

Comparison of Wooden and Polyethylene Cutting Boards: Potential for the Attachment and Removal of Bacteria from Ground Beef[†]

ARTHUR J. MILLER,* TARA BROWN, and JEFFREY E. CALL

U.S. Department of Agriculture, Agricultural Research Service, Eastern Regional Research Center, Microbial Food Safety Research Unit,
600 East Mermaid Lane, Wyndmoor, Pennsylvania 19038

(MS# 95-30: Received 24 October 1995/Accepted 4 January 1996)

ABSTRACT

The potentials for removal of beef bacterial microflora from unscored polyethylene and hardwood cutting boards were compared. Ground beef was placed for 0 to 90 min onto cutting boards at room temperature and then removed; the surfaces were swabbed and the bacteria were enumerated. The boards were cleaned with various cleaning agents and then analyzed for bacterial removal. In addition, aqueous extracts from eight hardwoods were incubated with *Escherichia coli* O157:H7 for 0 to 30 h at 37°C to determine their inhibitory potential. Differences between the bacterial levels on wooden and plastic boards were not significant regardless of contact time. Washing with any cleaner, including water, removed most bacteria from either type of board. White ash extracts reduced *E. coli* O157:H7 levels to undetectable within 24 h; black cherry and red oak exhibited low inhibitory activity. Slight growth was observed in extracts from all other hardwoods, including hard maple, suggesting that aqueous extractable agents that are active against *E. coli* O157:H7 are not generally present in hardwoods. This study demonstrates the need to control cutting board sanitation regardless of composition.

Key words: cutting boards, ground beef, microbial attachment

Cutting boards have been used for millennia to aid in the preparation of foods, and until recently wood was used almost exclusively for this purpose. Nonetheless, the potential for food to become contaminated by bacteria impregnated in wood has been recognized for some time. Cameron et al. (10), for example, showed that replacement of wooden brine tanks, hot water tanks, and blanchers with metal or enameled equipment significantly reduced or eliminated thermophilic spoilage in canned vegetables. Other investigators also reported bacterial contamination of food by wood from fish holding boxes (24), wood chips (15), and food

preparation surfaces (19). Attempts to reduce bacterial levels historically included boiling wooden food-contact materials in bicarbonate solutions followed by air drying (12), planing cutting boards to remove cuts and food residues, or rubbing surfaces with salt and/or vinegar (16). Despite these efforts, wooden food preparation surfaces were demonstrated to be difficult to clean (18). In fact, Highlands and Williams (15) reported that bacterial counts on hardwood fish-packing tables reached nearly 1 million, although tables were scrupulously cleaned, scrubbed with detergent, and maintained under continuous state inspection.

Wooden surfaces also serve as an important point of cross-contamination (9, 11), which has been associated with foodborne illness, especially salmonellosis and campylobacteriosis (6). Kampelmacher et al. (16) cited a host of foodborne illness outbreaks that implicated the consumption of ready-to-eat products after they were placed onto wooden cutting boards that were contaminated with pathogens from raw muscle foods. Bryan (7) indicated that improper cleaning of equipment or utensils, and cross-contamination from raw to cooked foods, contributed to 6% and 5%, respectively, of all foodborne illness outbreaks from U.S. food-service establishments between 1973 and 1982.

The demonstrated risks associated with food-preparation surfaces has led to their identification as a potential hazard to be monitored in hazard analysis critical control point (HACCP) programs, particularly in food-service operations (23). Moreover, the transfer of organisms from improperly controlled cutting and deboning operations was ranked as a high-risk hazard for meat and poultry processing, with potential for severe or chronic illness resulting (8). Therefore, in order to minimize public health risks there needs to be clarification of what the most suitable material is for cutting boards, and development of sound maintenance and sanitation programs.

Generally, when wood and plastic cutting boards were compared for bacterial adherence and removal potential the latter material was found to be more satisfactory (1, 5, 13, 14, 17, 22). However, recent studies by Ak et al. (3, 4) suggest that the common practice of using synthetic polymer

* Author for correspondence. Tel: 215-233-6620; Email: amiller@arserrc.gov.

[†] Mention of brand or firm names does not constitute an endorsement by the U.S. Department of Agriculture over others of a similar nature not mentioned.

cutting boards, and the abandonment of wooden boards, occurred and was encouraged without full consideration of the merits and shortcomings of each material. For example, evidence presented by Ak et al. (3, 4) indicates that wood may contain endogenous antibacterial properties.

