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Disinfection of Household Cutting Boards with a Microwave Oven

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ABSTRACT

Used cutting boards with numerous knife marks, particularly those made of polymers, are difficult to disinfect manually. Plastic cutting boards have been preferred to wood because they can be washed in dishwashers and used in microwave ovens. Our study tested the microwave oven for disinfection of cutting boards. Surfaces of plastic and wooden cutting boards were inoculated with up to 10^9 CFU of *Escherichia coli* or other bacteria in broth culture and later sampled by contact with agar medium for CFU assay or by swabbing for ATP bioluminescence assay. On wood, almost total elimination of vegetative cells occurred with exposure times of the 3 to 4 min at a high setting on typical 450 to 600 g wooden boards, depending on board size, bacterial load, and moisture level. On plastic, microwave energy had almost no lethal effect on bacteria: 12 min of exposure did not reduce the number of bacteria significantly. Increased moisture (wetness) enhanced killing efficiency on wood, but was negligible on plastic. Temperatures near the wood surface reached 95°C within the first 4 min, whereas plastic surfaces reached no more than 40°C. Our study indicates that brief "cooking" of wooden boards at a "high" setting in a microwave oven is an effective way to kill bacteria, and thus a very simple and cheap method to protect food against cross-contaminating pathogens. Because plastic is relatively inert to microwaves, disinfection of plastic boards in a microwave oven is impractical.

Key words: Microwave, disinfection, plastic, wood

The main concern with food-contact surfaces such as cutting boards is cross-contamination by bacteria from animal sources *(5, 10)*. The U.S. Department of Agriculture *(11)* and the National Sanitation Foundation *(1)* strongly recommend that plastic cutting boards be used in the kitchen because wooden boards are allegedly harder to decontaminate than plastic due to wood's inherent porosity. However, this conclusion derives from lack of data and insufficient understanding of the structure of wood.

Kampelmacher et al. *(8)* explain that the structure of wood is complex. Aside from the standard x, y, and z spatial coordinates, these authors point out that one must also take into consideration the ζ coordinate, which relates to the heterogeneous structures of wood and how bacteria are located in these structures. Wood structure is distinguished by conductive tubules (xylem) and fibers arranged alternatively in more and less dense arrays (annular rings) as a result of seasonal changes *(13)* (Fig. 1). This structure affects how wood is used; in particular, moisture conductivity is typically greatest from an end-grain surface, less from edge grain, and less still from face grain. The work surface of a butcher block has typically been end-grain, whereas cutting boards sold for home use typically present face or edge grain.

In contrast, plastics are generally homogeneous. However, the foamed polypropylene often sold for use in home kitchens is quite porous, and all plastics scarred by knife edges retain bacteria after manual cleaning *(3)*. Our original study concerned the persistence of inoculated bacteria on the surfaces of plastic and wooden cutting boards *(2)*. Although our findings indicated that wood is at least as safe as plastic, others have expressed concerns about the decontamination of wood *(6, 12)*.

Our main objective in this study was to find a simple and effective automated means of decontaminating household cutting boards. Both the mechanical dishwasher and the microwave oven were considered. The mechanical dishwasher decontaminated even badly knife-scarred plastic boards (unpublished data), but the process took approximately an hour and thus was more likely to be applied after a meal than during preparation. With one exception (Tri-Ply Dishwasher-Safe from Bemis, Sheboygan Falls, WI), wooden boards were damaged by repeated cleaning in the dishwasher: glue joints were loosened, and the wood warped. Plastic cutting boards are often sold as "microwaveable," and microwave treatment of wooden boards is known (Mark D. Sobsey, personal communication); but the microbiological effect of this treatment apparently has yet to be determined, although studies of microwave destruction of pathogens in food have been conducted *(4, 7)*. Therefore, this study evaluated the effectiveness of kitchen microwave ovens in disinfecting plastic and wooden cutting boards by using challenge studies of *Escherichia coli* and *Staphylococ-*

