THE IMPORTANCE OF CAMPYLOBACTER JEJUNI TO THE MEAT INDUSTRY:
A REVIEW

Anthony W. Kotula and Norman J. Stern
US Department of Agriculture
Beltsville, MD 20705

Summary

Campylobacter jejuni is a microorganism that only recently has been implicated in gastroenteritis in humans. As appropriate methods used for detection of the bacterium have been developed, the rates of illness caused by the pathogen were found to approach or surpass those attributed to Salmonella. Substantial evidence has been gathered to document that the route for human infection is through the ingestion of adulterated food and drink. Some slaughter animals harbor this potential pathogen among the intestinal flora and, consequently, transfer of the organism to carcasses and to the resulting meat products does occur. The most frequently implicated meat is poultry, with an incidence of recovery of C. jejuni from the store-bought poultry meat reported to be at least 50%. Red meat from slaughter animals have also yielded this bacterium from carcasses, but at lower incidence levels. Foodborne disease has been associated most frequently with the ingestion of raw milk, but poultry, hamburger, and other foods have all been implicated as potential sources. However, cause and effect relating the presence of C. jejuni in meat and human gastroenteritis has not been demonstrated. Additional research is needed to determine whether C. jejuni isolated from meat causes gastroenteritis and whether all strains of the organism are virulent. Recognition of C. jejuni as a potential meatborne pathogen by the meat industry is necessary, and appropriate sanitary practices to prevent passage of the organism through meat products should be implemented.
(Key Words: Campylobacter jejuni, Potential Pathogen, Meat Industry, Bacteria, Meat.)

Introduction

The microorganism, Campylobacter jejuni, is associated with human gastroenteritis. The organism has recently been recognized as causing more human illness than do salmonellae. With the development of improved media employing antibiotics to inhibit growth of competitive bacteria, C. jejuni has been isolated successfully from a number of animal products but its distribution, mode of transmission and virulence have not been adequately characterized. Published reports during the last few years have dealt mainly with its nomenclature, taxonomical criteria, presence in livestock, its importance to humans, methods for detection and methods of control. This paper addresses what is presently known of this emerging potential pathogen and identifies additional researchable areas concerning C. jejuni.

Nomenclature

The nomenclature of the bacterium Campylobacter jejuni has changed substantially in the last 70 yr. McFadyean and Stockman (1913) first reported the involvement of the pathogen with abortion of sheep and cattle. Because of morphological similarities with other bacteria within the genus Vibrio, it was classified Vibrio fetus (Smith and Taylor, 1919). Sebald and Veron (1963) reported that the G + C (guanine plus cytosine) ratio of V. fetus accounted for about 35% of the DNA base pairs, whereas in V. cholera and other species of Vibrio, the G + C ratio approximated 45%. V. fetus differed further in its inability to ferment carbohydrates and its requirement of a microaerobic atmosphere for growth. Veron and Chatelain (1973) named the bacterium Campylobacter fetus. Smibert (1974) called the organism C. fetus with three subspecies; C. fetus ssp. jejuni, C. fetus ssp. fetus, and C. fetus ssp. intestinalis. The International Committee of Systematic Bacteriology (Skerman et al., 1980) has desig-
nated C. fetus ssp. jejuni as C. jejuni/coli. This nomenclature takes precedence over all others previously used. Additional information concerning the evolution of the classification of C. jejuni is provided in an excellent review article by Doyle (1981).

**Taxonomical Criteria**

C. jejuni/coli differs from C. fetus and C. intestinalis in that it is typically nalidixic acid sensitive, does not grow at 25 C and may or may not grow in 1% glycine. Whereas C. fetus is nalidixic acid resistant, grows in 1% glycine and gives a mixed growth response at 25 C. C. intestinalis grows at 25 C, grows in 1% glycine and is resistant to nalidixic acid. C. coli differs from C. jejuni in that C. coli is predominantly associated with swine rather than humans, it grows at 30.5 C, does not hydrolyze hippurate and is resistant to 2,3,5-triphenyl tetrazolium chloride. C. jejuni, more commonly associated with human infection, grows above 30.5 C, will hydrolyze hippurate and is sensitive to 2,3,5-triphenyl tetrazolium chloride.