Thus, while there is little debate about the importance of food-processing surfaces in the risk of foodborne disease, issues surrounding the composition of the surface are more contentious. It was the purpose of this study, therefore, to compare the potential for adherence of native beef bacterial microflora to polyethylene and hardwood cutting boards and for removal using four cleaners and water. In addition, we determined the potential of aqueous extracts of eight hardwood species to inhibit *E. coli* O157:H7.

MATERIALS AND METHODS

Meat samples and preparation

Top round steaks (2.54 cm thick) were obtained from a local supermarket and stored at 5°C for no longer than 6 h. Steaks were removed from refrigeration, cut into approximately 80-cm² portions, ground through 9.5-mm and then 4.8-mm die plates using a Hobart Corporation (Troy, NY) bench-top grinder and then incubated at 12°C for 18 h to elevate bacterial levels.

Cutting boards

Cutting boards were purchased at a local kitchen-supply retail store. The wooden boards were labeled mixed hardwood and were laminated along the longitudinal direction of the wood grain. The woods were tentatively identified as heart and sapwoods from maple and/or beech. The plastic boards were polyethylene. All boards were cut into approximately 80-cm² pieces with a table saw. Wooden board sections always contained at least four hardwood laminates. The cut pieces were washed with detergent (Liqui-Nox, Alconox, Inc., New York, NY) to remove manufacturing or packaging residues. After each experiment, cutting-board pieces were cleaned with detergent (Liqui-Nox) and water and then air dried. Prior to each experiment, the wooden boards were covered and autoclaved at 121°C for 15 min, while polyethylene boards were chemically treated by immersion for 2 min in 95% ethanol and then air dried.

Cutting-board experiments

The ground beef was formed into 75- to 100-g patties that were flattened onto randomly chosen cutting boards and allowed to stand at room temperature for 0, 30, 60, or 90 min. Duplicate wooden and plastic boards were used throughout. Temperature was monitored during the contact period by inserting a copper-constantan thermometer at the beef surface of the beef-cutting board interface. The patties were removed at the end of the contact period and the boards were rinsed with 25 ml of room-temperature tap water and then flooded with 50 ml of tap water or one of 4 chemical cleaners, all at room temperature. Liqui-Nox (1%) is a phosphate-free laboratory detergent. Ajax (Colgate-Palmolive Co, New York, NY) (1%) is a household cleaner with abrasives and contains bleach. Liquid Rite-Away (Alex C. Ferusson, Inc., Frazer, PA) (1:320) is an industrial cleaner containing sodium metasilicate, sodium tripolyphosphate, and dodecylbenzene sulfonic acid; Ultra Kleen (Sterilex, Owings Mills, MD) (1:250) is an industrial formulation that contains quaternary ammonium and hydrogen peroxide. Boards containing the cleaners or tap water were scrubbed for 60 s with a small laboratory brush in perpendicular

directions, each for 30 s. They were rinsed with 25 ml of room-temperature tap water. Cleaned boards were dried with a paper towel in a standardized manner and then were swabbed using calcium alginate swabs (Calgiswab type 2) (Spectrum Inc., Houston, TX) over a surface area of 25 cm² defined by a template. Swabs were transferred to 9.9 ml of 0.1% peptone-water dilution tubes, mixed with a vortex mixer, and then samples were enumerated on nutrient agar (Difco Laboratories, Detroit, MI) dishes using a Spiral Plater (Model D, Spiral Systems, Inc., Cincinnati, OH). Aerobic incubation time was 48 h at 37°C. Nutrient agar was chosen because it is a rich general bacteriological medium. It was assumed that chemical cleaner residues were diluted and neutralized by the water and peptone. At each sampling time a set of duplicate wood and plastic boards were not washed after the contact period and were swabbed 5 min after beef patty removal. These boards were enumerated as above. The theoretical sensitivity of the bacteriological assay was 1 CFU/cm², although actual recoveries were most likely lower. Duplicate trials were performed for each chemical cleaner. Thus, eight separate experiments were conducted. Bacteriological results were statistically analyzed using the SAS general linear model analysis (SAS Institute, Cary, NC).

