Microbiological Quality of Broilers During Processing in a Modern Commercial Slaughterhouse in Kuwait


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ABSTRACT

The effect of processing procedures and overall environmental and hygienic conditions on the microbiological quality and safety of chicken carcasses was studied in a modern processing plant on two separate days. The level of microorganisms on chicken carcasses was assessed by a neck-skin "maceration" method. Carcasses were heavily contaminated by different types of organisms, including indicator organisms (total aerobics, Enterobacteriaceae, coliforms and Escherichia coli) and pathogens (e.g., Salmonella, Campylobacter and Staphylococcus aureus). Microbial levels varied during processing, but the highest levels were detected after scalding and defeathering. Microbial levels did not change during vent opening or evisceration.

Spray washing after evisceration did not reduce levels of bacteria. No substantial change occurred in bacteria levels during air-chilling, packaging and cold-storage; however, the finished product was heavily contaminated. In the freshly processed carcasses, mean counts (log colony forming units [CFU]/g neck-skin) of aerobic bacteria Enterobacteriaceae, coliforms, E. coli, Campylobacter and S. aureus were 6.6, 4.5, 4.1, 3.6, 5.2 and 2.7 on the first sampling day, and 6.5, 4.6, 4.9, 3.6, 4.7 and 4.1 on the second day. Salmonella was present in all birds examined, including those coming directly from the farm. Major serotypes detected on dressed carcasses were Salmonella onio, Salmonella enteritidis, Salmonella paratyphi and Salmonella krefeld.

Key Words: Slaughterhouse, poultry, processing, contamination, microbiological quality.

The microbiological quality and safety of commercially processed poultry products is a major area of concern for producers, consumers and public health officials worldwide. Products excessively contaminated with microorganisms are undesirable from the standpoint of public health, storage quality and general aesthetics. At the processing plant, the microbiological quality of freshly processed poultry carcasses depends on the level of coming contamination from live birds, numbers and types of microorganisms introduced, spread of contamination or cross-contamination, technical design (type) of processing equipment, efficiency of processing methods, temperature control, and sanitary and hygienic practices in the plant.

During processing, most of the gram-positive bacteria originating from incoming birds is removed and replaced by a heterogeneous population largely composed of gram-negative bacteria, including pseudomonads, flavobacteria, Acinetobacter/Moraxella and Enterobacteriaceae. Although not all these microorganisms are involved in carcass spoilage or cause foodborne diseases, their presence in excessive amounts, indicates unsatisfactory processing, improper sanitary and hygienic practices in the plant, or both.

Studies in the laboratory (unpublished work) showed that freshly produced broiler carcasses were contaminated by indicator microorganisms and pathogens. Since no information exists as to the level of contamination in poultry slaughterhouses, the present work was undertaken: (i) to study the effect of processing procedures and overall environmental and hygienic conditions on the microbial load of carcasses at different locations on a processing line in a modern broiler slaughterhouse; and (ii) to help the local poultry industry to improve the quality and safety of their products.

MATERIALS AND METHODS

Live birds are delivered to a modern slaughterhouse at 40 to 45 days of age and are processed at the rate of 2,000 birds/hour on one processing line. After slaughtering and bleeding for 1 to 2 min, the birds are immersed for scalding for 3 min at 51.5 to 53°C. Scalding water is changed once a day. This step is followed by defeathering, neck-skin cutting, head removal, vent cutting and opening, evisceration, removal of internal organs (e.g., gizzard, liver and heart), lung vacuuming, spray washing, driping, hook cutting, air chilling (75 min at 0 to 5°C), packaging in O2 and CO2-permeable polyethylene bags (thickness of 0.05 mm) and refrigeration at 0°C for retail. Processing each bird, from slaughter to packaging, averages about 90 min.

Sampling procedures.

Samples were taken at midnight directly from the plant's slaughter line in two different occasions: Day 1 and day 2.