The organism, as typically observed in its late log stage of growth (figure 1), appears as gull or spiral shape (Stern, 1982a). In latter stages, it will typically assume a coccoidal shape. The gull-shaped, gram negative C. jejuni has an individual flagella on either end of the organism and is highly motile. The bacterium is characterized by its darting, to and fro corkscrew motion. Conditions for optimum and inhibitory growth of this organism are presented in Table 1. Meat is generally refrigerated below 4 C and the optimum growth temperature is 42 C, so growth of C. jejuni on refrigerated meat is unlikely unless the product suffers temperature abuse. Similarly, the optimal pH of 6.5 to 7.5 and low (5%) oxygen optimum enforces the precept that C. jejuni will not grow on meat that is stored properly.

The pathogenicity of C. jejuni has been demonstrated by Robinson (1981). He isolated C. jejuni from the diarrhea of a stricken individual, grew the organism in pure culture, added 500 cells to milk and drank the milk. Diarrhea resulted in the previously healthy individual and he was able to isolate C. jejuni from his diarrheal specimens.

**Presence in Livestock and Meat**

Stern (1981a,b) reported 0, 73 and 87% isolation of C. jejuni from the intestinal contents of 31 cattle, 15 sheep and 38 swine, respectively. Luechtefeld and Wang (1982) reported 43, 23 and 66% positive fecal samples from 130 cattle, 35 sheep and 71 swine, respectively. Contamination may be transferred from feces to carcasses of slaughter animals. Stern (1981b)

**TABLE 1. GROWTH CONDITIONS FOR C. JEJUNI**

<table>
<thead>
<tr>
<th>Factor</th>
<th>Optimum</th>
<th>Inhibitory</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperature</td>
<td>42 C</td>
<td>&lt;30 C; &gt;48 C</td>
<td>Doyle and Roman (1981)</td>
</tr>
<tr>
<td>pH</td>
<td>6.5–7.5</td>
<td>&lt;4.7; &gt;8.2</td>
<td>Doyle and Roman (1981)</td>
</tr>
<tr>
<td>O₂</td>
<td>5–10%</td>
<td>0; &gt;14%</td>
<td>Smibert (1974)</td>
</tr>
<tr>
<td>Salt</td>
<td>.5</td>
<td>2%</td>
<td>Doyle and Roman (1982b)</td>
</tr>
<tr>
<td>Relative humidity at 4 C</td>
<td>14%</td>
<td>&lt;35%</td>
<td>Doyle and Roman (1982a)</td>
</tr>
</tbody>
</table>

Figure 1. Late log stage of growth of Campylobacter jejuni demonstrating typical gull or spiral shape.
evaluated unwashed carcasses using relatively insensitive methods and reported 2, 24 and 38% positive for C. jejuni on 58 cattle, 54 sheep and 58 swine carcasses, respectively. Simmons and Gibbs (1979) reported 72% of 50 chickens to be positive. Luechtefeld and Wang (1981) found 94% of 83 turkeys were positive, whereas Luechtefeld et al. (1980) reported at 35% of 445 wild ducks were found to be positive. Effective in-plant sanitation procedures should eliminate many of these organisms before the carcasses pass into our meat supply.

**Importance to Humans**

Symptoms of gastroenteritis caused by C. jejuni include diarrhea, sometimes bloody in the later stages, abdominal cramps, fever and vomiting (Bokkenheuser and Mosenthal, 1981). The onset of the symptoms occurs 2 to 7 d after exposure and the illness may last 7 to 10 d. Erythromycin and tetracycline have been used successfully to halt the progression of the infection (Blaser et al., 1979).