Bacterial cultures, hardwood extract preparation, and challenge experiments

Enterohemolytic *Escherichia coli* O157:H7 was obtained from the Eastern Regional Research Center Collection (Wyndmoor, PA). It was grown overnight in brain heart infusion broth (Difco) at 37°C with shaking at 150 rpm. Hardwood extracts were prepared by adding 1 g of freshly planed wood shavings from eight hardwoods to 50 ml of 0.1 M sodium phosphate buffer (pH 7.0) and incubating with shaking at 37°C for 48 h. The hardwoods used were white ash, black cherry, honey locust, hard maple, red oak, poplar, pauldalk, and African zebrawood. Approximately 7 log cells per ml were added to the 37°C extracts, which were incubated at 37°C. Portions for testing were withdrawn at 0, 5, 24, and 30 h, diluted in 0.1% peptone, and quantitatively enumerated by spiral plating for recovery on nutrient agar dishes, after a 24-h aerobic incubation at 37°C.

RESULTS

The meat that was held overnight at 12°C had an average aerobic bacterial load of 6.7 log CFU/g for the eight experimental trials. During the 90-min beef and cutting-board contact period at room temperature the ground beef-cutting board interface increased from 17.3 to 21.2°C, on average.

Figure 1 shows pooled results from all experimental trials of potential for bacterial attachment and removal using wooden and polyethylene cutting boards. There was a significant ($P < 0.01$) time effect on the bacterial attachment to the cutting boards. Most of the effect, however, could be attributed to the increase in the microbiota on the boards during the first 30 min of contact. After 30 min of contact, 2.5 to 3 log CFU/cm² were observed on the cutting boards; increasing contact time to 90 min did not significantly ($P > 0.05$) affect attachment. Bonferroni mean separation analysis indicated a significant ($P < 0.01$) bacterial reduction after washing the boards.

Table 1 shows the specific effect of water or individual cleaners on the removal of ground beef bacteria from the wooden and polyethylene cutting boards. Water removed

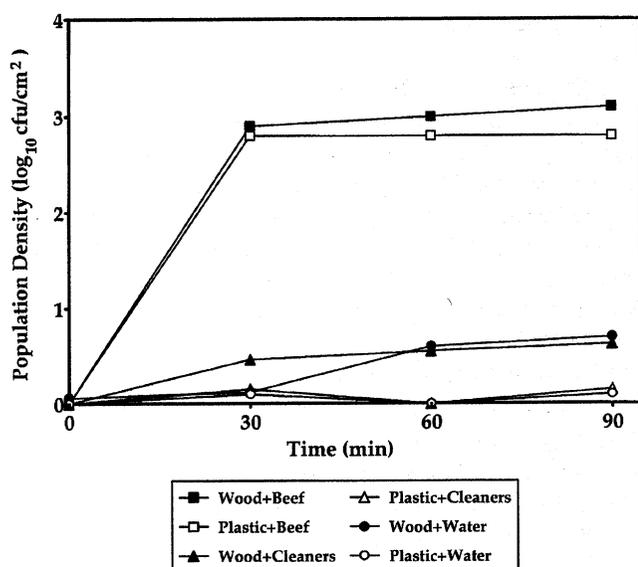


FIGURE 1. Attachment to and removal from wooden and polyethylene cutting boards of ground beef microbiota.

approximately 2.3 log CFU/cm²; Rite-Away removed 1.45 to 2.30 log CFU/cm²; Ultra Kleen, 1.1 to 2.1 log CFU/cm²; Liqui-Nox, 1.6 to 3.0 log CFU/cm²; and Ajax removed approximately 2.9 log CFU/cm². An analysis of variance indicated no significant differences between cutting board types ($P > 0.05$). The inference was that the ground beef microbiota attached to and were removed equally from the cutting boards. There was no statistical difference ($P > 0.05$), in addition, between water and chemical cleaning.

TABLE 1. Efficacy of removal of ground beef bacteria from wooden and polyethylene cutting boards by water and chemical cleaners

Treatment	Difference in bacterial population (log CFU/cm ²) detected between unwashed and washed cutting boards at time (min):		
	30	60	90
Water			
Plastic	2.40 ^a	2.38	2.25
Wood	2.41	2.13	2.18
Rite-Away			
Plastic	1.60	2.00	1.50
Wood	1.45	2.30	1.50
Ultra Kleen			
Plastic	2.10	1.60	1.10
Wood	2.10	1.80	2.20
Liqui-Nox			
Plastic	3.00	3.00	3.00
Wood	2.70	1.60	1.90
Ajax			
Plastic	3.00	2.90	2.80
Wood	2.60	3.10	3.20

^a Values represent means of three replicate trials. Analysis of variance indicated no significant difference ($P > 0.05$) between levels on plastic or wooden cutting boards. ANOVA indicated a significant ($P < 0.01$) effect due to washing with each cleaner or water.