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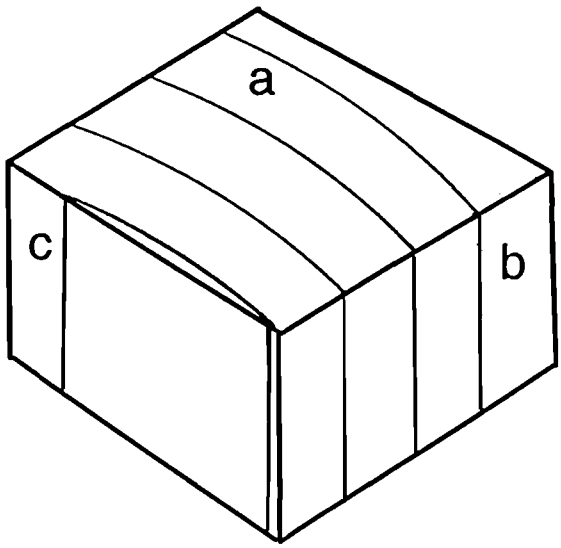

FIGURE 1. *Grain orientation in wood structure, based on location of annular rings: (a) end, (b) edge, and (c) face.*

cus aureus on these boards and measuring variables such as temperature and moisture loss.

MATERIALS AND METHODS

The feasibility of disinfecting plastic and wooden cutting boards (blocks) in a kitchen microwave oven was tested. In a series of challenge studies, bacteria were inoculated onto the surfaces, the blocks were heated in a microwave oven, and viable cells were detected using two microbial assays (contact with an agar plate, and ATP bioluminescence) and four sampling methods, including two specialized for wood (liquid perfusion, gouge).

Bacterial cultures

E. coli K12 Hfr (ATCC 23631) and *S. aureus* (provided by K.A. Glass, Food Research Institute, UW—Madison) were grown in nutrient broth (Difco Laboratories, Detroit, MI) at 37°C for 12 h. Bacteria were inoculated onto the plastic and wood surfaces by depositing 0.5 ml of the broth culture (at 10^5 to 10^9 CFU/25 cm^2) and spread evenly with a 1-ml disposable pipette tip. For plate counts, MacConkey and nutrient agar plates (Difco, 1.5% agar) were used to grow *E. coli* and *S. aureus,* respectively.

Contact surfaces

Plastic and wooden cutting boards were tested. Manufacturers donated new boards; private individuals provided used boards. Plastics included polyacrylic, polyethylene, foamed polypropylene, and polystyrene. Wood varieties tested were birch (*Betula* sp.) and hard maple (*Acer saccharum*). Both new and used products were tested. Plastic blocks were cut into 5 by 5 by 1 cm size (face area 25 cm^2) and exposed to germicidal UV light at a mean distance of 50 cm from the 30-W source at 20 to 25°C for 12 h. Wood blocks were cut into 5 by 5 by 2.5 cm size (face area 25 cm^2); the surface was exposed similarly to UV light and microwaved (at 800 W) for 60 s to disinfect the surface and interior before inoculation. A 467 g full-size wooden cutting board (16 × 35 × 2.5 cm) was also exposed to UV and microwaved at full power (800 W) for 3 min.

Sampling methods

Direct contact. MacConkey and nutrient agar plates (100 by 15 mm; 20 ml of agar) were used to make contact impression by putting the blocks face down on the agar surfaces and pressing gently for 20 s so that all four corners made an imprint on the agar. The plates were then incubated at 37°C overnight.

Swabs. Calcium alginate swabs were moistened in saline solution (0.09% NaCl solution in double distilled deionized water) for 10 s and applied to a sampling surface of 25 cm^2 with gentle pressure. Care was taken so that contact was even and no area was swabbed more than once.

Liquid perfusion (for wood only). The inoculum was allowed to soak into the wood for 4 h for 10^5 CFU per block, and 48 h for 10^9 CFU per block (the time until viable cells could no longer be detected on the surface). Twenty milliliters of Dulbecco's phosphate-buffered saline (D-PBS; GIBCO Laboratories, Grand Island, NY), pH 7.4, was delivered to the inverted lid of a petri dish and the wood block gently placed into the liquid.

