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A Comparison of Urethane and Cellulose Sponges as Cleaning Tools in Household Kitchens

ABSTRACT

Household kitchen sponges are known to harbor enteric bacteria and are believed to play a role in cross contamination during food preparation. This study compared the reduction of chlorine and a quaternary ammonium disinfectant, and of bacterial load, for polyurethane and cellulose sponges used in households. Chlorine levels were not reduced after 30 minutes when polyurethane sponges were used, but cellulous sponges use reduced chlorine levels by 24%. Polyurethane sponges always had fewer total bacteria, coliforms and *Escherichia coli* than cellulose sponges. This was also the case of both types of sponges containing an antimicrobial. A risk assessment comparison indicated that this difference resulted in a reduced risk of infection by almost 90% if pathogenic *E. coli* were present in polyurethane sponges vs. cellulose sponges. Overall, use of the polyurethane sponges used in this study has several advantages over use of cellulose sponges in reducing exposure to enteric bacteria in the kitchen.

INTRODUCTION

Cleaning tools such as sponges and cloths are known to harbor large numbers of bacteria and are a potential source of spreading microorganisms throughout food preparation areas during use *(4)*. The moist environment and uptake of biodegradable organics (e.g., food debris) encourage bacterial growth and persistence. Thus, the use of these cleaning tools can result in cross-contamination of surfaces and foods during cleaning and in contamination of the user's hands, resulting in increased risk of infection from organisms such as pathogenic *Escherichia coli* and *Salmonella (1)*, especially in kitchens where bacteria such as *E. coli* and *Salmonella* can grow in the sponges and increase to very high numbers within a few days *(1, 2, 4, 5)*. The average geometric mean of total coliform bacteria from liquid squeezed from cellulose sponges in one study was found to average 115,000/ml and fecal coliforms 446/ml. Another shortcoming of

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such cleaning tools is that they tend to bind or combine with commonly used disinfectants such as chlorine and quaternary ammonium disinfectants (quats), reducing the concentration of these disinfectants and thus decreasing their effectiveness on surfaces *(3)*.

The goals of this study were to determine whether polyurethane sponges offered advantages over cellulose sponges in terms of reducing the growth of *E. coli*, the risk of infection if a bacterial pathogen was present, and the amount of commonly used disinfectants required.

MATERIAL AND METHODS

Cleaning tools

Cellulose and urethane sponges, regular and containing an antimicrobial, were purchased at local stores in Tucson, AZ. Sponges were soaked in tap water; the water was hand squeezed out ten times to remove any preservatives; and sponges were then dried for 24 hours.

Reaction with disinfectants

The sponges (triplicate) (~nine grams in weight) were placed in beakers containing 1000 ml of a solution of quaternary ammonium disinfectant (Lysol Fresh and Clean, Reckitt Benckiser, Parsippany, NJ; a mixture of alkyl – 50% C_{14}, 40% C_{12},10% C_{16}- dimethyl ammonium chlorides) (510 to 530 mg/l) or chlorine bleach (Clorox Company, Oakland, CA) (230 to 270 mg/l). They were tested for residual disinfectant after 30 minutes of contact. Chlorine residual was measured by use of the DPD test and quat by the AOAC 961.02 test, using a spectrophotometer (Hach Chemical Company, Loveland, CO).

Bacterial assays

To determine the occurrence of bacteria in the sponges, they were placed in households to be used for 28 days; each household had 4 to 6 members, and 20 households participated in the study. Each household received one cellulose and one urethane sponge. Volunteers were asked to use each sponge for cleaning half of the household dishes each day. This was repeated with the use of cellulose and urethane sponges containing an antimicrobial for an additional 28 days. The sponges were sampled by being placed in a sterile plastic bag and being squeezed to extract one ml of fluid from each sponge, after which 0.1 ml of DE (Dey/Engley) neutralizing broth (Difco, Sparks, MD) was added to the fluid extracted from each sponge. The samples were then transported to the laboratory, held on ice at 4°C to prevent bacterial growth during transport, and assayed for bacteria immediately after return to the laboratory. After dilution in phosphate buffered saline, 0.1 ml amounts of diluted sample were spread plated on the appropriate media. R2A agar (Difco) was used for assay of heterotrophic plate count (HPC). The R2A medium was incubated at room temperature for five days, after which colonies were counted. Coliforms and *E. coli* were assayed using the MPN Colilert Quantity Tray system (IDDEX, Westbrook, ME) incubated at 35°C. Selected isolates were tested to confirm *E. coli* by using API 20 identification biochemical identification test kits 20E (bioMerieux, Marcy-I'Etiole, France).