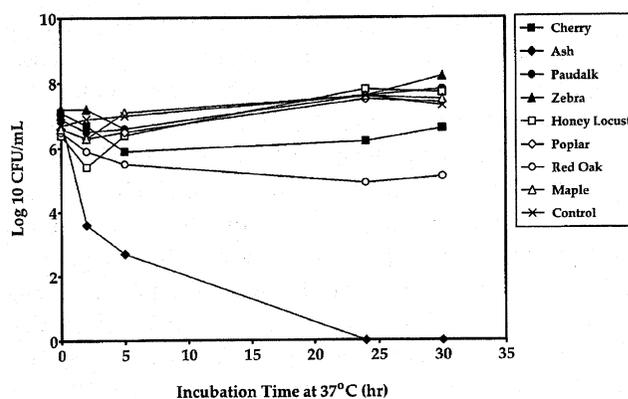


FIGURE 2. Inhibitory potential of aqueous hardwood extracts on *E. coli* O157:H7 in solution at 37°C for 0 to 30 h.

Results are shown in Figure 2 of the potential for aqueous hardwood extracts to inhibit *E. coli* O157:H7 over a 30-h incubation period at 37°C. Most of the hardwood extracts supported some level of growth, including paudalk (0.9 log CFU/ml), African zebrawood (1.0 log CFU/ml), honey locust (1.3 log CFU/ml), poplar (0.8 log CFU/ml), and sugar maple (0.9 log CFU/ml). Some inhibition was observed in extracts from black cherry (-0.5 log CFU/ml) and red oak (-1.4 log CFU/ml). Only white ash demonstrated a considerable level of inhibitory activity against *E. coli* O157:H7 at 2 h, 3.3 log CFU/ml were killed, while levels dropped another 0.9 log CFU/ml by 5 h. No organisms could be detected in the 24- or 30-h samples.

DISCUSSION

A significant finding of the study was that beef bacterial microbiota on polyethylene and wooden cutting boards had statistically similar patterns of potential for attachment and removal. Earlier research by Gilbert and Watson (14) indicated that more microorganisms were present on wooden boards after contact with food products. This is noteworthy because Schmidt (22) indicated that within 2 h of initiation of production in a meat-processing plant, cutting surfaces had reached maximum bacterial count levels and remained at those levels until the end of the work day. A further study by Abrishami et al. (1) showed that after cleaning, more bacteria are retained on wooden than plastic cutting-board surfaces. Furthermore, Gehring (13) recommended the use of acrylic cutting boards after showing that, when thoroughly cleaned and disinfected each day, they were cleaner than wooden boards. Kersken (17) recommended use of cutting boards made from low-density polyethylene over boards made from wood. Bartels et al. (5) found that polypropylene or polyethylene cutting boards were free of bacteria after cleaning and overnight soaking in commercial disinfectant. Gilbert and Watson (14) showed that unused and scored wooden cutting boards always had higher plate counts than those made from plastic. They also concluded that wooden surfaces could harbor and disseminate salmonellae. Acuff et al. (2) reported that commercial dish-washing detergent did not remove *Campylobacter jejuni* from a

wooden cutting board. The porosity and absorbency of wood could account for these observations. In contrast, the studies by Ak et al. (3, 4) demonstrated that wood contains antibacterial agents that can reduce the total microflora burden.

The contrasting methods used in the current and prior research may help explain differences in results. For example, while unscored plastic boards were used in the current study, Ak et al. (4) showed the ease of cleaning new and the difficulty of cleaning knife-scarred plastic cutting boards. Previously, Ruosch and Hess (21) recommended that plastic cutting boards be examined for cuts and scratches, since they found that recently planed plastic cutting boards were easier to clean than when they are rough and scratched. Additional factors affecting adherence and removal of bacteria from wood were discussed by Kampelmacher et al. (16) and included microscopic topography, occurrence of chains or clusters of organisms, adsorptive and desorptive phenomena, and sublethal injury of organisms due to drying and oxygen. Fat, nutrient, and moisture level, and presence of residual antibacterial substances also can affect bacterial counts on cutting boards (22). The factors listed above are essential considerations in the design of cutting board maintenance and cleaning programs. Another difference is that autoclaved cutting boards were used in the present study to mimic a worse-case scenario. We observed raised wood grain, similar to that which would occur when longitudinal wood sections are exposed to repeated water application.

