Bacteria in food packaging paper and board

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INTRODUCTION

Paperboard is manufactured from natural raw materials, e.g. cellulose pulp, native and modified starch and resin sizers. The inherent biodegradability of these materials means that microbial growth will occur in the production process. The paper machinery is an open environment, and the water content of the slurry in the headbox (tank in which the papermaking materials are mixed and fed on the wire), pH, and the temperature are favourable for microbial growth. The micro-organisms may penetrate at least partially into the final paper. The microbial content of food quality paper and board is regulated by health authorities in many countries (Anon. 1975, 1978, 1989). Very little information has been published about the microbial flora of paper and board. This paper describes some of the dominant species found in food quality paper and board products.

MATERIALS AND METHODS

Tryptone glucose yeast agar (standard plate count agar) was used for bacterial isolations and viable counts as described by Väisänen et al. (1989). Whole cell fatty acids of the bacteria were analysed as described by Väisänen & Salkinoja-Salonen (1989). The bacteria were examined with light microscopy (phase contrast and Gram-stain) and then identified on the basis of their fatty acid composition with the aid of database software (version 3.0) of Microbial ID, Inc. (Newark, DE, USA).

RESULTS AND DISCUSSION

Bacteria were isolated from the products of five different paper and board machines. With some of the strains whole cell fatty acid analysis was insufficient for identification, but when a similarity dendogram based on the fatty acid compositions was constructed, all strains could be assigned to species or group of species. The results are shown in Table 1. Strains of Bacillus polymyxa group (B. polymyxa, B. circulans, B. macerans, B. pabuli), B. cereus group (B. cereus, B. mycoides, B. thuringiensis), B. brevis and B. licheniformis were most frequently found. Among the other organisms Staphylococcus, Corynebacterium and Enterobacter were identified. Gram-negative bacteria were abundant in white water (water circulating through the papermaking process) and papermaking chemicals (results not shown) but were found only sporadically in board or paper. The heat of the drums at the dry end of the machine (surface temperature ca 140°C) probably kills the non-spore-formers.

Figure 1 shows the relationship between the counts of aerobic spore-forming bacteria and the total aerobic bacterial counts of the product of one of the board machines. Most of the aerobic bacteria found in the board formed heat-resistant spores as was the case with the other paper and board machines. Bacilli thus appeared as main contaminants of paper and board.
Table 1 Number of bacteria isolated from paper and board products

<table>
<thead>
<tr>
<th>Species</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Bacillus brevis</em></td>
<td>3</td>
<td>1</td>
<td>10</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td><em>B. cereus</em> group*</td>
<td>2</td>
<td>3</td>
<td>1</td>
<td>9</td>
<td></td>
</tr>
<tr>
<td><em>(B. cereus, B. mycoides, B. thuringiensis)</em></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>B. globisporus</em></td>
<td></td>
<td></td>
<td></td>
<td>8</td>
<td></td>
</tr>
<tr>
<td><em>B. licheniformis</em></td>
<td>10</td>
<td>3</td>
<td>3</td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>B. megaterium</em></td>
<td>1</td>
<td>1</td>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>B. polymyx</em> group*</td>
<td>11</td>
<td>13</td>
<td>4</td>
<td>23</td>
<td>1</td>
</tr>
<tr>
<td><em>(B. polymyx, B. circulans, B. macerans, B. pabuli)</em></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>B. pumilus</em></td>
<td></td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>B. subtilis</em></td>
<td></td>
<td></td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Non-bacilli</td>
<td>5</td>
<td>2</td>
<td>3</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>22</td>
<td>30</td>
<td>18</td>
<td>57</td>
<td>9</td>
</tr>
</tbody>
</table>

* Quality of the product and pH in the headbox stock of the different paper and board machines studied: A, Liquid packaging board coated with kaolin (pH 4-5); B, fully bleached pigment coated (calcium carbonate and kaolin) liquid packaging board (pH 6-9); C, fully bleached liquid packaging board sized with starch with no mineral pigments (pH 9-10); D, duplex liquid packaging board of unbleached (80%) kraft pulp topped with bleached pulp (pH 7); E, grease-proof pergamin paper of Ca-sulphite pulp (pH 5-6).

Figure 2 shows that the number of spore-forming bacteria in the broke correlated well with that of the final product of the same machine. Of the components that make the stock for papermaking, the pulp itself was sterile, but the sizing agents (starch and resin sizers) and mineral pigments always contained large quantities ($10^3$-$10^6$ cfu/g) of bacteria. Fungi were less frequent ($0$-$10^2$ cfu/g when counted on potato dextrose or Sabouraud maltose agar). Thus the broke was the main, but not the only source of contamination of the product. No correlation was found between the numbers of bacteria in the final product and those in the white water or papermaking chemicals (starch

![Fig. 1](image1.png)

**Fig. 1** Relationship between spore counts and total aerobic bacterial counts in products or board machine C (Table 1). Each symbol represents a sample of one machine roll.

![Fig. 2](image2.png)

**Fig. 2** Correlation between the numbers of spore-forming bacteria in board of machine C (Table 1) and the contemporary broke (rejected board, which is repulped and recycled into the process) of the same machine. The symbols represent different sampling times over a period of two years.
sizers, resin sizers, kaolin, calcium carbonate, surface sizers) (results not shown).

The main contaminant in milk and other dairy products is \textit{B. cereus} (Ahmed \textit{et al.} 1983; Wong \textit{et al.} 1988), which is caseolytic (Claus & Berkeley 1986), and may produce toxins (Christiansson \textit{et al.} 1989). Such properties are undesirable in materials used for milk packaging. We compared strains of \textit{B. cereus} group isolated from packaging boards and board machines with those isolated from spoiled dairy products and their raw materials using whole cell fatty acid analysis, phage typing and measurement of minimum growth temperature, and found no overlap between these populations (Väisänen \textit{et al.} 1990). Thus, although strains of \textit{B. cereus} group were commonly found in food packaging paper and board, their role for dairy product spoilage may be of little significance.

We found hairy spores in one of the \textit{B. pumilus} strains isolated from food packaging paper (Fig. 3). Cerf & Metro (1977) described similar hairy spores in a strain of \textit{B. licheniformis} isolated from milk. They observed that these spores were exceptionally resistant to killing by hot hydrogen peroxide, probably due to clump formation through the hairs. The presence of this kind of spores in food packaging materials might thus cause contamination problems in the dairy.

Strains of \textit{B. polymyxa} group were the most frequent bacilli found in boards, but little is known about their potential hazards in foods.

Eight strains were identified as \textit{B. globisporus} by fatty acid analysis. These strains did not have spherical spores as does \textit{B. globisporus sensu stricto}, but they did grow at +4°C, which may be noteworthy considering the use of the paper or board for cold-storage packaging of food.

The dominance of bacilli in the paper and board products may be explained by the following facts: (1) the recycling of broke, which contains large numbers of spore-formers, constantly infects the stock in the headbox; (2) the thermoresistant spores survive the heat during the drying of the paper and board; (3) most bacilli are amylolytic and some cellulolytic (Claus & Berkeley 1986; Väisänen \textit{et al.} 1991) and thus grow well in an environment rich in starch and cellulose; and (4) bacilli are very resistant to many slime-destroying agents used in paper and board machines (Väisänen \textit{et al.} 1989), which may give them selective advantage in the environment where these agents are constantly used.

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