Poultry meat samples. On both sampling days (n = 6) and (n = 5), carcasses were removed from eight control points (I to 8) on the processing line (Fig. 1). Carcasses were packaged in sterile polyethylene bags and transported superchilled (at 0°C) in
ice containers to the laboratory. The carcasses were then homogenized within 24 h by skin-blending (13): 25 g of carcass neck-skin were excised and blended with 225 ml of 0.2% sterile lactose broth at high speed for 2 min using a Waring™ blender. The homogenates obtained were serially diluted in 0.2% sterile lactose broth and used for microbiological analysis.

Figure I. Scheme of a modern poultry processing plant for the production of air-chilled broilers; I-VI, product samples; I-VI, temperature measurements.

Water samples. Well water samples (25 ml each) were collected from the main water tank, scalding tank, water sprayer and dripping water from the carcasses after spray washing (n = 4 for each), and microbiologically analyzed for APC, E. coli and coliforms, Salmonella, Campylobacter and S. aureus (13).

Air sampling. Air sampling was carried out using agar plates (9 mm in diameter) containing aerobic plate count-agar (APCagar) for the enumeration of aerobic bacteria and appropriate selective media for the enumeration of E. coli and coliforms, Salmonella, Campylobacter and S. aureus (13).

Equipment and utensil swabs. Equipment and utensils used at the processing plant were sampled using the swab technique, as described by Kitchell et al. (14). An absorbent cotton swab was firmly rolled over a sterile stainless steel template with a 1 cm² opening to prevent contact with non-sampled areas. The swabs were homogenized in the laboratory and processed according to standard procedures to enumerate aerobic bacteria.

Microbiological analysis. The colony counts of aerobic bacteria, Enterobacteriaceae, coliforms and E. coli were determined as outlined by the International Commission on Microbiological Specifications for Food (ICMSF) (13), using APC-agar (Oxoid), violet-red glucose bile (Oxoid) and Levin's eosin-methylene blue agar (Difco Laboratories, Detroit MI), respectively, as growth media. Salmonellae were isolated and identified following the methods as described by ICMSF (13) and Bailey et al. (3), and typed serologically at the Public Health Laboratory (PHL), Kuwait. Campylobacter were isolated by spreading 0.1 ml of each dilution onto a Campylobacter base-agar (Difco) supplemented with 7% horse blood and Skirrow's selective supplement (Oxoid). Campylobacter plates were incubated at 43°C for 1 to 2 days in a microaerophilic atmosphere (85% N₂, 10% CO₂ and 5% O₂), using gas generating kits (Oxoid; BR 56). Staphylococcus aureus was recovered by spreading 0.1 ml of each dilution on Baird-Parker egg yolk-tellurite emulsion medium (Difco/Oxoid). After 1 to 2 days of incubation at 37°C, typical coagulase- and DNase-positive S. aureus were confirmed using coagulase (rabbit plasma, Difco) and DNase tests, as outlined by ICMSF (13) and Collins (6).

Statistical analysis.

Data were analyzed by analysis of variance and Duncan's Multiple Range Test using the Statistical Analysis System (SAS) (27).

RESULTS AND DISCUSSION

Microbial load on chicken carcasses.

Microorganisms of hygiene and sanitary quality. Table 1 shows the mean counts of microorganisms of hygiene and sanitary quality (e.g., aerobic bacteria, Enterobacteriaceae, total coliforms and E. coli) isolated from chicken carcasses at different points on the processing line during sampling days 1 and 2. On both occasions, the highest bacterial counts were obtained at points 2, 3 and 4, e.g., after soft scalding and defeathering, vent opening and evisceration. These findings are in agreement that slaughtering has a decisive effect on the microbial contamination of processed poultry (20,21,24). The high counts recovered after scalding and defeathering (step 2) indicate that cross-contamination may have occurred in the scalding tank, possibly from the scalding water itself (Table 3), from the defeathering machine and/or from other carcasses. These findings were in general agreement with those reported by other investigators, who have shown that higher microbial loads in scalding water, and/or on the defeathering machines, increase bacterial loads on carcass skin (10,19,23).

