

# Recovery of Microorganisms from Various Locations in Apartments Occupied by College Students

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## Abbreviations

CFU - colony-forming units

TSA - tryptic soy agar

DRBC- dichloran rose-bengal chloramphenicol

MRSA - methicillin-resistant *Staphylococcus aureus*

YM - yeasts and molds

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## Abstract

**Introduction:** Microbial contamination in living quarters is important for public health and contamination of different locations within the home is of general interest. **Objective:** The objective of this study was to determine the level of contamination at five different locations in university apartments. **Method:** Total aerobic microorganisms and yeast and mold populations were enumerated from kitchen sink drains, kitchen counters, refrigerator door handles, toilet seats, and kitchen sponges over a 6-week period. **Results:** Kitchen sponges were found to harbor the highest bacterial and yeast/mold populations among the five locations sampled. Kitchen sink drains were the second most contaminated location with the kitchen counter, refrigerator door handle and toilet seat containing the fewest number of microorganisms from among the locations tested. **Conclusions:** This points to the importance of finding an alternative method of cleaning or changing sponges frequently.

**Keywords:** bacterial contamination, home surfaces, college apartments, microbiology, bacterial enumeration

## 1. Introduction

There has been a general interest in the levels of microorganisms found in different locations in the home (Higuera and Jewell, 2020; Maheshwari, 2021; Bennett, 2023; Gibbs, 2023; Gilwit, 2023; Knobloch and Potts, 2023; Leverette, 2022). Bacteria are found on nearly all surfaces, including those in the home and maintaining clean living spaces is important for personal health. College apartments create an ideal environment for bacterial contamination partly due to the number of people living in close proximity, less attention to regular cleaning and high traffic in these living spaces. In a study by Mitz (2016), swabs were used to collect bacteria on shower tubs and drains, the kitchen sink drains, showerheads, kitchen faucet handles, dish sponges, and coffee makers. *Escherichia coli*, coliforms, Methicillin-resistant *Staphylococcus aureus* (MRSA) and yeast and mold (YM) were present on all of these surfaces (Mintz, 2016). In a similar study, Xiong and Olson (2017) used 3M™ aerobic plates to test the kitchen environment of students attending a private college and found that students seldom clean their kitchen drains.

Evans and Redmond (2019) found that the highest contamination levels among various household locations were actively used cleaning tools like dish brushes, dishcloths, and sponges. Dish brush usage duration was significantly linked to *Enterobacteriaceae* contamination (Evans & Redmond, 2019). According to Knoll (2019), samples taken from kitchen sponges, and bacterial loads were measured over a 28-day period and among the 14 samples, three samples exhibited a logarithmic value exceeding  $>9 \log \text{CFU/cm}^3$  with the average bacterial load of  $7.5 \log \text{CFU/cm}^3$ .

Borrusso and Quinlan (2017) tested kitchen swab samples in 100 homes and found fecal coliforms in 44% of the homes, mainly in kitchen sinks, sponges, and dishcloths, and *E. coli* in 15% of homes, primarily in kitchen sinks. They noted that finding fecal coliforms or *S. aureus* on a sponge or dishcloth indicated a likelihood of similar contamination on other kitchen surfaces, underscoring the role of sponges and dishcloths as bacterial reservoirs and carriers in the kitchen. Speirs et al. (1995) indicated that moist locations surrounding the sink, including the countertop, drain, and drying area, along with cleaning materials like dishcloths, sponges, and tea towels, exhibited the highest concentrations of microorganisms. These researchers observed that Gram-negative rods were predominantly present in the sink, while Gram-positive cocci were more prevalent in cloths (Speirs et al., 1995).

### 1.1 Research Problem

Research on the distribution of microorganisms in the household environment shows that bacterial contamination is widespread. Microorganisms gain entry into homes from air, water, soil, pets, food products, people, rodents and pests (Hussain et al., 2024). The risk of bacterial contamination in college apartments requires an understanding of which areas may have higher levels of contamination. The studies in Michigan (Mintz, 2016) and Minnesota (Xiong and Olson, 2017) raised awareness of the high levels of contamination in the kitchen, and microbial contamination within college apartments in general.

### 1.2 Research Objective

The objective of this study was to determine the level of total aerobic microorganism as well as yeasts and molds recovered from five different locations in college apartments. Data from our investigation will enhance awareness of possible health risks associated with surface contamination and encourage the public to practice effective sanitation practices.

## 2. Materials and Methods

### 2.1 Materials

Materials included: Q swab™ ready-to-use surface sampling swabs with buffered peptone water (Hygiena International, UK), 5 x 5 cm sterile sampling templates, gloves, Scotch Brite heavy duty scrub sponges (111 mm X 66 mm X 17 mm), Dichloran Rose Bengal Chloramphenicol (DRBC) agar to determine yeast and mold (YM), Tryptic Soy Agar (TSA) to determine total aerobic bacteria population.

