Comparison of Media for Determining Temperature Abuse of Fresh Broiler Carcasses Using Impedance Microbiology

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ABSTRACT

Experiments were conducted to determine the ideal medium for detection of temperature abuse of fresh broiler chicken using impedance microbiological techniques. In three separate trials, 15 ready-to-cook broiler chicken carcasses were obtained from the chiller exit of three separate processing plants. Five carcasses were sampled immediately (day 0), 5 carcasses were sampled after temperature abusing at 25°C for 12 h and holding at 3°C for 6 days (temperature abused), and the remaining 5 carcasses were sampled after holding at 3°C for 7 days (day 7 controls). Whole-carcass rinses were diluted by placing 1 ml from each carcass into 9 ml of each of the following media: (1) brain heart infusion broth (BHI), (2) EC broth with 3% added dextrose (ECD), (3) CM medium with 2% added dextrose (CMD), (4) EC broth (EC), and (5) CM medium (CM). The diluted samples were assayed in duplicate at 43°C using impedance microbiological techniques. Once a detection time (DT) was recorded, one ml of the sample was immediately recovered from the module well, diluted to 10-6, 10-7, and 10-8, and spread plated onto plate count agar. Two colonies from each carcass on plates with the highest dilution were randomly selected and identified. Since both gram-positive and gram-negative genera of bacteria were isolated from BHI-cultured carcass rinses and were responsible for changing the impedance of the medium, DTs were variable. EC and ECD media were not suitable for conducting temperature-abuse determinations. Using CMD medium to select for the growth of gram-negative bacteria, specifically E. coli, temperature-abuse determinations were more accurate than using a general medium, such as BHI. CMD appears to be the most effective medium tested to conduct temperature abuse determinations using impedance microbiological techniques.

Key words: Temperature abuse, impedance, chicken, CM medium, E. coli

Decreased shelf life of fresh broiler chicken is generally a function of holding temperature. Currently, the only means by which processing companies can monitor the holding temperature of broiler chickens during transport is by placing temperature-recording devices with the product as it is shipped. These devices are expensive and cumbersome, and results will vary depending on placement of the device within the load.

A rapid microbiological method was described by Russell et al. (9) to differentiate temperature-abused broiler-chicken carcasses from those held at proper storage temperatures (<4°C). This technique is based on the concept that if carcasses are stored at temperatures below 4°C, populations of mesophilic bacteria will remain the same or decrease; whereas, if carcasses are temperature abused, mesophilic bacterial populations will increase in number. By use of impedimetric microbiological techniques and incubation of samples at 42°C, mesophilic bacteria associated with broiler carcasses were differentiated from the indigenous psychrotrophic spoilage flora and were enumerated (9). Carcasses temperature abused for longer than 12 h at 15°C could be microbiologically distinguished from those which were held properly at 4°C; however, carcasses abused for short periods of time or at low temperatures, such as 10°C, could not be differentiated from those held below 4°C. The inability to detect low levels of temperature abuse was attributed to the high coefficient of variation associated with impedance detection times, which was possibly due to the use of a general, rather than a specific, growth medium.

Coliform bacteria, and more specifically Escherichia coli, are present on almost all broiler-chicken carcasses (1, 2). Since E. coli grows well at 42 to 43°C and does not multiply at temperatures below 4°C, it may be suitable as an indicator of temperature abuse of fresh broiler chicken. To enumerate one particular species from a mixed sample, multiplication of target bacterial populations should be encouraged while the growth of competing microorganisms is suppressed. Firstenberg-Eden and Klein (6) evaluated CM medium (CM), lauryl tryptose broth (LTB), MacConkey (MAC), brilliant green bile broth (BGB), and EC broth (EC) and determined that, with use of impedance microbiology, CM was the most effective medium to enumerate coliforms. In another study, CM provided more reproducible impedance signals than conventional media and was more selective than LTB and violet red bile agar for enumerating coliform bacteria (7).

The objectives of this study were (1) to identify the genera and species of bacteria that contribute most to impedance changes in temperature-abused-carcass rinses using five dif-
ferent media; (2) to determine if one particular species of
to determine the optimal medium for
 enumeration of these indicator organisms using impedance
microbiological techniques.