Vent opening and evisceration caused only a slight change in the bacterial counts on carcasses sampled on both days. Contamination or cross-contamination may have also occurred during these processes, with the number of microorganisms added being nearly equal to the number removed. Reports on the effect of the evisceration (including vent opening) on the microbial load of poultry carcasses are varied. Lahallec et al. (16), as well as Notermans et al. (25), reported no change in bacterial counts after evisceration whereas Schmitt et al. (28) found that evisceration increased the total bacterial counts by 1 log cycle.

Spray washing after evisceration (step 5) reduced the number of aerobes by 1 log cycle, which is consistent with literature reports (28). However, the reduction was less consistently observed with the Enterobacteriaceae, E. coli and coliform counts, observed with the Enterobacteriaceae, E. coli and coliform counts, probably due to the strong attachment of these organisms to the carcass skin (18,23,24).

No substantial change in bacterial counts occurred during air chilling (step 6). These findings agree in general with those reported by other authors (21,28), who indicated that air chilling does not affect or reduce bacterial counts on chilled carcasses, due to the washing effect of immersion water and/or the effect of bactericides such as chlorine being used in the chill-water (17,20,21,36). In general,
### TABLE 1. Bacteria associated with chicken carcasses at various stages of processing in a local plant.

<table>
<thead>
<tr>
<th>Control point**</th>
<th>Aerobes</th>
<th>Enterobacteriaceae</th>
<th>Coliforms</th>
<th>E. coli</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>1 Bleeding (Pre-scalding)</td>
<td>ND</td>
<td>5.2 (0.20)*</td>
<td>ND</td>
<td>4.8 (0.79)*</td>
</tr>
<tr>
<td>2 Defeathering</td>
<td>7.0 (0.39)*</td>
<td>7.2 (0.30)*</td>
<td>5.5 (0.76)*</td>
<td>5.6 (0.87)*</td>
</tr>
<tr>
<td>3 Vent opening</td>
<td>7.1 (0.36)*</td>
<td>7.2 (0.33)*</td>
<td>5.2 (0.58)*</td>
<td>5.4 (0.39)*</td>
</tr>
<tr>
<td>4 Lung sucking</td>
<td>7.2 (0.50)*</td>
<td>7.2 (0.70)*</td>
<td>5.3 (0.58)*</td>
<td>5.4 (0.39)*</td>
</tr>
<tr>
<td>5 Spray washing</td>
<td>6.0 (0.38)*</td>
<td>6.3 (0.45)*</td>
<td>5.2 (0.50)*</td>
<td>5.2 (0.79)*</td>
</tr>
<tr>
<td>6 Air chilling</td>
<td>6.0 (0.28)*</td>
<td>6.1 (0.45)*</td>
<td>5.3 (0.43)*</td>
<td>5.0 (0.55)*</td>
</tr>
<tr>
<td>7 Packaging</td>
<td>6.4 (0.44)*</td>
<td>6.5 (0.47)*</td>
<td>5.4 (0.65)*</td>
<td>5.0 (0.30)*</td>
</tr>
<tr>
<td>8 Cold storage</td>
<td>6.6 (0.22)*</td>
<td>6.5 (0.28)*</td>
<td>4.5 (0.18)*</td>
<td>4.6 (0.18)*</td>
</tr>
</tbody>
</table>

* Means of the results for 6 and 5 carcasses obtained on days 1 and 2, respectively.
** Samples were taken following the processes named.
ND Not determined.

Values in columns which are not significantly different (P>0.05) are followed by the same superscript.

### TABLE 2. Microorganisms of significance to public that were recovered from chicken carcasses at different stages of processing.