### 2.2 Sampling

Four of the five locations (kitchen sink drain, kitchen countertop next to stove, refrigerator door handle, toilet seat) within student apartments were swabbed weekly for 6 weeks and kitchen sponges were sampled every week for 6 weeks. The sponges were replaced each of the first three weeks then the same sponge was used for the last three weeks of the study. These data were analyzed separately. Prior to sampling surfaces, the snap valve on swabs was broken by bending it forward and backward, expelling the liquid into the tube and wetting the swab tip. The swab was then removed from the tube, and the surface was swabbed using a 5 x 5 cm sterile template. The swabbing technique utilized a zigzag pattern of a total of 5 lines from left to right, from top to bottom, from the top left corner to the bottom right corner, and also from the top right corner to the bottom left corner (for a total of 20 lines). The swab was then placed back in the tube and transported to the lab. Upon returning to the laboratory, tubes were vigorously shaken by hand for 5-10 seconds before sampling.

### 2.3 Enumeration of Microorganisms

Seven and two tenths (7.2) ml and nine ml test tubes of sterile peptone solution (0.1%) were used for serial dilution of samples. One tenth of one ml from sample dilutions were pipetted and spread manually onto TSA and DRBC agar plates. For the Q-swab samples, 0.1 ml of the sample was pipetted onto TSA and DRBC agar plates. The remaining 0.8 ml of peptone in the swab tube was first transferred to a 7.2 ml tube for the initial dilution, followed by additional dilution in 9 ml tubes. After manual spread-plate, TSA plates were inverted and placed in an incubator (VWR® symphony Gravity Convection Incubator, Radnor Corporate Center, Radnor, PA, USA) for 24-48 hours at 37°C while DRBC plates were inverted and incubated at 25 °C for 4-5 days. After incubation, bacteria and YM were counted using a colony counter (Quebec® Darkfield Manual Colony Counter (220V/50Hz), Reichert Technologies World Headquarters & North American Service Center, Depew, NY, USA). Populations were reported as colony forming unit (CFU) per 25 cm<sup>2</sup> sampling area.

### 2.4 Research Design and Statistical Analysis

Six replications on different weeks were conducted in 14 different apartments per replication. The same apartments and same locations within each apartment were sampled for each replication and students were instructed to not change their cleaning routine. A general linear model procedure was used (proc glm) in SAS® OnDemand for

Academics/SAS® Studio (SAS OnDemand for Academics) to analyze the data that included replication and location of sampling in the model. Since the main effects were significant ( $p \leq 0.05$ ), means were separated at the  $p \leq 0.05$  level using the least significant difference command.

### 3. Results and Discussion

#### 3.1 College Apartment Locations

Recovery of total aerobic microorganisms was highest in kitchen sponges (6.9 log CFU/25 cm<sup>2</sup>), followed by kitchen sink drains (4.5 log CFU/25 cm<sup>2</sup>) (Figure 1). Toilet seats (2.6 log CFU/25 cm<sup>2</sup>) had moderate levels of total aerobic microorganisms, and these numbers were similar to the levels recovered from kitchen countertops (2.5 log CFU/25 cm<sup>2</sup>). The refrigerator door handle (2.0 log CFU/25 cm<sup>2</sup>) had the lowest logarithmic value among all locations, which suggests that it has the least concentration of aerobic organisms on its surface.

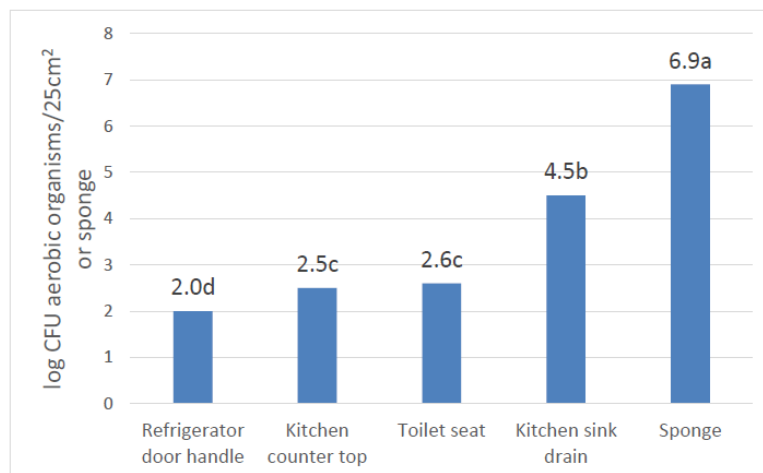


Figure 1. Log<sub>10</sub> CFU per 25 cm<sup>2</sup> surface or per sponge for different locations in student apartments a,b,c,d means with different letters are significantly different ( $p \leq 0.05$ ). n=84. Standard error = 0.16.