MATERIALS AND METHODS

In each of three separate trials, 15 whole ready-to-cook
temperature abuse; (2) to determine if one particular species of
broiler-chicken carcasses were obtained from the chiller exit
of three different commercial processing plants. The car-
carcasses were placed on ice, transported to the laboratory,
individually bagged in sterile polyethylene bags, and main-
tained at 3°C within 1 h of collection. Five carcasses were
were able to reach the threshold DT level, EC would not
samples after holding at 3°C for 7 days (day 7
organisms using impedance
were sampled on the day of collection (day 0 control). 5 carcasses
were sampled after holding at 25°C for 6 days (temperature abused),
and 5 carcasses were sampled after holding at 3°C for 7 days (day 7
control). Carcasses were sampled by rinsing in 100 ml of sterile
dilution with 3 or more colonies per plate were used for selection.

Diluent (1 ml) from each carcass was placed into 9 ml of
each of the following growth media: brain heart infusion broth
(BHI) (Difco Laboratories, Detroit, MI), EC broth (Difco)
with 3% dextrose (ECD), CM medium (bioMérieux Vitek,
Inc., Hazelwood, MO) with 2% dextrose (CMD), EC broth
(EC) (Difco), and CM medium (CM) (bioMérieux). Lactose
is the primary source of energy for bacteria growing in EC and
CM (8). Lactose, in combination with the other selective
ingredients in these media, is used to select for the growth of
lactose-fermenting gram-negative enteric bacteria, such as
E. coli (8). Dextrose was added to ECD and CMD to increase the
temperature abuse, the bacteria that reached the threshold level
were primarily gram-negative. This difference demonstrates
that in previous temperature-abuse studies using BHI as the
culture medium, the bacterial genera which changed the
impedance of the medium at day 0 or day 7 were different,
with regard to their gram-stain characteristics, from those
which contributed to impedance changes if the carcasses were
temperature abused (9). This may explain the high coefficient
of variation and inability to detect low levels of temperature
abuse observed in that study.

Since Escherichia coli was the most common species of
gram-negative bacteria to reach the threshold DT level using
a general growth medium such as BHI, efforts were made to
select for its growth. EC broth and CM medium were chosen
because they are commercially available media commonly
used to select for the multiplication of E. coli.

With ECD, E. coli was isolated in the highest populations
on day 0 and day 7 (Table 2). However, for temperature-
abused samples, other gram-negative bacteria such as:
Aeromonas sobria, Escherichia vulneris, and Serratia fonticola
contributed to impedance changes. Instead of allowing E. coli
to multiply, the addition of dextrose to EC allowed other species
of bacteria to multiply. The addition of dextrose was disadvantageous
because DTs based on the growth of many species of bacteria are
often more erratic than DTs for samples in which only 1
species was able to reach the threshold DT level consistently
(5).

Addition of dextrose to CM allowed E. coli to multiply
and outcompete other species of bacteria. Using
CMD, E. coli was responsible for 60 out of 65 DTs (Table 3).
Another Escherichia species and Hafnia alvei were the only
species of bacteria other than E. coli that were able to reach the
threshold level of 10^6 cells per ml.

Staphylococcus sciuri (gram-positive), Proteus mirabilis,
Aeromonas sobria, Acinetobacter calcoaceticus, and Kleb-
siella pneumoniae were able to grow in EC (Table 4). Since a
gram-positive bacterium and many genera of gram-negative
bacteria were able to reach the threshold DT level, EC would not

RESULTS AND DISCUSSION

The number of isolates recovered from broiler carcasses
obtained from three processing plants (A, B, or C) at day 0,
following temperature abuse (TA), or from day 7 control
carcasses using BHI, ECD, CMD, EC, and CM as the culture
media are presented in Tables 1 to 5, respectively. On a
general growth medium such as BHI (Table 1), a number of
bacterial genera were able to reach the threshold DT level of
10^6 cells per ml. For control carcasses obtained from plants A
and C and sampled at day 0 or day 7, gram-positive species
reached the threshold level. For carcasses subjected to
temperature abuse, the bacteria that reached the threshold level
were often more erratic than DTs for samples in which only 1
species was able to reach the threshold DT level consistently
(5).