Risk assessment

Risk of infection from sponges contaminated with pathogenic *E. coli* may be related to cross-contamination of foods or contamination of the hands. In this study, we considered the risk of infection from contamination of the hands and direct ingestion via the hands. Chaidez et al. *(2)* used a similar approach to assess the risk of infection from *Salmonella* present in household kitchen sponges in Mexico. This model considers both the probability of infection from ingestion of different amounts of pathogenic *E. coli* and the dynamics of hand activity in contamination of the hand and transfer to the mouth.

Exposure model

To determine the Dose, *D*, ingested by a person, the following model, shown as equation 1, was applied to *E. coli* concentrations on hands as determined in this study.

$$D = \frac{C_{Hand}}{A_{Hand}} \times \sum_{i=1}^{m} \left(f_{2,i} \times A_i \times N_i \times T_i \right)$$

in which

D:	is the dose or total count of viable *E. coli* ingested by a person in time *T* (CFU);
Csponge:	is concentration of viable *E. coli* measured in sponge, (CFU/2 ml of liquid);
f1:	Transfer efficiency of *E. coli* from sponge to hands (fraction, dimensionless);
A_{Hand}:	area of 2 hands (cm^2);
f2,i:	hand to orifice *"i"* transfer efficiency of *E. coli* (fraction; dimensionless);
i:	orifice i through which the *E. coli* can enter the body, such as mouth, nose or eye (1, 2, 3, 4 ….*m*);
m:	total number of orifices;
Ai:	surface area of hand that touches orifice *"i"* (cm^2);
Ni	Number of times a person touches his/her orifice *"i"* (per minute);
Ti	Time duration of exposure (minutes)

It should be noted that the concentration of *E. coli* on hands, C_{hand}, is calculated using equation 2.

$$C_{hand} = f_1 \times C_{Sponge}$$

Dose response model for *E. coli*

Ferguson and June *(6)* and June et al. *(7)* conducted similar studies to determine dose response (probability of infection) of ingested pathogenic *E. coli* by humans. Results

from the two studies were pooled as for the development of the dose response model in this study. The data that best fit a beta-Poisson dose response curve (equation 3) were the coefficients of $\propto = 0.1664$ and a $\beta = 23{,}503$, predicting the probability of infection from ingestion with goodness of fit measure of 0.999998. N is the number of pathogenic *E. coli* ingested.

$$\text{Probability (Infection)} = 1 - (1 + N/\beta)^{-\alpha} \quad (3)$$

Sources of data for exposure parameters

To determine hand-to-mouth contacts per minute, data from Nicas and Best *(9)* was utilized, using bootstrapping techniques *(8, 15)*. The developed hand-to-mouth contact distribution has an average of 0.1332 per minute and a 95% confidence interval of [0.0694, 0.2283]. To determine the area of mouth and hand, raw data obtained from USEPA *(14)* and from Snyder et al. *(13)* were utilized to generate the distributions, again, by use of bootstrapping techniques. Area of mouth was on average 6.89 cm^2, with a 95% Confidence Interval of [6.63, 7.13]. Area of hand distribution was on average 658 cm^2, with a 95% confidence interval of [533.1, 881.6].