<table>
<thead>
<tr>
<th>Control point**</th>
<th>Salmonella incidence rate %</th>
<th>Campylobacter</th>
<th>S. aureus</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1 2</td>
<td>1 2</td>
<td>1 2</td>
</tr>
<tr>
<td>1 Bleeding (Pre-scalding)</td>
<td>100 100</td>
<td>ND</td>
<td>3.9 (0.82)*</td>
</tr>
<tr>
<td>2 Defeathering</td>
<td>100 100</td>
<td>6.0 (0.80)*</td>
<td>5.5 (0.77)*</td>
</tr>
<tr>
<td>3 Vent opening</td>
<td>100 100</td>
<td>6.5 (0.62)*</td>
<td>5.5 (0.70)*</td>
</tr>
<tr>
<td>4 Lung sucking</td>
<td>100 100</td>
<td>6.0 (0.63)*</td>
<td>5.4 (0.88)*</td>
</tr>
<tr>
<td>5 Spray washing</td>
<td>100 100</td>
<td>5.5 (0.63)*</td>
<td>4.7 (0.72)*</td>
</tr>
<tr>
<td>6 Air chilling</td>
<td>100 100</td>
<td>5.3 (0.38)*</td>
<td>4.6 (0.60)*</td>
</tr>
<tr>
<td>7 Packaging</td>
<td>100 100</td>
<td>5.6 (0.26)*</td>
<td>4.7 (0.78)*</td>
</tr>
<tr>
<td>8 Cold storage</td>
<td>100 100</td>
<td>5.2 (0.45)*</td>
<td>4.7 (0.80)*</td>
</tr>
</tbody>
</table>

* Mean counts of 6 and 5 carcasses examined on days 1 and 2, respectively. Data in columns which are not significantly different (P>0.05) are followed by the same superscript.
** Samples were taken following the processes named.
ND Not determined.

### TABLE 3. Bacterial counts of water samples from a local poultry processing plant.

<table>
<thead>
<tr>
<th>Water source</th>
<th>Aerobes</th>
<th>Coliform bacteria</th>
<th>E. coli</th>
<th>S. aureus</th>
<th>Campylobactaer</th>
<th>Salmonella</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1 2</td>
<td>1 2</td>
<td>1 2</td>
<td>1 2</td>
<td>1 2</td>
<td>1 2</td>
</tr>
<tr>
<td>Main tank</td>
<td>2.2 2.1</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Spray water</td>
<td>2.9 2.5</td>
<td>-</td>
<td>2.0</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Dripping water</td>
<td>5.7 5.4</td>
<td>4.0</td>
<td>4.2</td>
<td>ND</td>
<td>4.0</td>
<td>3.7</td>
</tr>
<tr>
<td>Scalding water At tank entry</td>
<td>7.2 7.5</td>
<td>5.8</td>
<td>4.4</td>
<td>ND</td>
<td>3.3</td>
<td>4.5</td>
</tr>
<tr>
<td>Middle</td>
<td>7.0 7.4</td>
<td>5.8</td>
<td>4.8</td>
<td></td>
<td>4.1</td>
<td>4.0</td>
</tr>
<tr>
<td>Exit</td>
<td>8.0 7.6</td>
<td>5.9</td>
<td>5.4</td>
<td>5.7</td>
<td>3.6</td>
<td>4.4</td>
</tr>
</tbody>
</table>

* Mean of the results of four samples (n=4) collected on days 1 and 2, respectively.
** Dripping water drip collected from chicken carcasses after spray washing.
- Not detected.
ND Not determined.
reports on the microbiological quality of poultry chilled by both methods are varied. Whereas, some authors found that air-chilled birds had lower bacterial counts than water immersion-chilled birds (5,15), others reported that air-chilled carcasses were always likely to carry more organisms than those chilled in a properly controlled immersion system (20,36). Thomas (33) cited literature suggesting that the soft-scaled carcasses required for air chilling sustain less thermal destruction of bacteria than carcasses scalded at higher temperatures for immersion chilling. However, Schmitt et al. (28) found that both chilling methods had only marginal effect on the increase in bacterial counts during storage; and hence, no difference was found in the shelf-life of air- or immersion-chilled birds. These findings, as well as those reported in the present work, indicate that contamination and/or cross-contamination of birds must be avoided or controlled throughout earlier processes for any chilling method to yield a microbiologically sound product. During subsequent air chilling, packaging and storage at 0°C (steps 6, 7 and 8, respectively), no substantial change in bacterial counts was observed, also consistent with the literature (20,21).