As soon as the impedance detection time (DT) was
recorded, 1 ml of the sample was immediately taken from the
module well, placed into 9 ml of sterile Bacto-peptone (Difco),
diluted to 10^6, 10^7, or 10^8, spread onto duplicate plate count
agar (PCA) (Difco) plates, and incubated at 35°C for 48 h.
Samples were diluted and plated because studies have shown
that bacteria must multiply to 10^6 cells per ml or more before
they are able to change the impedance of the medium suffi-
ciently to be detected by the instrument (4). By culturing the
sample immediately after detection, the bacteria found on the
plate at the highest dilution are assumed to be those responsible
for changing the impedance of the medium. Plates at the highest
dilution with 3 or more colonies per plate were used for selection
of isolates for identification. Two colonies per carcass were
randomly selected, restreaked for isolation and purity on PCA,
and incubated at 35°C for 48 h. For BHI-cultured samples from
plant 1, more than 2 bacterial colonies per carcass were identified
because differences in colony morphology were observed.

In some of the media analyzed, detection times for day 0
and day 7 carcasses required more than 11 h to obtain. In these
cases, samples were not collected and the organisms were not
identified because the impedance method was used to rapidly
decrease the time required to detect temperature abuse and an
assay that required >1 h to conduct was not considered rapid.

Colonies isolated for identification were analyzed for
gram reaction, cytochrome oxidase activity, and ability to
produce the enzyme catalase. Bacteria were subsequently
identified using the Vitek AutoMicrobic System (bioMérieux).

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TABLE 1. Number of isolates recovered from broiler carcasses (n = 45) obtained from three processing plants (A, B, or C) at day 0, following temperature abuse (TA), or from day 7 control carcasses, using brain heart infusion (BHI) as the culture medium.

<table>
<thead>
<tr>
<th>Bacterium</th>
<th>Total</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>A</th>
<th>B</th>
<th>C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Escherichia coli</td>
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<td>6</td>
<td>7</td>
<td>7</td>
<td>6</td>
<td>3</td>
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<tr>
<td>Aeromonas sobria</td>
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<td>0</td>
<td>11</td>
<td>6</td>
<td>7</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
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<td>7</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
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<tr>
<td>Staphylococcus auricularis</td>
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<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
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<tr>
<td>Listeria spp.</td>
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<td>2</td>
<td>0</td>
<td>3</td>
<td>0</td>
<td>0</td>
<td>0</td>
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<td>Corynebacterium xerosis</td>
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<td>0</td>
<td>0</td>
<td>0</td>
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<td>0</td>
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<td>0</td>
<td>0</td>
<td>3</td>
<td>0</td>
<td>1</td>
<td>0</td>
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<td>Enterococcus faecalis</td>
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<td>3</td>
<td>0</td>
<td>0</td>
<td>0</td>
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<td>0</td>
<td>0</td>
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<td>0</td>
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<tr>
<td>Enterococcus faecium</td>
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<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>0</td>
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<td>Escherichia fergusonii</td>
<td>3</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
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<td>Staphylococcus cohnii</td>
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<td>0</td>
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<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Acinetobacter calcoaceticus</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Klebsiella ozaenae</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Serratia liquefaciens</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Kluyvera spp.</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Aeromonas hydrophila</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Staphylococcus haemolyticus</td>
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<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
</tbody>
</table>

TABLE 2. Number of isolates recovered from broiler carcasses (n = 45) obtained from three processing plants (A, B, or C) at day 0, following temperature abuse (TA), or from day 7 control carcasses, using EC broth with 3% dextrose (ECD) as the culture medium.

<table>
<thead>
<tr>
<th>Bacterium</th>
<th>Total</th>
<th>Day 0</th>
<th>TA</th>
<th>Day 7 control</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>A</td>
<td>B</td>
<td>C</td>
</tr>
<tr>
<td>Escherichia coli</td>
<td>36</td>
<td>10</td>
<td>6</td>
<td>2</td>
</tr>
<tr>
<td>Aeromonas sobria</td>
<td>15</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Serratia fonticola</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Escherichia vulneris</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Staphylococcus simulans</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

be suitable for temperature-abuse determinations because, as with BHI, variations in DT preclude the possibility of detecting short periods or low levels of temperature abuse.

E. coli was the dominant bacterium growing in CM; however, other bacteria contributed to impedance changes (Table 5). The other organisms able to grow more rapidly than E. coli and reach the threshold DT level in CM included Klebsiella pneumoniae, Escherichia fergusonii, Serratia liquefaciens, Aeromonas sobria, and A. hydrophila.