A point estimate of 0.339 for transfer efficiency of *E. coli* from hand to nose, hand to eye and hand to mouth was used in the model, based on Rusin et al. *(11)*, the only data available in the literature. Parameters derived from the bootstrapping are shown in *Table 1.*

Modeling probability of *E. coli* infection

E. coli usually enters the body through the mouth; hence using parameters presented in *Table 1* in equation 1, 2 and 3 yields equation 4, in which CSponge is the measured concentration of *E. coli* found on the sponge:

$$D = \frac{f_1 \times C_{Sponge}}{A_{Hand}} \times \sum_{i=1}^{m} (f_{2,i} \times A_i \times N_i \times T_i)$$

$$D = \frac{0.0003 \times C_{Sponge}\,(CFU/2\ ml)}{658.94\ cm^2} \times \left(0.39 \times 6.89 cm^2 \times \frac{0.0848}{minute}\ 60\ minutes\right)$$

RESULTS

Reaction of unused sponges with disinfectants

All assays for residual chlorine and quat were done in triplicate for each time point at which they were tested. The average reduction of the disinfectants is shown in *Table 2*. In 30 minutes of contact, the least of chlorine loss was with the polyurethane sponge (0%) and the most by the cellulose sponge (24%); however, quat reduction was similar with both types of sponges.

Occurrence of bacteria in the sponges

Sponges were place in homes and the numbers of total bacteria (HPC bacteria), coliform bacteria and *E. coli* were monitored once per week over a four-week (28 day) period. *Table 3* shows the geometric means of the different types of bacteria in the different types of sponges after 28 days. Although a significant difference was not always seen in the geometric average number of bacteria, numbers were always lower in the polyurethane sponges than in the cellulose sponges. Numbers of *E. coli* in the polyurethane sponges were 99.9% lower than in the cellulose sponges after 28 days. This difference was statistically significant ($P = 0.031$). Numbers of total bacteria in the polyurethane sponges were also significantly lower.

The numbers of HPC bacteria in the antimicrobial cellulose sponges were greater than in the regular sponges after 28 days. The numbers of coliform bacteria and *E. coli* were similar in both types of sponges. In a previous study, we noted that a cellulose sponge with an antimicrobial claim retarded the growth of only HPC bacteria, and the levels after 7 days were similar in both regular and antimicrobial cellulose sponges *(4)*. Information was not provided by the manufacturer on the nature of the antimicrobial in the sponges used in this study.

Probability of infection from pathogenic *E. coli*

The probability of infection from the presence of

TABLE 1. Parameters for use with Equation 1

Parameter	Parameter Unit	Distribution	95% Confidence Interval		Mean Value Used in the Model	Source
			Lower Limit	Upper Limit		
A_{Hand}	cm^2	Bootstrapping	533.1	881.6	658.94	*13, 14*
$f1$	fraction	Point Estimate	-	-	0.0003	*11*
$f2_{,Mouth}$	fraction	Point Estimate	-	-	0.339	*11*
A_{Mouth}	cm^2	Bootstrapping	6.63	7.13	6.89	*14*
N_{Mouth}	per minute	Bootstrapping	0.0694	0.2283	0.1332	*9*

TABLE 2. Reduction of disinfectants by sponges after 30 minutes*

Sponge	Percent Reduction	
	Chlorine	Quat
Polyurethane	0	6
Cellulose	24	8

*initial chlorine concentration was 230 to 270 mg/L; quat concentration was 510 to 530 mg/L

TABLE 3. Geometric averages of bacteria in tested sponges after 28 days

Type of Sponge	Geometric Average Per Sponge		
	HPC	Coliforms	*E. coli*
Cellulose	238,000	1,220	45.8
Antimicrobial Cellulose	479,000	1,120	56.5
Polyurethane	129,000	590	0.27
Antimicrobial Polyurethane	45,700	552	0.23

TABLE 4. Probability of infection with pathogenic *E. coli* from use of sponges

Concentration of *E. coli* on Sponge (CFU/2 ml)	Probability of Infection One Time Event			Probability of Infection for One Month of Sponge Used 3 Times per Day		
	Antimicrobial Cellulose Sponges	Antimicrobial Polyurethane Sponges	% Reduction	Antimicrobial Cellulose Sponges	Antimicrobial Polyurethane Sponges	% Reduction
1,000,000	1.1e-3	1.2e-4	89.4	9.7e-2	1.1e-2	88.9
100,000	1.2e-4	1.2e-5	89.7	1.0e-2	1.1e-3	89.6
10,000	1.1e-5	1.0e-6	89.7	1.0e-3	1.1e-4	89.7
1,000	1.0e-6	2.0e-7	89.7	1.0e-4	1.1e-5	89.7
100	1.0e-7	1.0e-8	89.7	1.0e-5	2.0e-6	89.7

