

Use of Microbial Modeling and Monte Carlo Simulation to Determine Microbial Performance Criteria on Plastic Cutting Boards in Use in Foodservice Kitchens

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SUMMARY

Many foodservice food safety regulation and consumer information bulletins advise frequent cutting board changes. However, few published data are available on microbial contamination rates of in-use cutting boards. The objective of this research was to determine microbial contamination rates, over time, on cutting boards being used in a real foodservice setting. Twelve different cutting boards were tested at five-minute intervals, over a two-week period, both before use and as they were used to chop various vegetables and raw meats. More than 400 individual observations were made during the two-week period. Food type, area of the cutting board, and sampling time did not influence the rate of bacterial increase over time. Change in bacterial population for each five-minute interval ranged from a decrease of 4 colony forming units (CFU)/4 cm² to an increase of 13 CFU/4 cm². The median increase was 3 CFU/4 cm² per 5-minute interval. The logistic distribution (2.42, 1.22) was chosen to describe the data and was used to create a simple simulation of cutting board contamination over time. Simulation results were used to investigate the relationship between guidelines for cutting board cleanliness and four different frequencies for cutting board change. The simulation predicts that cutting boards used for 15 minutes will contain < 20 CFU/4 cm² most of the time. Cutting boards used for 45 minutes would contain < 40 CFU/4 cm² more than 99% of the time. Cutting boards used for 60 minutes will usually pass a microbial criterion of 50 CFU/4 cm².

A peer-reviewed article

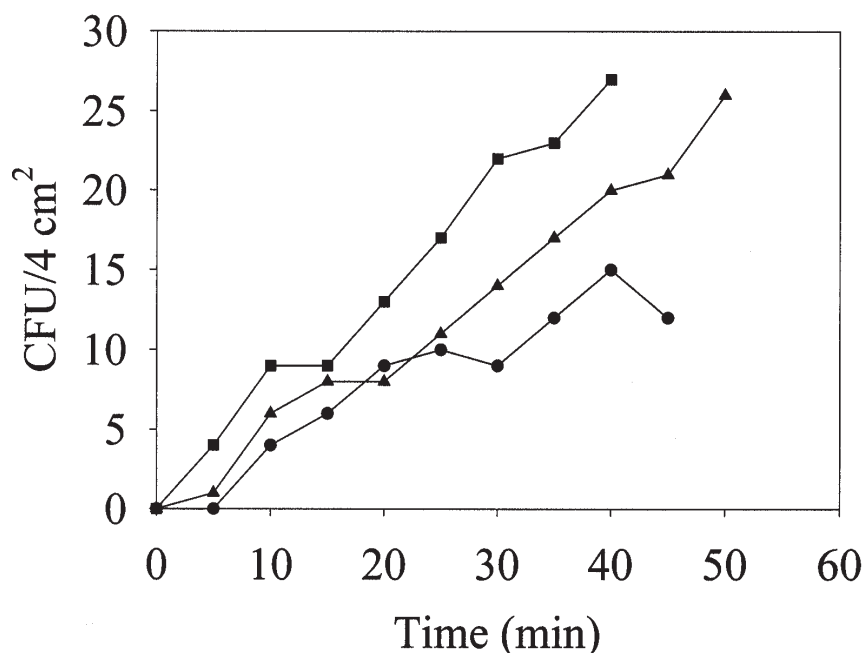
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TABLE 1. Current Rutgers Division of Dining Services guidelines on allowed levels of microbial contamination on surfaces (CFU/4 cm²)

Condition	Stored	In use
Acceptable	< 5	< 20
Some Concern	5 – 10	20 – 40
High Concern	> 10	> 40

FIGURE 1. Typical data demonstrating the increase in bacterial populations on plastic cutting boards in use in a food service kitchen over time. Each symbol represents results from a different experiment



INTRODUCTION

A foodservice food safety program has been in place at Rutgers University since 1973 (3, 8, 9). This program was instituted in response to a large food poisoning outbreak in one university dining hall. Since its creation, the program has been highly effective in preventing the occurrence of any other reported cases of food poisoning linked to university foodservice operations.

