonella spp.</td>
<td>1/18 (6)</td>
<td>1/20 (5)</td>
<td></td>
<td></td>
<td>0.73</td>
</tr>
<tr>
<td></td>
<td>Yersinia spp.</td>
<td>0/18 (0)</td>
<td>0/20 (0)</td>
<td></td>
<td></td>
<td>1.00</td>
</tr>
<tr>
<td></td>
<td>Cronobacter sakazakii</td>
<td>3/18 (17)</td>
<td>1/20 (5)</td>
<td></td>
<td></td>
<td>0.26</td>
</tr>
<tr>
<td></td>
<td>Listeria spp.</td>
<td>0/18 (0)</td>
<td>0/20 (0)</td>
<td></td>
<td></td>
<td>1.00</td>
</tr>
<tr>
<td></td>
<td>Bacillus cereus</td>
<td>7/18 (39)</td>
<td>6/20 (30)</td>
<td></td>
<td></td>
<td>0.41</td>
</tr>
<tr>
<td></td>
<td>Staphylococcus spp.</td>
<td>12/18 (67)</td>
<td>5/20 (25)</td>
<td></td>
<td></td>
<td>0.01</td>
</tr>
</tbody>
</table>

The contamination rate of each 7 pathogens into 3 categories of foods samples was analyzed. The samples included in the category of "fermented pork or fish" did not compared because we purchased all of them from open market. A statistically significant difference of the contamination rates of Salmonella spp. or Staphylococcus spp. in fish or seafoods and Staphylococcus spp. in vegetable was observed.

Discussion

Recently, Minami et al. (2010) found Salmonella spp. at a 30% prevalence (13 of 44 meat samples, including 48% of chicken samples, but not in any beef or pork samples) in open market meat samples and at a 25% prevalence (12 of 49 meat samples, including 57% of chicken, 24% of beef, and 12% of pork samples) in supermarket meat samples. Similar to this study, there were no statistically significant differences in the prevalence of Salmonella spp. in meat samples between the two types of market (p>0.05). In contrast, Vindigni et al. (2007) found that 93% of meat samples from open market (74 of 80 samples, including 85% of chicken, 100% of beef, and 93% of pork samples) were contaminated with Salmonella spp., while 57% of meat samples from supermarkets (40 of 70 samples, including 35% of chicken, 63% of beef, and 74% of pork samples) were contaminated. Results from these three studies suggest that improvement of hygienic conditions is required at retail outlets especially in open markets. Although we could not observe a significant difference in the prevalence of foodborne pathogens in meat between open markets (67%) and supermarkets (73%), open markets are more susceptible to cross-contamination than supermarkets due to constant exposure to environmental factors such as dust, rodents, and insects. However, if the products displayed at the open markets are received directly from the slaughter house and are sold out at the end of the selling day, the growth of the contaminating pathogens might be limited. Ultimately, efforts must be made by vendors to improve the levels of hygienic conditions to reach that of supermarkets at least.

The prevalence of Salmonella spp. (65%) and Staphylococcus spp. (41%) in fish or seafood from open markets was higher than that in samples from supermarkets (10% and 5%, respectively; Table 2). We observed a statistically significant (p<0.05) difference in the prevalence of foodborne pathogens in fish or seafood between open markets (65%) and supermarkets (10%). One reason for this difference in prevalence may be due to differences in food hygiene control (in the process of food cutting, for example) used between the two types of market.

Table 3. Production of Diarrheal Enterotoxins and Presence of the Cereulide Synthetic Enzyme (CRS) Gene in Isolated B. cereus

<table>
<thead>
<tr>
<th>Categories of foods</th>
<th>Number of tested sample</th>
<th>Number of isolated B. cereus</th>
<th>Number of enterotoxin producing strains</th>
</tr>
</thead>
<tbody>
<tr>
<td>Meat</td>
<td>51</td>
<td>1</td>
<td>10</td>
</tr>
<tr>
<td>Fish or seafood</td>
<td>38</td>
<td>13</td>
<td>1</td>
</tr>
<tr>
<td>Vegetable</td>
<td>37</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>Fermented pork or fish</td>
<td>11</td>
<td>9</td>
<td>6</td>
</tr>
<tr>
<td>Total</td>
<td>137</td>
<td>27</td>
<td>18</td>
</tr>
</tbody>
</table>

A 67% of isolated B. cereus strains produced enterotoxin but no strain harbored CRS gene.
in each type of market. In addition, the higher percentage of *Staphylococcus* spp. in open market samples could be a result of contamination of foods samples by unsuitable handling of foods.