Microbial assays were done by contact or spread plate count and ATP bioluminescence at appropriate periods up to (i) 12 h postinoculation (or after 8 h of soaking) for 10^5 CFU per block concentration or (ii) 84 h post-inoculation (or after 36 h of soaking) for 10^9 CFU per block concentration. These were the periods for maximum recovery of viable cells—after these times cell counts decreased. MacConkey agar was used to selectively grow *E. coli.*

Gouge (destructive sampling method for wood). As above, sampling was conducted at the appropriate time. A wood gouge (WorkBench Tool) was used to obtain a wood sliver at average size of 10 by 3 mm with a depth of ca. 0.3 mm. The weight was ca. 1 mg. The wood sample was immersed in 10.0 ml of H_2O and stirred vigorously with a Vortex mixer for 20 s. Then, 0.1 ml of the sample solution was withdrawn, spread on an agar plate, and incubated at 37°C for 12 to 24 h. Triplet samplings were taken for each assay.

Microbial assays

Plate count. Direct contact plates were incubated at 37°C for 12 h and counted for colonies using a Quebec colony counter. For plates with very high numbers (i.e., greater than 1,000 CFU), an estimated count was acquired by selecting an area that was countable (usually 1/8th of the whole) and multiplying it by the factor corresponding to the ratio of the area to the whole area (by 8 in this case).

ATP bioluminescence assay. GEM Biomedicals BG-P Optocomp 1 luminometer (Hamden, CT) and GEM Biomedicals ATP Surface Hygiene Monitoring Kit (Sparks, NV) were used. After surface sampling, the calcium alginate swab was transferred to a 12 by 75 mm round-bottom polystyrene cuvette (Falcon, Lincoln Park, NJ), and 500 μl of ATP Releasing Reagent (solution of ionic surfactants) was added. The swab was swirled vigorously for 20 s and pressed to allow a maximum amount of liquid to remain in the cuvette. The swab was discarded. Then 500 μl of ATP Monitoring Reagent (luciferin-luciferase, bovine serum albumin, and inorganic pyrophosphate stabilizers in 100 mM Tris-acetate buffer and 2 mM EDTA, pH 7.75) was added to the cuvette, mixed gently, and inserted into the luminometer. Light output was measured by the luminometer for 30 s in relative light units (RLU).

Microwave heating

A General Electric (Louisville, KY) Spacemaker microwave oven model JEM31M with an output of 800 W at 2,450 MHZ and a built-in temperature probe was used. Samples were placed in the center of the oven (to avoid cold spots) and were heated at the highest power setting. Temperatures were monitored during microwave heating by fiber-optic probe and sensing units (Model 1400,

Metricor Inc., Woodinville, WA). The probes were inserted through the rear right of the oven and implanted into holes drilled in the plastic and wood (depth of 3 mm for surface and 15 mm for interior). A thermocouple (Atkins Technical Inc., Gainesville, FL, Model 38653-K) was used to determine temperatures after microwaving.

RESULTS

Plastic and wood: effect of microwave energy on bacterial viability

E. coli and *S. aureus* responded analogously to microwave treatment. Therefore, the data presented derive mostly from *E. coli* for simplicity. Results were also consistent among types of plastic polymers or of wood species, so for some figures not all types of polymers or wood species are presented.

Contact plate. There were rapid decreases in viable bacteria on the wooden surfaces after microwave exposure (Fig. 2). Within 60 s, there were no live cells detected on the wooden blocks inoculated initially with a cell concentration of $1 \times 10^4/25$ cm^2. At 1.0×10^9 CFU/25 cm^2, complete killing occurred in 120 s (Fig. 3). On the other hand, *E. coli* on plastic blocks showed no decrease in CFU after 180 s of microwaving at full power. Killing was <90% on foamed polypropylene even after 12 min (Fig. 4).

ATP bioluminescence assay. This technique yielded similar results. Calcium alginate swabs were used to collect bacteria from the surface. Beginning with 110,000 RLU, there was virtually no detectable ATP activity on wood within 2 min, whereas there was still 40,000 RLU from microbial ATP on the plastic after 10 min in the microwave oven. Clearly, a significant residue of live bacteria remained on the plastic. There was a difference of ca. 3,000 RLU between microwave treated and untreated wooden blocks after 120 s of treatment.