One feature of this food safety program is a surface sanitation guide-

line that specifies the amount of microbial contamination allowed on food contact surfaces. Although the program guidelines are known to be rigorous, we have always believed that a conscientious foodservice manager could achieve them with reasonable effort. As part of a complete re-evaluation of the program, we have been reviewing the current guidelines to see if they are in fact both reasonable and achievable. Specifically, we became interested in how frequently a cutting board would need to be

changed to meet the guidelines shown in Table 1.

Many foodservice food safety regulations and consumer information bulletins advise frequent cutting board changes. Bacterial recovery and transfer of artificially inoculated pathogens have been demonstrated in numerous studies (1, 5, 6, 10, 11). Zhao and others were able to recover *Enterobacter aerogenes* from plastic cutting boards up to 4 hours after inoculation and Abrishami and others (1) were able to recover *Escherichia coli* up to 24 hours after inoculation. Transfer rates ranged from 1 to 55% from *E. aerogenes*-contaminated cutting boards to lettuce (4). However, few published data are available on microbial contamination rates of in-use cutting boards.

The objective of this research was to quantify the increase in microbial contamination, over time, on cutting boards used in a real foodservice setting. This quantitative data was then described by mathematical models and incorporated into a Monte Carlo simulation. Results of the Monte Carlo simulation were used to evaluate two different microbial performance criteria for cutting board sanitary quality and the effect of the frequency of cutting board changes on the ability of a foodservice operation to meet those criteria.

METHODS

Twelve different cutting boards were tested over a two-week time period in a dining hall kitchen at Rutgers University. Boards were sampled in five general locations (top left, bottom left, center, top right, and bottom right), each location having an area approximately 4 cm², before and during use. A dining hall employee chopped a variety of vegetables and raw meats (as part of regular food preparation) on the cutting board. Five locations on each cutting board were sampled every five minutes during food preparation.

TABLE 2. Summary of the effect of food type on bacterial increase on plastic cutting boards in use in foodservice kitchens

Food	Number of observations	Change in total bacterial count (CFU/4 cm ²)	
		Average	Variance
Beef	34	3.50	7.23
Cabbage	10	2.00	5.11
Carrots	34	1.97	6.03
Chicken	24	2.04	3.69
Cucumbers	14	2.43	5.49
Fish	25	2.08	5.58
Greens	46	2.09	3.06
Mushrooms	15	1.80	10.17
Onions	20	2.85	4.13
Peppers	32	2.13	5.27
Pork	25	2.52	3.26
Potatoes	38	2.26	5.55
Tomatoes	44	2.00	5.81

TABLE 3. Summary of the effect of cutting board location on bacterial increase on plastic cutting boards in use in foodservice kitchens

Location	Number of observations	Change in total bacterial count (CFU/4 cm ²)	
		Average	Variance
Rear left	65	2.38	5.58
Rear right	65	2.06	2.21
Center	65	2.20	5.32
Front left	83	2.36	7.09
Front right	83	2.39	5.83

Testing continued for up to 55 minutes, depending upon the length of time the cutting board was in use. Sterile “Con-Tact-It” adhesive tape (Birko Corporation, Henderson, CO) was used to transfer bacteria from the cutting board to total plate count (TPC) agar (Difco, Detroit, MI). The

tape was pressed onto the board, then touched onto TPC agar. Plates were incubated for 24 h at 35°C before enumeration. For purposes of comparison, it would be helpful to note that 10 colonies from the adhesive contact transfer would be equivalent to 70 to 80 colonies on a 4 in² agar

contact plate (9). More than 400 individual observations were made during the two-week period.

Analysis of Variance (ANOVA) was conducted using Excel (Microsoft, Redmond, WA). Counts were transformed into frequency histograms by use of Excel and fit to a variety of statistical distributions using BestFit (Palisades Corporation, Newfield, NY). A Monte Carlo simulation was run using 1,000 iterations in @risk (Palisades Corporation, Newfield, NY).