Detection times for samples cultured in BHI, ECD, CMD, EC, and CM are presented in Table 6. DTs for samples cultured in BHI were adequate to differentiate temperature-abused carcasses from controls; however, lower levels of abuse would be more difficult to detect. The difference between values for temperature-abused broilers and values recorded on day 0 or day 7 was not as large as that for samples cultured in CMD or CM. Therefore, as levels of temperature abuse decrease, values for temperature-abused carcasses would approach and overlap values for controls, using BHI. It is possible that DT values for temperature-abused carcasses using CMD or CM would remain significantly different from unabused controls, even under less severe conditions of temperature abuse. This could not be analyzed using the data obtained from this experiment because many of the values were >11 h.

Since more than one genus of bacteria reached the threshold level and contributed to impedance changes when ECD was used as the culture medium, temperature-abused carcasses would be more difficult to differentiate from controls than with BHI, CMD, or CM. Therefore, lower levels of temperature-abuse may not be detected. For plants B and C, impedance changes were not able to be detected by the instrument and DT values were inconsistent. ECD would not be suitable for conducting temperature abuse determinations.

Many bacterial species reached the threshold DT level when samples were cultured in EC. The differences in DT for day 0 versus temperature-abused and day 7 versus temperature-abused carcasses were not pronounced. Hence, EC would not be suitable for use in temperature abuse evaluations, because in some instances for individual data points, the temperature-abused carcasses had greater DTs than unabused day 7 controls. This indicates that the medium was not suitable for distinguishing carcasses that had been abused from those that were held at proper refrigeration temperatures.
TABLE 3. Number of isolates recovered from broiler carcasses (n = 45) obtained from three processing plants (A, B, or C) at day 0, following temperature abuse (TA), or from day 7 control carcasses, using CM medium with 2% dextrose (CMD) as the culture medium.

<table>
<thead>
<tr>
<th>Bacterium</th>
<th>Total</th>
<th>Day 0 A</th>
<th>B</th>
<th>C</th>
<th>TA A</th>
<th>B</th>
<th>C</th>
<th>Day 7 control A</th>
<th>B</th>
<th>C</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Escherichia coli</em></td>
<td>59</td>
<td>10</td>
<td>10</td>
<td>1</td>
<td>5</td>
<td>8</td>
<td>9</td>
<td>6</td>
<td>0</td>
<td>10</td>
</tr>
<tr>
<td><em>Hafnia alvei</em></td>
<td>3</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td><em>Escherichia fergusonii</em></td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td><em>Escherichia coli</em> (type A-D)</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

TABLE 4. Number of isolates recovered from broiler carcasses (n = 45) obtained from three processing plants (A, B, or C) at day 0, following temperature abuse (TA), or from day 7 control carcasses, using EC broth (EC) as the culture medium.

<table>
<thead>
<tr>
<th>Bacterium</th>
<th>Total</th>
<th>Day 0 A</th>
<th>B</th>
<th>C</th>
<th>TA A</th>
<th>B</th>
<th>C</th>
<th>Day 7 control A</th>
<th>B</th>
<th>C</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Escherichia coli</em></td>
<td>66</td>
<td>10</td>
<td>10</td>
<td>9</td>
<td>10</td>
<td>9</td>
<td>2</td>
<td>6</td>
<td>6</td>
<td>4</td>
</tr>
<tr>
<td><em>Escherichia coli</em> (type A-D)</td>
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<td>0</td>
<td>0</td>
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<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td><em>Aeromonas sobria</em></td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td><em>Klebsiella pneumoniae</em></td>
<td>2</td>
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<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td><em>Staphylococcus sciuri</em></td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
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<tr>
<td><em>Proteus mirabilis</em></td>
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<td>0</td>
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</tr>
</tbody>
</table>

TABLE 5. Number of isolates recovered from broiler carcasses (n = 45) obtained from three processing plants (A, B, or C) at day 0, following temperature abuse (TA), or from day 7 control carcasses, using CM medium (CM) as the culture medium.