Kitchen sponges had the highest levels of YM contamination (5.5 log CFU/25 cm<sup>2</sup>) and numbers were considerably higher than the other surfaces tested (Figure 2). The refrigerator door handle and bathroom toilet seat had the lowest levels of YM (0.5 and 0.6 log CFU/25 cm<sup>2</sup>, respectively). Kitchen countertops had moderately low levels of YM (1.1 log CFU/25 cm<sup>2</sup>), while the kitchen sink had considerably high numbers of YM (3.3 log CFU/25 cm<sup>2</sup>) when compared to the other three surfaces tested.

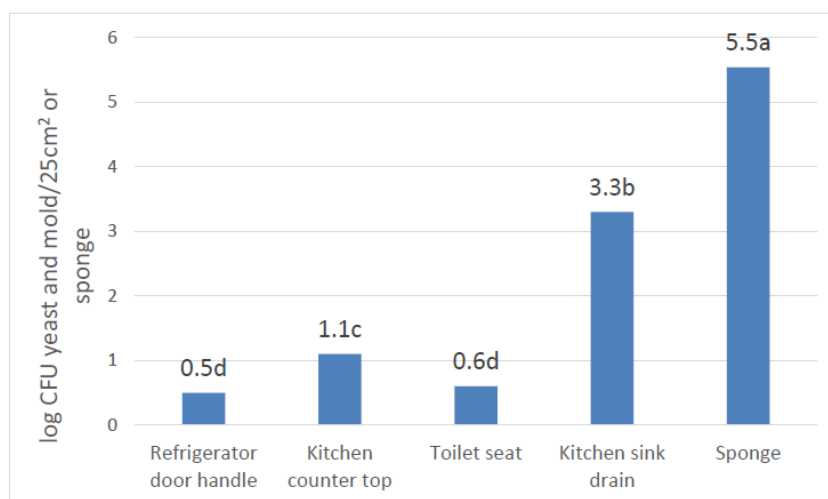


Figure 2. Log<sub>10</sub> CFU/25 cm<sup>2</sup> surface or per sponge of yeast and mold for different locations in student apartments

a,b,c,d means with different letters are significantly different ( $p \leq 0.05$ ). n=84. Standard error = 0.15.

Microbial contamination is common in household environments, with kitchens often being among the most heavily contaminated areas. Rusin et al. (1998) found more bacteria in the kitchen than the bathroom, with the toilet seat being the least contaminated. These same authors detected high levels of fecal coliforms, coliforms, and heterotrophic plate count bacteria in the sponge, dishcloth, kitchen sink drain, kitchen faucet handle(s), and cutting board, while the refrigerator handle, kitchen countertop, and floor in front of the kitchen sink had lower levels of contamination (Rusin et al., 1998). Donofrio et al. (2012) reported the ten most contaminated household items, from highest to lowest, consisting of the dish sponge, toothbrush holder, pet bowl, kitchen sink, coffee reservoir, kitchen countertop, stove knob, pet toy, toilet seat, and bathroom faucet handle. Coliforms were predominantly present in kitchen-related items like sponges, sinks, and cutting boards. Yeast and molds were detected on materials such as leather, fabric, porcelain, and laminate, while *Staphylococcus aureus* was identified on personal belongings and pet items (Donofrio et al., 2012).

Another study (NSF, 2011) performed swab analysis on 30 frequently utilized household items, such as dish sponge/rag, kitchen sink, toothbrush holder, coffee machine reservoir, bathroom faucet handle, countertop, stove knobs, cutting board, toilet seat in 22 residences. The findings indicated that the kitchen harbored a greater abundance of bacteria compared to the bathroom. The study identified the dish sponge/rag, kitchen sink, toothbrush holder, pet bowl, and kitchen countertop as the top five locations with the most germs. Coliform bacteria were found in high percentages in various areas, including over 75% of dish sponges/rags, 45% of kitchen sinks, 32% of kitchen countertops, 9% of refrigerator handles, and 5% of toilet seats. Staphylococcal species were present in 18% of dish sponges/rags, 14% of refrigerator handles, and 5% of toilet seats, but not on kitchen countertops or in kitchen sinks. Additionally, yeast and molds were detected in 86% of dish sponges/rags, 27% of kitchen sinks, 18% of kitchen countertops, 23% of refrigerator handles, and 27% of toilet seats in households (NSF, 2011). Josephson et al. (1997) found that sponges and sinks were the most consistently contaminated sites among eight areas examined in kitchens. Sponge, sink basin, countertop, refrigerator door, cutting board, and faucet handle, table and oven control were monitored for total heterotrophs, *Staphylococci*, *Pseudomonas*, total coliforms, and fecal coliforms (Josephson et al., 1997). These authors found high levels of fecal coliforms in both sponges and sinks, with 67% and 63% of samples testing positive, respectively (Josephson et al., 1997). *E. coli* was found on 33.3% of sponges and 16.7% of sink surfaces. *Staphylococcus* and *Pseudomonas* were identified at lower levels, with notable populations of *Pseudomonas* exclusively in sponge and sink samples, possibly due to moisture. *Salmonella* was detected once, and *Campylobacter* twice in the study (Josephson et al., 1997).