In developed countries, 3 to 14% of the clinical gastroenteritis cases have been attributed to C. jejuni. In developing countries the organism has also been isolated from healthy people (Blaser, 1982). This finding raises concern over the possibility that human-to-human transmission may be involved in the etiology of the infection. Pai et al. (1979) reported that of the 1,004 children with gastroenteritis that he evaluated, 5.1% was caused by Salmonella, 4.3% by C. jejuni, 2.8% by Y. enterocolitica and 1.4% by Shigella. Other authors have reported a higher incidence of gastroenteritis due to C. jejuni as compared with Salmonella. Bruton and Heggie (1977) reported 2.5% of their isolations were Salmonella and 8.7% were C. jejuni. Bruce et al. (1977) reported 2.9% and 13.9% for Salmonella and C. jejuni, respectively; whereas Blaser et al. (1979) reported 3.7 and 5.1%, respectively. The presence of C. jejuni in diarrheal patients suffering from gastroenteritis is well documented. The incidence of C. jejuni among people with gastroenteritis in several countries is summarized in table 2. The incidence ranged from a low of 4.0 in Belgium to a high of 34% in South Africa. Somewhat surprisingly the incidence of the organism in persons without gastroenteritis ranged from a low of 1.3% for children in Belgium to a high of 12.5% for children in South Africa (table 3). The sources of Campylobacter infection are not clearly documented. Undercooked chicken has repeatedly been associated with clinical cases of gastroenteritis (Hayek and Cruickshank, 1977; Brouwer et al., 1979; Schaefer et al., 1979; Severin, 1982), but the organism was not isolated from the chicken. Ground beef was eaten raw in the Netherlands (Oosterom, 1981), but likewise, C. jejuni was not isolated from the raw ground beef. In Japan, 800 of 2,500 children exhibited gastroenteritis after eating vinegared pork (Yanagisawa, 1980), but the pork was not evaluated for the presence of C. jejuni. These meats were strongly and epidemiologically incriminated as vehicles of enteritis caused by C. jejuni, but there is a small possibility that other food or water also could have been responsible for the infections.

**Detection Methodology**

The methodology for isolating C. jejuni is based on inhibiting the growth of competing bacteria by incorporating antibiotics into the media. Blaser et al. (1979) recommended adding 10 mg vancomycin, 2,500 IU polymyxin B, 2 mg trimethoprim, 2 mg amphotericin B and 15 mg cephalothin/liter. The food or swab sample can be plated directly on agar containing those or similar antibiotics. Stern (1982c)

<table>
<thead>
<tr>
<th>Country</th>
<th>Source</th>
<th>Number sampled</th>
<th>% positive</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Belgium</td>
<td>Children</td>
<td>800</td>
<td>5.1</td>
<td>Butzler et al. (1973)</td>
</tr>
<tr>
<td>Belgium</td>
<td>Adults</td>
<td>100</td>
<td>4.0</td>
<td>Butzler et al. (1973)</td>
</tr>
<tr>
<td>Canada</td>
<td>Children</td>
<td>1,004</td>
<td>4.3</td>
<td>Pai et al. (1979)</td>
</tr>
<tr>
<td>England</td>
<td>Patients</td>
<td>803</td>
<td>7.1</td>
<td>Skirrow (1977)</td>
</tr>
<tr>
<td>South Africa</td>
<td>Children</td>
<td>34.0</td>
<td>34.0</td>
<td>Bokkenheuser et al. (1979)</td>
</tr>
<tr>
<td>United States</td>
<td>Patients</td>
<td>514</td>
<td>5.1</td>
<td>Blaser et al. (1979)</td>
</tr>
</tbody>
</table>
TABLE 3. C. JEJUNI ISOLATED FROM HUMANS WITHOUT GASTROENTERITIS

<table>
<thead>
<tr>
<th>Country</th>
<th>Source</th>
<th>Number sampled</th>
<th>% positive</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Belgium</td>
<td>Children</td>
<td>1,000</td>
<td>1.3</td>
<td>Butzler et al. (1973)</td>
</tr>
<tr>
<td>Canada</td>
<td>Children</td>
<td>176</td>
<td>0</td>
<td>Pai et al. (1979)</td>
</tr>
<tr>
<td>England</td>
<td>People</td>
<td>194</td>
<td>0</td>
<td>Skirrow (1977)</td>
</tr>
<tr>
<td>South Africa</td>
<td></td>
<td>12.5</td>
<td></td>
<td>Bokkenheuser et al. (1979)</td>
</tr>
<tr>
<td>United States</td>
<td></td>
<td>81</td>
<td>0</td>
<td>Blaser et al. (1979)</td>
</tr>
</tbody>
</table>

reported the Butzler medium (Lauwers et al., 1978) was most selective, while the Campy-BAP medium (Blaser et al., 1979) was most sensitive in detecting C. jejuni inoculated into ground beef. Typical colonies on agar are nonhemolytic, flat or slightly raised having an irregular or round edge, and are translucent gray to pink or tan in color. The colonies appear similar to a water droplet and tend to show confluent growth on a wet surface. A few drops of glycerol on filter paper can be used as a humectant to minimize spreading (Stern, 1982c). Characteristic colonies should be prepared for wet mount, phase contrast microscopic examination. If the wet mount contains C. jejuni, the cells will appear gull, spiral or comma shaped and will exhibit rapid cork-screw-like motion.