It was shown in the current study that water removed a highly significant level of bacteria from the cutting-board surfaces; use of chemical cleaners did not statistically improve performance. It is noteworthy that only 100 ml of water (with the aid of brushing) was capable of removing most of the microorganisms. Abrishami et al. (1) found that more *E. coli* could be removed using an automatic dishwasher, with cold water and without detergent, from plastic cutting boards than from wooden boards. These investigators also found that after a cold-water rinse, more bacteria were retained on new than on used wooden boards. Schmidt (22) observed a 3-log CFU reduction in bacterial counts if 8 liters of water per m² were used to rinse polyethylene cutting boards after cleaning, in order to dilute residual nutrients left on the boards. In addition to rinsing, dry storage and disinfection significantly reduced counts on boards. Nonetheless, Ruosch (20) found that cold water did not adequately remove a thick covering of fat and meat on cutting boards.

Liqui-Nox and Ajax, used in the present study, are atypical for use in commercial operations, although Ultra Kleen and Liquid Rite-Away are used in the food-processing industry. In addition, the quantity of water used in the present study is low compared to customary commercial practices. It would be prudent to wash cutting boards with hot water and to use a chemical cleaning agent to minimize the residual bacterial load on cutting board surfaces. Kampelmacher et al. (16), recommended cleaning cutting boards with abrasive alkaline detergent and a sanitizer. Since the present study was not designed or conducted to compare the relative efficacy of the various chemical cleaners, it would

be inappropriate to rank them for bacterial-removing efficacy.

The observation from the present study that aqueous extracts of white ash dramatically reduced the recovery of *E. coli* O157:H7 after solution exposure supports an observation by Ak et al. (3). They found that *E. coli* O157:H7 counts dropped on ash cutting boards from an initial level of about 7 log to <1.5 log CFU/cm² within 12 h. Our data on white ash extracts, however, partially contradicts their statement (4) that antibacterial substances in wood are not readily water soluble. The choice of *E. coli* O157:H7 was based on the likelihood that contaminated cutting boards or other food-preparation surfaces are a source of contamination of trimmings used for ground beef—a common vehicle for enterohemolytic *E. coli*-induced gastroenteritis. The inhibitory effects were most likely not from a pH affect since the test system was buffered to neutrality (pH 7.0).

A host of variables exist to complicate comparison of studies on the safety of cutting-board materials. Some of these include the specific synthetic polymer or wood species, the liquid or solid nature of the product in contact with the surface, prior board use, cleaning conditions, and bacteriological sampling and analytical methods. A key point, however, is that food-preparation surfaces, in general, have been identified as a critical control point, and that regardless of the surface material, cutting boards need to be constantly maintained and monitored for cleanliness. This can be best accomplished through a rigorous sanitation and HACCP program.

ACKNOWLEDGMENTS

The authors thank O. Peter Snyder (Hospitality Institute of Technology & Management, St. Paul, MN) and Marc Cutrufelli (USDA-Food Safety & Inspection Service, Washington, D.C.) for their critical review of the manuscript.