This study revealed that the rate of contamination by *Staphylococcus* spp. in vegetables from open markets was higher than that in vegetables from supermarkets. No significant (*p > 0.05*) difference in the prevalence of foodborne pathogens in vegetables between open markets (39%) and supermarkets (30%) was observed. The vegetables sold in supermarkets in Thailand are produced by companies on high-quality farms with good packaging and/or wrapping and distribution practices. These companies usually maintain cool temperatures throughout the distribution process and during display at the supermarket prior to purchase by the consumer. In contrast, vegetables sold in open markets are produced by private farms that have poor management of distribution practices and are sold by different vendors. Unwrapped vegetables are often placed directly on benches at ambient temperature until consumption. A higher prevalence of *Staphylococcus* spp. in open markets occurred due to human contamination of foods samples. Two vegetable samples, one from a supermarket and one from an open market, were contaminated with *Salmonella* spp. The prevalence of *Salmonella* in fresh vegetables is generally considered to be lower than in meat (Baard-Parker, 1991). *Salmonella* outbreaks are often caused by the consumption of meats; however, a foodborne salmonellosis outbreak caused by consumption of vegetables was reported in Thailand (Ministry of Public Health, 2007). Recently, the incidence of *Salmonella* in raw vegetables was reported to be 3% in Selangor, Malaysia (Salleh et al., 2003). The potential hazard of pathogenic bacteria present in vegetables should not be underestimated, particularly in those vegetables eaten raw or lightly cooked.

*Listeria monocytogenes* is the most important human pathogen within the genus *Listeria*. Among the other listerial species, *L. ivanovii*, *L. seeligeri*, and *L. welshimeri* are rarely pathogenic for humans, while *L. grayi*, *L. innocua*, and *L. murrayi* are considered to be non-pathogenic (Graham and Collins, 1991). In this study, *L. monocytogenes* was found at 4% prevalence in 51 meat samples from open markets. In a previous report, *L. monocytogenes* was found at 8% prevalence in 297 meat samples, including 12% of 140 meat samples from open markets and 4% of 157 meat samples from supermarkets (Minami et al., 2010). Recently, Indrawattana et al. (2011) reported a 15.4% prevalence of *L. monocytogenes* in 104 meat samples, supermarkets in Bangkok. Together, these results showed differences in the prevalence of *L. monocytogenes* in retail meat samples from both types of market, for reasons including the environmental conditions of the collection area, the properties of the meat samples, the number of samples, and the time of collection.

Rice is arguably the most important foodstuff associated with *B. cereus* food poisoning (Adams and Moss, 2000). Because of the particular cultivation conditions in rice paddies, where *B. cereus* constitutes approximately 10% of the soil microflora (Varnam and Evans, 1991), raw rice is contaminated to varying degrees by *B. cereus* (Sarrias et al., 2002). Many outbreaks of *B. cereus* food poisoning have been associated with the bulk preparation of rice in advance of consumption or with storage at room temperature for an extended period of time (Adams and Moss, 2000; Mossel et al., 1991). In this study, a high prevalence of *B. cereus* was found in fermented food samples, and this prevalence might be due to contamination of sticky rice, which is an ingredient of traditional fermented pork and fish in Thailand. Thus, a critical step in the fermentation process is to reduce *B. cereus* contamination in cooked rice. However, no *Y. enterocolitica*, *C. sakazukii*, or *Listeria* spp. were isolated from fermented food, and *Salmonella* spp. and *Staphylococcus* spp. were detected at a low frequency. It is likely that lactic acid bacteria (LAB) will suppress the growth of *Listeria* spp. and other pathogenic bacteria because LAB can produce a variety of organic acids and bacteriocins. However, two *Y. enterocolitica* strains were isolated from beef and shrimp samples. Recently, Boonmar et al. (2003) found 2.4% chicken meat samples from retail markets in Thailand were contaminated with non-pathogenic *Y. enterocolitica*.

In this study, we observed substantial microbial contamination of retail foods from both open markets and supermarkets in four food categories. Improvement of hygienic conditions could reduce the risk of food poisoning or spoilage of foods purchased in Thai markets. This study documents the prevalence of microbial contamination in retail food samples in Thailand and provides a foundation for future studies. To provide information on the risk of eating Thai food, we will continue to study the level of contamination in Thai food in the future.

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**References**


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