The enrichment culture resulted in twice the number of isolations from store bought chickens, when compared with direct plating (Park et al., 1981). Enrichment procedures have been described in detail by both Park and Stankiewicz (1981) and Doyle and Roman (1982a). Both research teams utilized antibiotic supplemented broth and 5% oxygen atmospheres. Park and Stankiewicz (1981) incubated the enrichment broth at 42°C for 1 to 2 d, passed the enrichment culture through a .65 μm pore filter and were able to detect 1 C. jejuni cell among 10^6 indigenous cells. Doyle and Roman (1982a) incubated the inoculated broth at 42°C for 18 h and were able to detect 1 cell among log_{10} 9.0 cells of other organisms. Thus, methodologies have been improved to the degree that C. jejuni can routinely be isolated from meat and meat products.

Control
The carcass of slaughter animals may become contaminated during evisceration. The organism is able to survive storage at 4°C for at least 14 d, but is inactivated by frozen storage at −15°C in as few as 3 d (Stern and Kotula, 1982). On turkeys, C. jejuni was reportedly unaffected by overnight exposure to 340 ppm chlorine (Luechtefeld and Wang, 1981). Heating brucella broth menstruum at 55°C caused about one log reduction in cell numbers over 10 min, whereas heating at 60°C reduced the organism from an initial count of log_{10} 9.0/g to log_{10} 3.0/g in 4 min (Stern, 1982b). Meat is usually cooked to at least 60°C so that heat treatment, if uniform, should be adequate to destroy C. jejuni, if present on meat.

Discussion
What has not been answered is whether there are pathogenic and nonpathogenic strains of C. jejuni. If nonpathogenic strains exist, under which conditions is pathogenicity gained or lost outside of the host? Because the organism has been recovered from asymptomatic people, were the C. jejuni nonpathogenic or were they being controlled by the host immune system? The role of plasmids in causing pathogenicity of the bacterium is unclear, as are the conditions that may precipitate pathogenicity. What nonhuman animal models can be utilized for assessing pathogenicity?

Many documented cases of human gastroenteritis, which have been correctly or incorrectly attributed to C. jejuni in meat, were due to improper handling, such as undercooking. Good sanitary practices to prevent contamination of meat with C. jejuni continue to be necessary. Meat should be cooked properly to destroy C. jejuni, if present. It appears that the organism is more sensitive to inactivation than Salmonella sp.

A cause and effect relationship between C. jejuni in meat and human gastroenteritis has not been demonstrated. The supposition of a high correlation between the presence of C.
jejuni in livestock fecal samples and(or) meat, with its presence in diarrheal samples in humans, may be too simplistic an approach. The research scientist should now focus attention on trying to document a cause and effect (epidemiology) relationship between the presence of C. jejuni in meat and C. jejuni as a causative agent in human gastroenteritis. The presence of such a relationship can be investigated by characterizing the pathogenity of C. jejuni isolates from both sources, using a nonhuman animal model.

Research should also be directed at characterizing whether C. jejuni can survive on meat packaged with oxygen-permeable or vacuum packaging because neither may provide the proper 5 to 10% oxygen necessary for the bacterium. Campylobacters appear to be very sensitive to drying (Doyle and Roman, 1982a; Oosterom, 1983). Likewise, because C. jejuni grows optimally at 42 C and meat is stored at 4 C or below, is properly refrigerated meat able to provide an adequately large dose of the bacteria to cause gastroenteritis? Thus, the future of C. jejuni as a potential pathogen will focus on continued sanitary practices to prevent contamination of meat with the bacterium and research to better understand the implication of its presence on meat.

**Literature Cited**


McFadyean, J. and S. Stockman. 1913. Report of the departmental committee appointed by the Board of Agriculture and Fisheries to enquire into epizootic abortion. His Majesty’s Stationary Office, London.