REFERENCES

1. Abrishami, S. H., B. D. Tall, T. J. Bruursema, P. S. Epstein, and D. B. Shah. 1994. Bacterial adherence and viability on cutting board surfaces. *J. Food Safety* 14:153-172.
2. Acuff, G. R., C. Vanderzant, M. O. Hanna, J. G. Ehlers, and F. A. Gardner. 1986. Effects of handling and preparation of turkey products on the survival of *Campylobacter jejuni*. *J. Food Prot.* 49:627-631.
3. Ak, N. O., D. O. Cliver, and C. W. Kaspar. 1994. Cutting boards of plastic and wood contaminated experimentally with bacteria. *J. Food Prot.* 57:16-22.
4. Ak, N. O., D. O. Cliver, and C. W. Kaspar. 1994. Decontamination of plastic and wooden cutting boards for kitchen use. *J. Food Prot.* 57:23-36.
5. Bartels, H., H. J. Klare, H. P. Woehner, and W. Hosper. 1973. Suitability of plastic cutting boards for meat processing plants. *Fleischwirtschaft* 53:1071-1072. (In German.)
6. Brown, P., D. Kidd, T. Riordan, and R. A. Barrell. 1988. An outbreak of food-borne *Campylobacter jejuni* infection and the possible role of cross-contamination. *J. Infect. Dis.* 17:171-176.
7. Bryan, F. L. 1988. Risks associated with vehicles of foodborne pathogens and toxins. *J. Food Prot.* 51:498-508.
8. Bryan, F., C. A. Bartleson, O. D. Cook, P. Fisher, J. J. Guzewich, B. J. Humm, R. C. Swanson, and E. C. D. Todd. 1991. Procedures to implement the hazard analysis critical control point system. International Association of Milk Food and Environmental Sanitarians, Ames, IA.
9. Bryan, F. L., P. Teufel, S. Riaz, S. Roohi, F. Qadar, and Z.-U.-R. Malik. 1992. Hazards and critical control points of street-vending

- operations in a mountain resort town in Pakistan. *J. Food Prot.* 55:701-707.
10. Cameron, E. J., C. C. Williams, and R. J. Thompson. 1928. Bacteriological field studies in canning. *Bull. 25-L, National Canners Association, Washington, D.C.*
 11. de Boer, E., and M. Hahne. 1990. Cross-contamination with *Campylobacter jejuni* and *Salmonella* spp. from raw chicken products during food preparation. *J. Food Prot.* 53:1067-1068.
 12. Edelmeyer, H. 1984. Clean cutting boards and knives: is this too much to expect? *Fleischwirtschaft* 64:1370-1370.
 13. Gehring, F. 1962. Über die Verwendung von Plexiglas als Schneidunterlagen in Fischverarbeitungsbetrieben: gleichzeitig ein Beitrag zur Methodik von Desinfektionsunterlagen. *Arch. Lebensmittelhyg.* 13: 239-241.
 14. Gilbert, R. J., and H. M. Watson. 1971. Some laboratory experiments on various meat preparation surfaces with regard to surface contamination and cleaning. *J. Food Technol.* 6:163-170.
 15. Highlands, M. E., and O. B. Williams. 1944. A bacteriological survey of sardine canning in Maine. *Food Res.* 9:34-41.
 16. Kampelmacher, E. H., D. A. A. Mossell, M. van Schothorst, L. M. van Noorle Jansen. 1971. Quantitative investigations on the efficacy of methods for decontaminating wooden surfaces used in meat preparation. *Alimenta* 1971:70-76. (In German.)
 17. Kersken, H. 1973. Suitability of cutting boards for practical use. *Fleischwirtschaft* 53:939-940. (In German.)
 18. Mossel, D. A. A., and I. Bergenthun. 1965. Experiments in determining the bactericidal effect of the ampholytic soap preparation Tegel. *Fleischwirtschaft* 45:632-633. (In German.)
 19. Mossel, D. A. A., E. H. Kampelmacher, and L. M. van Noorle Jansen. 1966. Verification of adequate sanitation of wooden surfaces used in meat and poultry processing. *Zentralbl. Bakteriol. Parasitenkde. Abt. 1 Orig.* 210:91-104.
 20. Ruosch, W. 1981. Quantitative germ count of wood or plastic surfaces. *Schweiz. Arch. Tierheilk.* 123:97-103. (In German.)
 21. Ruosch, W., and E. Hess. 1977. Cleaning and disinfection of 3 butcheries by 3 cleaning firms. *Alimenta* 16:179-181. (In German.)
 22. Schmidt, U. 1989. Cleaning and disinfection methods: effect of rinsing on surface bacterial count. *Fleischwirtschaft* 69:71-74.
 23. Solberg, M., J. J. Buckalew, C. M. Chen, D. W. Schaffner, K. O'Neill, J. McDowell, L. S. Post, and M. Boderck. 1990. Microbiological safety assurance system for foodservice facilities. *Food Technol.* 44(12):68-73.
 24. Spencer, R. 1959. The sanitation of fish boxes. I. The quantitative and qualitative bacteriology of commercial wooden fish boxes. *J. Appl. Bacteriol.* 22:73-84.