<table>
<thead>
<tr>
<th>Bacterium</th>
<th>Total</th>
<th>Day 0 A</th>
<th>B</th>
<th>C</th>
<th>TA A</th>
<th>B</th>
<th>C</th>
<th>Day 7 control A</th>
<th>B</th>
<th>C</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Escherichia coli</em></td>
<td>58</td>
<td>7</td>
<td>10</td>
<td>6</td>
<td>8</td>
<td>9</td>
<td>4</td>
<td>2</td>
<td>4</td>
<td>8</td>
</tr>
<tr>
<td><em>Klebsiella pneumoniae</em></td>
<td>4</td>
<td>1</td>
<td>0</td>
<td>2</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td><em>Aeromonas sobria</em></td>
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<td>0</td>
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<td>4</td>
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</tr>
<tr>
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</tr>
<tr>
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<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
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<tr>
<td><em>Serratia liquefaciens</em></td>
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<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
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<td>0</td>
</tr>
<tr>
<td><em>Aeromonas hydrophila</em></td>
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<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
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</tr>
</tbody>
</table>

TABLE 6. Impedance detection times (h) at 43°C for broilers (n = 45) collected from three processing plants (A, B, or C) using BHI, ECD, CMD, EC, or CM as the culture medium on day 0, temperature-abused (TA), or day 7 control carcasses.

<table>
<thead>
<tr>
<th>Culture Medium</th>
<th>Day 0 A</th>
<th>B</th>
<th>C</th>
<th>TA A</th>
<th>B</th>
<th>C</th>
<th>Day 7 control A</th>
<th>B</th>
<th>C</th>
</tr>
</thead>
<tbody>
<tr>
<td>BHI</td>
<td>5.9</td>
<td>5.6</td>
<td>--</td>
<td>3.1</td>
<td>3.3</td>
<td>--</td>
<td>6.5</td>
<td>6.4</td>
<td>--</td>
</tr>
<tr>
<td>ECD</td>
<td>&gt;11.0</td>
<td>&gt;11.0</td>
<td>5.3</td>
<td>--</td>
<td>--</td>
<td>&gt;11.0</td>
<td>&gt;11.0</td>
<td>&gt;11.0</td>
<td></td>
</tr>
<tr>
<td>CMD</td>
<td>7.9</td>
<td>6.9</td>
<td>&gt;11.0</td>
<td>2.6</td>
<td>2.2</td>
<td>2.6</td>
<td>&gt;11.0</td>
<td>&gt;11.0</td>
<td>7.8</td>
</tr>
<tr>
<td>EC</td>
<td>8.3</td>
<td>9.1</td>
<td>8.4</td>
<td>6.0</td>
<td>5.8</td>
<td>7.0</td>
<td>9.1</td>
<td>&gt;11.0</td>
<td>9.3</td>
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<tr>
<td>CM</td>
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<td>7.8</td>
<td>10.1</td>
<td>2.3</td>
<td>2.2</td>
<td>2.4</td>
<td>&gt;11.0</td>
<td>&gt;11.0</td>
<td>7.9</td>
</tr>
</tbody>
</table>

- Culture media: BHI, brain heart infusion; ECD, EC broth with 3% dextrose; CMD, CM medium with 2% Dextrose; EC, EC broth; CM, CM medium.
- Impedance readings were not interpretable because of two inflection points in the impedance curve.

Although many gram-negative genera contributed to the DT when CM was used as the culture medium, *E. coli* was the species identified most often (60 out of 72 times). When CM was used, the temperature-abused carcasses had much lower DT than the day 0 or day 7 controls. CM medium would be suitable for use in temperature-abuse determinations.

CMD was the best medium analyzed to select for the growth of *E. coli* when performing impedance assays for determining tempera-
ture abuse. Using CMD, *E. coli* was able to outcompete other bacterial species and reach the threshold DT level. Enumeration of *E. coli* in CMD allows temperature-abused carcasses to be distinguished from unabused day 0 or day 7 controls more effectively than use of the other media tested. This suggests that short periods of temperature abuse might be detected using CMD as opposed to BHI. Additional studies should be conducted to determine if low levels of temperature abuse are detectable using CMD.

A comparison of the population of *E. coli* on carcasses immediately postprocessing to those enumerated on carcasses at different points in their marketing and distribution would aid in identifying critical control points which could then be monitored. This method may prove to be valuable to the poultry industry because sources of temperature abuse could be identified and corrected.

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REFERENCES