RESULTS

Figure 1 shows a summary of typical data collected in these experiments. Microbial counts generally are at or close to zero colony forming units (CFU)/4 cm² at the start of use, increasing steadily over time. Out of 37 observations of “clean” cutting boards before use, 18 (48%), had counts above zero, ranging from 1 to 7 CFU/4 cm². All “clean” cutting boards had some areas with 0 CFU/4 cm² and some areas with 1 CFU/4 cm² or greater. In some cases, the counts did not increase from one time interval to the next, and in rare instances, the counts decreased from one time interval to the next.

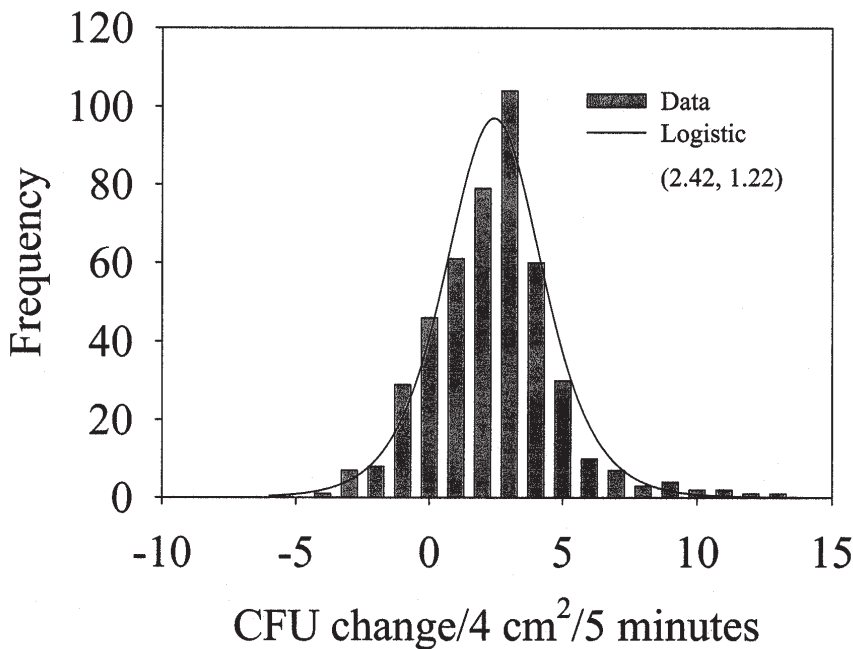
A summary of the ANOVA results for differences in CFU increases on cutting boards as influenced by food type is found in Table 2. Changes in bacterial populations ranged from 1.8 CFU/4 cm² for mushrooms to 3.5 CFU/4 cm² for beef. The changes in bacterial populations for most other foods fell between 2 and 2.5 CFU/4 cm². Analysis of Variance (ANOVA) found that the differences in CFU increase on cutting boards was not significantly influenced by food type ($P = 0.29$).

ANOVA results examining the influence of cutting board location sampled can be found in Table 3. A total of 65 observations were made for rear right, rear left, and center,

TABLE 4. Summary of the effect of sampling time on bacterial increase on plastic cutting boards in use in foodservice kitchens

Sampling time (min)	Number of observations	Change in total bacterial count (CFU/4 cm ²)	
		Average	Variance
5	39	2.44	7.30
10	39	1.87	3.48
15	39	2.15	4.34
20	39	2.49	4.15
25	39	3.18	7.05
30	39	2.18	6.41
35	39	2.00	4.21
40	39	2.26	3.72
45	32	1.84	6.85
50	12	2.83	7.24
55	5	1.80	2.70

FIGURE 2. Logistic distribution, with parameters $\alpha = 2.49$ and $\beta = 1.2168$ (solid line) fit to more than 400 observations (grey bars) describing the change in microbial populations on plastic cutting boards in use, in a food service kitchen