Microorganisms of public health significance. Table 2 presents the incidence of organisms considered to be significant public health concerns that were recovered from chicken carcasses at different processing stages on sampling days 1 and 2. The incidence of Salmonella on both days was 100% at all stages. The high incidence in birds sampled just before scalding (step 1) indicated that incoming flocks were heavily contaminated, which could contribute to carcass contamination or cross-contamination inside the processing plant (1,30). Moreover, the high incidence levels, especially after scalding and defeathering, indicated that salmonellae, like other microflora, survived scalding at 51 to 53.5°C for 3 min, as reported previously (22). Contamination or cross-contamination may have also occurred during vent opening and evisceration, but could not be demonstrated because the incidence did not change. Spray washing did not cause any reduction in salmonellae incidence, possibly due to the strong attachment of these organisms to carcass skin (18,35).

The major serotypes associated with chicken carcasses investigated in the present study were S. ohio, S. enteritidis, S. paratyphi and S. krefeld. The same serotypes were also isolated from retail chicken carcasses that originated from the same processing plant (unpublished work). None of the organisms most commonly incriminated in food poisoning attributed to poultry meat, were recovered (9,37), e.g., Staphylococcus typhimurium, Staphylococcus heidelberg and Staphylococcus infantis.

Campylobacters were also present in all birds examined (Table 2). The increase of 1.5 log cycles in the counts of campylobacters after scalding and defeathering, particularly in birds examined on day 2, indicated that contamination or cross-contamination may have occurred during both scalding and defeathering, which is consistent with the literature (10). In contrast to the findings of Baker et al. (4), no substantial change in contamination levels was observed during the subsequent vent opening and evisceration procedures, possibly because of cells added were equal to that removed from the carcasses. The subsequent spray washing step caused a reduction of log 1 cycle in campylobacters; however, the endproduct still carried high levels of organisms, (e.g., averages of log 5.2 and 4.7 CFU/g neck skin of carcasses sampled on days 1 and 2, respectively). Studies (unpublished work) on Campylobacter isolated from chicken carcasses obtained from the same processing plant showed that Campylobacter jejuni constituted 65% of the campylobacters recovered, suggesting that at the end of processing, the individual birds were contaminated by log 5.0 and log 4.5 U of C. jejuni on days 1 and 2, respectively. Campylobacters in general, and C. jejuni in particular, have been incriminated in acute gastroenteritis in humans (12,32); thus, high levels of campylobacters in the endproduct represent a potential health hazard for humans.

A similar trend was also observed for coagulase- and DNase-positive S. aureus. The organism was present in all birds examined, including those sampled before scalding. The relatively high counts of S. aureus isolated after scalding and defeathering (step 2) indicated that the organism survived scalding at low temperatures and that contamination or cross-contamination may have occurred during defeathering. Similar findings have been reported previously (1,26). During vent opening and evisceration, no substantial change occurred in S. aureus counts, which is in agreement with Surkiewicz et al. (30), and in partial agreement with Notermans et al. (25). The mean counts of S. aureus decreased after spray washing (Table 2), which is consistent with the literature (25). Air chilling, packaging and cold storage did not change the levels of contamination; however, the endproduct still contained high levels of S. aureus, with averages of log 2.7 and 4.1 CFU/g neck skin of carcasses examined on days 1 and 2, respectively. High levels of S. aureus in the endproduct are not desirable since they can be associated with the production of a heat-resistant enterotoxin responsible for a number of Staphylococcus food poisoning outbreaks attributed to the consumption of meat (11,25).

Overall environmental and hygienic conditions.

Analysis of water samples. The bacterial counts of water samples obtained from different sources in the slaughterhouse on days 1 and 2 are presented in Table 3. On both days, the highest bacterial counts were found in the scalding water sampled at three points in the scalding tank. This finding may be because the scald water is changed only once per day and/or because the scald temperature, 51 to 53.5°C, was not effective in killing many of the types of microorganisms found on chicken carcasses as reported by other investigators (21,22,31). The dripping water from the carcasses after spray washing was also contaminated indicating that spray washing was not effective in removing all bacteria attached to the carcasses. Similar findings were demonstrated by others (1). Compared with other water samples, the processing water (e.g., main water tank and spray) was nearly free of contamination, showing only negligible aerobic bacteria counts (log 2.2 to 2.9 and 2.1 to 2.5 CFU/ml in samples collected on days 1 and 2, respectively, but no Salmonella, Campylobacter, S. aureus, E. coli or coliforms).
TABLE 4. Bacterial counts in the atmosphere of a local poultry processing plant.