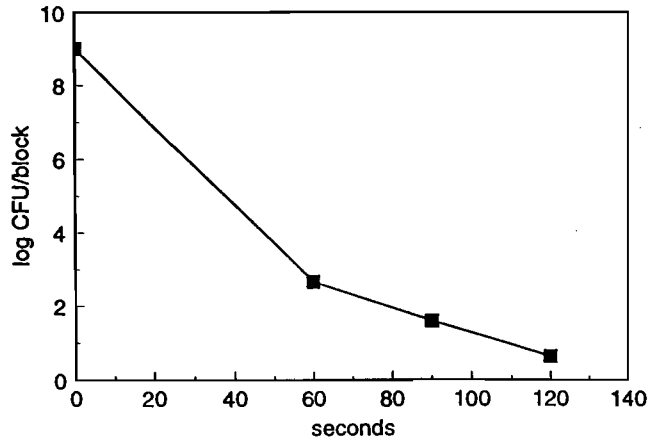

FIGURE 3. *Recovery of* E. coli *from wood that was treated with microwave energy. Approximately 1×10^9 CFU per block was inoculated on wood and sampled at 60, 90, and 120 s.*

Perfusion (wood only). This method was devised to "push" the bacteria back to the surface from the interior of the wood. After the inoculum was allowed to soak into the wood for 4 h, liquid (D-PBS) was used to soak the wood from the bottom. The ensuing capillary action flushed the bacteria from the interior to the surface, where they were sampled with the ATP bioluminescence assay and contact plates. The results were similar to those obtained by the previous methods, with a dramatic drop in viable bacteria after a short exposure (120 s) to microwaves. This finding showed that microwaves destroyed bacteria not only on the surface, but in the interior as well. Similar results were obtained by the gouge method.

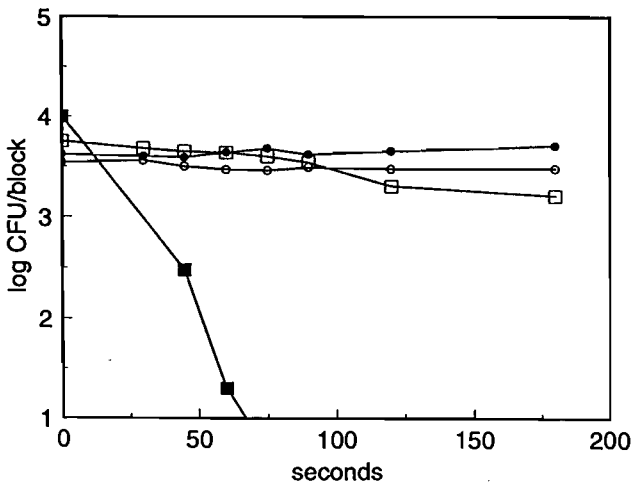

FIGURE 2. *Recovery of* E. coli *from new plastic and wood surfaces via MacConkey agar contact plates after exposure to microwave energy. Three representative plastics (acrylic (●), polyethylene (○), and foamed polypropylene (□), and wood (maple (■)) samples were tested. Eight blocks of each type were loaded with equal numbers of bacteria (ca. 1×10^4 CFU per block) and exposed to microwave energy at 800 W for 0, 30, 45, 60, 75, 90, 120, and 180 s.*

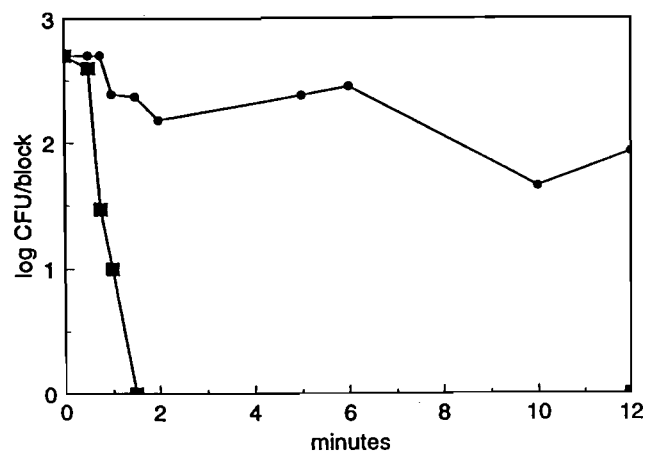

FIGURE 4. *Recovery of* E. coli *from new plastic (●) and wood (■) surfaces via MacConkey agar contact plates after 12 min exposure to microwave energy. Approximately 1×10^3 CFU per block was inoculated on 10 plastic (foamed polypropylene) and wood (birch or maple) blocks and exposed to microwave energy at 800 W for as long as 12 min. Wood was exposed for a maximum of 2 min because smoke was observed due to overheating. Zero value on the ordinate (log CFU per block) refers to 0 CFU detected using the agar contact sampling method.*