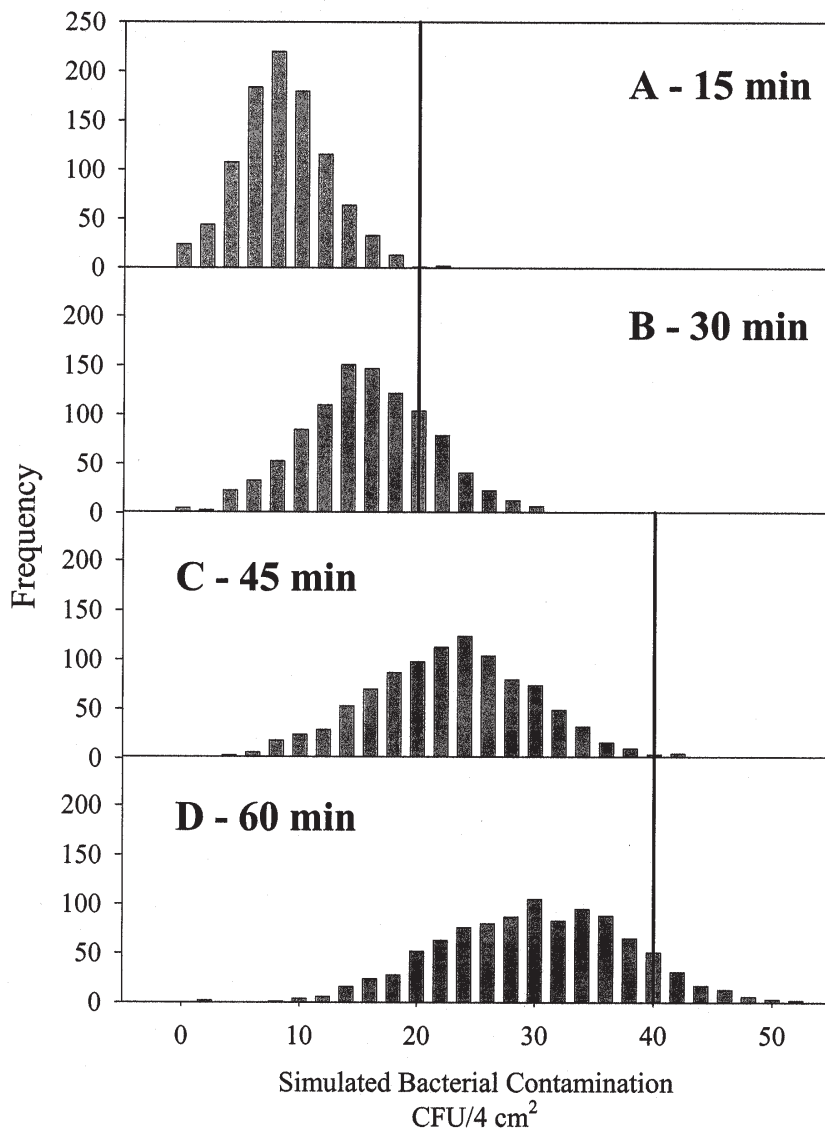
and 83 observations for front right and front left. Average change in contamination ranged from 2.06 (rear right) to 2.39 (front right) CFU/4 cm². ANOVA showed that contamination increases over time were not significantly influenced by cutting board location ($P = 0.90$).

ANOVA results on the influence of sampling time can be found in Table 4. Sampling times from 5 to 40 minutes had a total of 39 observations each, while times longer than 40 minutes had progressively fewer observations. Average change in contamination ranged from 1.80 (55 min) to 3.18 (25 min) CFU/4 cm². ANOVA showed that contamination increases over time were not significantly influenced by sampling time ($P = 0.39$).

When all the data were considered together (regardless of food being chopped, time, area of cutting board sampled, or sampling time) the change in bacterial population for each five-minute interval ranged from a maximum decrease of 4 CFU to a maximum increase of 13 CFU. The mode (most common) increase was 3 CFU per 5 minute interval (Fig. 2), while the median increase was 2 CFU per 5 minute interval (analysis not shown). When counts were transformed into frequency histograms and fit to a variety of statistical distributions, the logistic distribution with parameters $\alpha = 2.49$ and $\beta = 1.22$ provided an acceptable goodness of fit (Fig. 2).