<table>
<thead>
<tr>
<th>Sampling point</th>
<th>Aerobes</th>
<th>S. aureus</th>
<th>Coliform</th>
<th>E. coli</th>
<th>Campylobacter</th>
<th>Salmonella</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Slaughtering area</td>
<td>&gt;300&lt;sup&gt;b&lt;/sup&gt;</td>
<td>&gt;300&lt;sup&gt;b&lt;/sup&gt;</td>
<td>106</td>
<td>150</td>
<td>&gt;300&lt;sup&gt;a&lt;/sup&gt;</td>
<td>&gt;300&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Scalding area</td>
<td>84</td>
<td>&gt;300&lt;sup&gt;b&lt;/sup&gt;</td>
<td>44</td>
<td>70</td>
<td>&gt;300&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0</td>
</tr>
<tr>
<td>Evisceration area</td>
<td>168</td>
<td>170</td>
<td>4</td>
<td>17</td>
<td>32</td>
<td>89</td>
</tr>
<tr>
<td>Chilling area</td>
<td>6</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Packaging area</td>
<td>17</td>
<td>30</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>8</td>
</tr>
<tr>
<td>Chicken cutting</td>
<td>12</td>
<td>33</td>
<td>2</td>
<td>5</td>
<td>25</td>
<td>32</td>
</tr>
</tbody>
</table>

<sup>a</sup> Mean counts of 5 plates collected on days 1 and 2, respectively.
<sup>b</sup> Higher than the maximum number that can be counted in a plate.

Microbiological analysis of air samples. Table 4 presents the mean counts of microorganisms contaminating the slaughterhouse air sampled at different points of the processing line. The air in the slaughtering, scalding, defeathering and evisceration areas was contaminated with different types of airborne microflora on both days 1 and 2. Table 4 presents the microbial counts after 1 min of exposure to the atmosphere; extending the exposure time to more than 1 min yielded uncountable numbers of microorganisms, particularly aerobic and coliform bacteria. The high humidity observed in these areas may have stimulated the growth of these microorganisms. These findings corroborate data reported by other investigators, who showed that microbial contamination of the air was widespread and varied considerably between different processing locations (29). The relationship between air-contamination levels at the various locations in the processing plant and the microbial load on carcasses at these locations, especially at the scalding, defeathering, vent opening and evisceration (Tables 1 and 2) needs to be investigated.

Microbial load on equipment and utensils. Table 5 presents the aerobic counts on equipment and utensils in different locations in the processing plant. High bacterial counts were detected on all equipment and utensils tested in the evisceration and packaging areas. The overall contamination levels on equipment and utensils in the evisceration area ranged from log 4.1 to 7.7 and log 4.0 to 7.4 CFU/cm² on days 1 and 2, respectively, and were one log cycle higher than those observed in the packaging area. A direct correlation between the equipment and utensils contamination levels and the high counts of aerobic bacteria recovered from carcasses at these locations was not established; however, the results indicated that equipment and utensils were unsanitary, which might affect the dressed carcasses by increasing their microbial load and reducing their storage quality and safety.

CONCLUSIONS

In light of the data present in this study, it is essential that the local poultry industry continue to improve control, and enhance hygienic and safety measures to reduce the microbial contamination of carcasses resulting in spoilage and transmission of foodborne diseases. Improvements should be made both on the farm and at the processing plant. At the farm level, particular attention must be given to limiting infection of live birds with Salmonella, Campylobacter and other pathogens. At the processing plant, microbial contamination or cross-contamination of carcasses should be reduced by implementing satisfactory manufacturing practices (e.g., good sanitation of processing equipment and utensils, proper personnel hygiene, use of contamination-free water, etc.); proper freshwater input and overflow (especially in the scalding tank); and effective training of plant workers in hygiene, safety and quality assurance.

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REFERENCES