TABLE 1. *Recovery, using the gouge method, of* E. coli *(inoculum 1 × 10⁷/25 cm²) on a wood 467-g board (16 by 35 by 2.5 cm) exposed to microwave energy for up to 6 min*

	Sample (log CFU/25 cm²)	
Time (min)	Immediate[a]	After incubation[b]
0.0	6.9	TNTC
0.5	6.6	TNTC
1.0	<2	TNTC
1.5	<2	TNTC
2.0	<2	TNTC
3.0	<2	3
4.0	<2	<2
5.0	<2	<2
6.0	<2	<2

[a] Plate count on MacConkey agar of gouge sliver placed in 10 ml of nutrient broth immediately after sampling.

[b] Plate count of gouge sliver after overnight incubation in 10 ml of nutrient broth.

Gouge method. There were no detectable cells after 60 s of microwave heating on small blocks (25-cm² face area). For comparison, a 467-g wooden board (16 by 35 by 2.5 cm) was inoculated with *E. coli* (10^7 CFU/25 cm²). In this assay 4 min of microwaving was sufficient to eliminate bacteria (Table 1).

To learn whether wetness influenced the microwave effect (since cutting boards are frequently washed), dry and moist wood (rinsed for 0.5 min with tap water at 40°C) were inoculated with 1.0×10^6 CFU/25 cm² and sampled via the plate contact method. The kill was much more rapid with wet wood than dry (Fig. 5).

Thus, all four sampling and assay methods showed that microwave energy was very efficient in eliminating bacteria both from the surface and the interior of wood. However, microwave energy was not at all effective against bacteria on plastic.

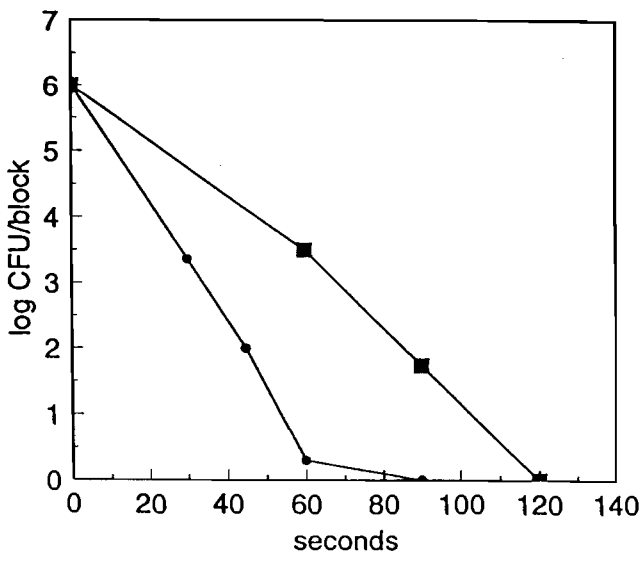

FIGURE 5. *Effect of microwave energy on moist and dry wood surfaces on recovery. Approximately 1 × 10⁶ CFU* E. coli *per block were inoculated on dry (■) and moist (●) wood (rinsed with water). Sampling was by direct contact plating. Zero value on the ordinate (log CFU per block) refers to 0 CFU detected using the above sampling method.*