pathogenic *E. coli* in the cellulose and polyurethane sponges containing an antimicrobial, from a onetime use and from multiple uses over 30 days, are shown in *Table 4*. The results indicate that the probability of infection is reduced by approximately 82 to 90% with the use of the antimicrobial polyurethane sponge vs. the antimicrobial cellulose sponge. It was assumed that the hands became contaminated with two ml of liquid from the sponges. The geometric average concentration was 3.13 CFU/2 ml for cellulose sponges and 2 CFU/2 ml for polyurethane sponges, with 176.8 CFU/2 ml being the highest value detected for cellulose sponges, and 2.0 CFU/2 ml the highest value detected for polyurethane sponges.

DISCUSSION

Kitchen sponges have been shown to be potential sources of enteric bacteria and pathogens in households *(1, 5)*. As such, they can contaminate surfaces and the hands of users, resulting in potential risks of infection to the users via the hands and foods consumed uncooked *(2)*. Use of sponges containing antimicrobials or soaking of sponges in bleach can reduce their numbers. Enriquez et al. *(4)* showed that the use of cellulose sponges containing an antimicrobial reduced the numbers of fecal coliforms on countertops in kitchens. Chaidez and Gerba *(2)* found that the risk of *Salmonella* infection in households was reduced by soaking cellulose sponges in bleach once a day. The goal of this study was to assess whether the sponge material could influence the bacterial load of household kitchen sponges.

The effectiveness of cleaning tools is influenced by binding or reaction of disinfectant used in the cleaning processes *(3)*. The polyurethane sponge was found to have no effect on the concentration of household chlorine bleach within 30 minutes of exposure, but the cellulose sponges reduced the concentration by 24%. In contrast, neither sponge resulted in a large loss of quat over the same period of time.

The levels of bacteria were always less in the polyurethane sponges (both regular and antimicrobial) than the cellulose sponges after use in households for one month. This difference was statistically significant for both the regular and antimicrobial sponges. The numbers of the fecal bacterium *E. coli* was always 99.9% less in the polyurethane sponges. A risk assessment assuming that pathogenic *E. coli* were in the sponges at the same level indicated that the risk of a person becoming infected by using the antibacterial polyurethane sponge was ~82 to 90% less than if the antibacterial cellulose sponge were used.

To further assess the benefits of the polyurethane sponges, a risk assessment was conducted to determine the probability of infection from the use of the different sponges in the kitchen. The risk of infection from the antimicrobial polyurethane sponges ranged from approximately 82 to 90% less than with the cellulose antimicrobial sponges. Guidance for acceptable risk of infection for drinking water in the United States for enteric organisms has been defined as 1:10,000 *(10)*. This is a daily risk of 2.7×10^{-7} *(12)*, or a 30-day risk of 8.1×10^{-6}. The frequency of pathogenic *E. coli* in household sponges in the United States is not known, nor is the actual concentration. Thus, risk may be under or overestimated. Enriquez et al. *(4)* found *Salmonella* in ~15% of the household sponges in homes in the United States, and Chaidez et al *(1)* detected it in 3.8% in household sponges in Mexico. Uncertainty in the estimate may also arise from over or underestimating the use of the sponges, duration of use, and infectivity of other strains of pathogenic *E. coli*. Factors that would over estimate risk include die-off of the *E. coli* on the hands before entering the body via the mouth or lip, and washing the hands after use of contaminated sponges.

CONCLUSIONS

- Cellulose sponge use reduced chlorine levels by 24% after 30 minutes, but no such reduction occurred with the polyurethane sponges. This would be expected to result in more effective disinfection with use of polyurethane sponges than with use of cellulose sponges.
- Total numbers of bacteria and *E. coli* were lower with use of regular polyurethane sponges than with use of regular cellulose sponges.
- Total numbers of bacteria and *E. coli* were less for antimicrobial polyurethane sponges than for antimicrobial cellulose sponges in this study.
- Use of polyurethane sponges could reduce the risk of infection by pathogenic (disease-causing) *E. coli* by up to almost 90%.

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