The logistic distribution was used in a simulation of contamination on a cutting board over time. The results are shown in Figure 3. Figure 3A shows the distribution of populations on a cutting board after 15 minutes of use. The data ranged from 0 to 22 CFU/4 cm², with only 21% of the simulated results falling above the 20 CFU/4 cm² in-use guideline. The simulation results for cutting board contamination after 30, 45, and 60 minutes of use are shown in 3B, 3C and 3D, respectively. As duration of

FIGURE 3. Results of a 1000 iteration Monte Carlo simulation, describing the bacterial population per 4 cm² on cutting boards after 15 minutes (A), 30 minutes (B), 45 minutes (C) or 60 minutes (D) of use. Lines are shown at 20 CFU per 4 cm² (Panels A and B) or 40 CFU per 4 cm² (Panels C and D)



use increased, the range of contamination increased, shifting to higher contamination levels, as expected. After 30 minutes of simulated use, about 16% of the virtual cutting boards had contamination levels in excess of 20 CFU/4 cm². When the simulated duration of use was increased to 45 minutes, most of the virtual cutting boards exceeded the guidelines of 20 CFU/4 cm², but only a very small percentage (0.41%) contained more than 40 CFU/4 cm².

When the simulation was extended to 60 minutes, about 7% of the virtual cutting boards contained more than 40 CFU/4 cm². A very small percentage (0.51%) had counts above 50 CFU/4 cm².

DISCUSSION

All cutting boards were found to have at least 1 CFU in one or more of the five areas sampled before use.

Although boards are not expected to be sterile, cutting board sanitation could still be improved. Cutting board used in Rutgers University dining halls were machine washed between uses with hot water and detergent, using automatic dishwashing equipment. Abrishami and others (1) demonstrated that machine-washing with cold water and no detergent reduced artificially inoculated *E. coli* on used plastic cutting board surfaces by 4.52 log₁₀ CFU. Welker and others (10) demonstrated that machine washing with hot water and detergent completely removed *E. coli* from plastic boards. Since washing appears to be quite effective in reducing bacterial contamination on cutting boards, it is likely that cutting boards are subject to low levels of contamination during storage after washing. There is also evidence that air drying of plastic boards accelerates bacterial death rates (2). If cutting boards were washed, re-contaminated and then stored wet, it is possible that this contributed to bacterial survival and/or growth.

Bacterial counts on the cutting boards changed over time, generally starting at or close to zero colony forming units (CFU)/4 cm² and then increasing steadily over time. In some cases the counts did not increase from one time interval to another, and in an occasional rare instance, the counts decreased from one time interval to another. Because of the time scale (i.e., sampling at 5-min intervals) these changes are not likely due to microbial growth, which would not occur this rapidly at room temperature. Instead, we believe these changes in bacterial populations on the cutting boards are due to transfer from the foods being prepared. Since these raw foods generally have high bacterial loads, and the cutting boards are relatively clean, the net transfer is from the food to the cutting board.

The type of food being chopped had no effect on the increase in bacterial populations over time. This

could be related to an inverse relationship between transfer rates and starting concentration, which has been investigated by our lab (7). We have observed that when bacterial populations on source surfaces are high, transfer rates are proportionally low, and conversely when concentrations are low, transfer rates are high. For example, even though raw beef may have higher bacterial populations than potatoes, if transfer rate is inversely proportional to the starting concentration, a greater percentage of bacteria would be transferred from potato than from beef. It is possible that if a food with a very low bacterial count (e.g., cooked chicken) were to be chopped on a cutting board, a difference in the rate of change would be observed. Overall, the mean and median increases per 4 cm² over 5 minutes were very low. Previous research (4) has shown transfer rates between cutting boards and food to be as low as 0.60% and as high as 45%, with a mean near 10%.

CONCLUSIONS

Our simple simulation can be used as a tool to investigate cutting board policy changes for dining halls. For example, the current microbial guideline for an in-use piece of equipment is < 20 CFU/4 cm². According

to our simulation, if cutting boards are in use for 15 minutes or less, they will meet this guideline most of the time. Since changing a cutting board every 15 minutes is not practical in most foodservice kitchens, other guidelines should be considered. For example, a less stringent guideline of 40 CFU/4 cm² would allow use of cutting boards for up to 45 minutes. Cutting boards in use for 45 minutes would meet the guideline more than 99% of the time. Finally, if managers wished to adopt a guideline that insured that cutting boards used more than 60 minutes had increasingly greater chance of failing a sanitary guideline then an appropriate sanitary microbial criterion of 50 CFU/4 cm² should be adopted.

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