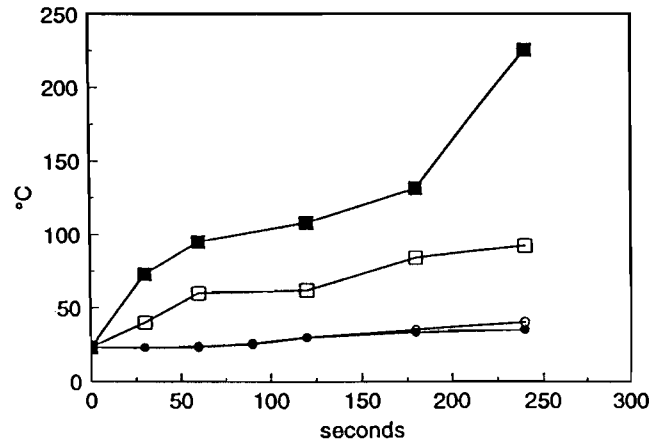

FIGURE 6. *Temperature profile of plastic and wood (5 by 5 cm block surface) during microwave heating. Plastic interior (○) and surface (●) temperatures, as well as those of wood interior (■) and surface (□) were measured by using a fiber-optic thermometer system.*

Temperature and moisture measurements

The temperature was measured during and after microwaving. Since arcing was a problem with conventional thermocouples, special fiber-optic probes were used. By varying the depths of probe-holes drilled into the wood, both the surface and interior temperatures could be measured. Surface and interior temperatures on wood (25-cm² block) approached 95°C and 200°C respectively after 4 min of microwave heating (a 75°C and 180°C increase), but on plastic that temperature reached only 35°C and 38°C respectively (Fig. 6). Smoke was seen coming from the wood after about 3 min of heating. The temperature was also measured on a 467-g wooden board (16 by 35 by 2.5 cm). The interior and surface temperatures reached ca. 100 and

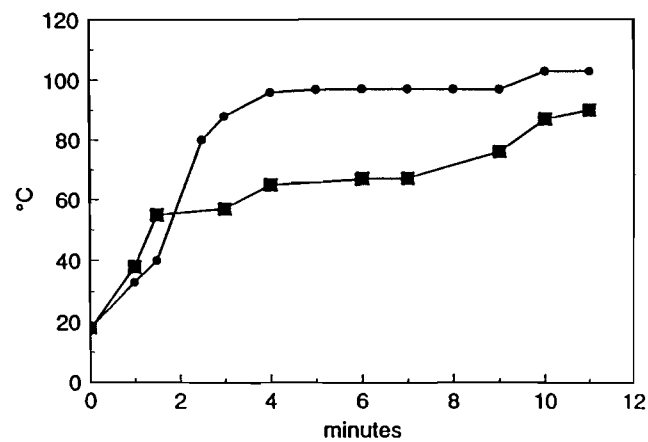

FIGURE 7. *Temperature profile of 467-g wooden cutting board (16 by 35 by 2.5 cm) heated in a microwave oven. Temperature was monitored with a fiber-optic thermometer system by inserting probes into predrilled holes at depths of 3 mm for surface (■) and 15 mm for interior (●).*

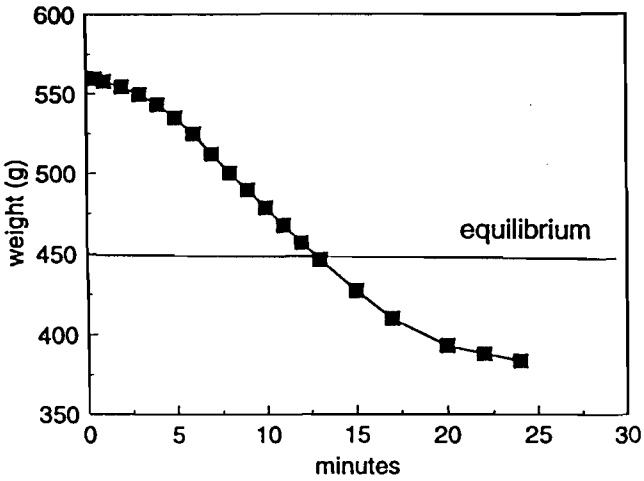

FIGURE 8. *Weight profile of water-saturated wood block during microwave heating at 800 W.*

65°C respectively after 4 min of heating. Smoke was seen at 11 min. This showed that a medium-sized cutting board can be safely microwaved up to 10 min without any detrimental side effects, such as smoking (Fig. 7). However, the previous data show that only about 4 min is really needed to eliminate bacteria and thus disinfect the surface.

Microwave heating is also very effective in drying wood. Wood that has been washed extensively often takes up water. A wooden board (15 by 25 by 2.5 cm, 450 g) was saturated with water by immersion. In 4 h, it gained 140 g of water (25% increase in weight). Fifteen minutes of microwaving returned the wood to its original weight (Fig. 8). Further heating drove out an additional 50 g of water below the wood's equilibrium weight.

Process variation

We observed that there were no differences in recovery of bacteria between new and used cutting boards, both plastic or wood, during or after microwaving.

A wood block that has been exposed to microwave heating for 2 min does not return to room temperature for about 10 min (30 min for a 467-g board after 4 min exposure). The additional killing effect of this residual heat was tested. One recovery was conducted (using the plate-contact method) immediately after heating, and another 10 min later. A very high load of bacteria was inoculated (10^9 CFU/25 cm^2). The residual heat produced a further decrease in bacterial numbers, particularly as more microwave energy was applied (Table 2).

TABLE 2. *Decrease in number of* S. aureus *inoculated on wood blocks (n = 2) at 1 × 10^9 CFU/cm^2 and exposed to microwave energy*

	Sample after microwave treatment (CFU/25 cm^2)	
Microwave Time (s)	Immediate	After 10 min at room temperature
0	TNTC	TNTC
30	TNTC	TNTC
60	1,513	794
90	691	251
120	4	0

DISCUSSION

This study was intended to test the use of a microwave oven to decontaminate plastic and wooden cutting boards. Although new plastic could be decontaminated by washing (machine and hand), older plastic boards have been shown to be very difficult to decontaminate *(3)*. The bacterial assay methods that were used in these challenge studies, contact by agar plate and ATP bioluminescence assay, showed that plastic cannot be effectively decontaminated by microwave heating. On wood, 3 to 4 min of heating of a 467-g board was sufficient enough to eliminate 6 to 7 log CFU of *E. coli.* Results with *S. aureus* were similar. Temperatures could exceed 100°C in the interior and approach 100°C on the surface. Because bacteria applied to the wood surface do not penetrate to great depths (data not shown), the temperature near the surface is of greater significance. Such temperatures are lethal for vegetative bacterial cells. Plastic, on the other hand, was inert to microwave action and had only a minimal rise in temperature; less than a decrease of 1 log CFU occurred during 12 min of microwave heating. Thus, only wood could be effectively decontaminated by microwave heating.

Questions have been raised concerning the viability of bacteria inside wood. Work in our laboratory (unpublished), and by others *(1, 8, 12)*, has shown that bacteria can remain viable for some time; however, these bacteria were unlikely to return to the wood surface, where they could contaminate food *(2)*. Therefore, the evidence does not support the common notion that wood surfaces are more likely than plastics to produce cross-contamination of food. Notwithstanding, the use of the microwave oven could alleviate any such lingering concern because the heat would kill the bacteria, inside and out. This was verified by our innovative sampling methods to detect bacteria inside the wood. The perfusion method allowed us to recover bacteria at the surface by "pushing" them to the top through liquid capillary pressure. The gouge method was not new *(8)*, but was modified by using a small gouge so as to permit collection of smaller, thinner samples of wood than had been done previously.

A recent FDA study on food-preparation behavior showed that 26% of American consumers do not bother to clean cutting boards after cutting raw meat or chicken *(9)*. Such behavior leads to a high risk of cross-contamination. Safe and efficient decontamination of wooden boards through microwave heating would seem to be the ideal solution. Although a consumer who does not bother to wipe a board may not put it in the microwave either, we believe that when consumers are alerted to the absolute effectiveness of this method, microwaving will certainly become a pertinent option.

We undertook this study to alleviate concern that wooden cutting boards cannot be satisfactorily disinfected due to porosity. We report here an easy but very practical way to decontaminate wood using a product that is available in most kitchens in the developed world: the microwave oven.

ACKNOWLEDGMENTS

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Note added in proof

Manufacturers of microwave ovens say that units with power ratings greater than 1,000 watts are no longer made for home use. We urge that those who have older, more powerful microwave ovens proceed cautiously in this application, using settings other than "high," shortening the heating time from 4 min, or both.

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