Unlike most previous reports, the current study focused on living quarters where college students reside and investigated the levels of total aerobic microorganisms and YM in the kitchen sponge, kitchen sink drain, kitchen counter, refrigerator door handle, and toilet seat. While total aerobic microorganisms and YM were present to some extent on all five locations, sponges exhibited the highest levels of aerobic microorganism and YM (6.9 and 5.5 log CFU/25 cm<sup>2</sup>, respectively), followed by the kitchen sink drain, which had levels of 4.5 log CFU/25 cm<sup>2</sup> for total aerobic microorganisms and 3.3 log CFU/25 cm<sup>2</sup> for YM. The notably high levels of contamination found on sponges underscore their status as the dirtiest surfaces in the study, a finding that has garnered significant attention in the literature.

### 3.2 Sponge Use over Multiple Weeks

There is a considerable difference between the amount of total aerobic microorganisms in a sponge used after one week (5.6 log CFU/25 cm<sup>2</sup>) and a sponge used after two weeks (7.3 log CFU/25 cm<sup>2</sup>). However, this pattern of increase did not continue when the sponge was used for three weeks (7.3 log CFU/25 cm<sup>2</sup>). A sponge used for two weeks by college students, and a sponge used for three weeks by college students contained comparable numbers of total aerobic microorganisms, yet both showed significantly more growth than the sponges at one week. Knoll (2019) also reported that bacterial contamination in sponges became high within two weeks of use but remained relatively constant between weeks two and four. This author noted that there was only an average 0.4% log increase of bacterial abundance in sponges when two-weeks of use was compared to four-weeks of use (Knoll, 2019). Erdoğan & Erbilir (2005) recovered 4.6 log CFU/sponge after day 3 and 6.9 log CFU/sponge of aerobic organisms in sponges used for 10 days in Turkey.

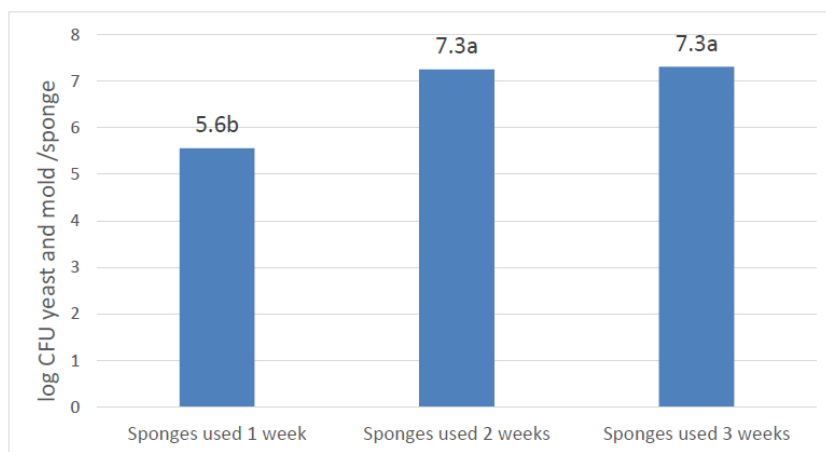


Figure 3. Log<sub>10</sub> CFU per sponge of total aerobic organisms per sponge used for one, two or three weeks. a,b means with different superscripts are significantly different ( $p \leq 0.05$ ).  $n=14$ . Standard error = 0.44.

When kitchen sponges were tested for levels of YM, a pattern similar to the one observed for total aerobic microorganisms was discovered. The growth of YM on a sponge after one week (7.0 log CFU/25 cm<sup>2</sup>) was significantly lower than the growth on sponges after two weeks (8.9 log CFU/25 cm<sup>2</sup>). Recovery of YM remained the same for sponges tested after two weeks and sponges tested after three weeks (8.9 log CFU/25 cm<sup>2</sup>). Overall, all three sponges showed a considerable amount of growth, but the jump from one week to two weeks showed the most notable change. Data from the present study and previous research suggest that two weeks may be the length of time required for microorganisms to reach the stationary growth phase in kitchen sponges where an equilibrium is established between cellular growth and decay.

In a study where sponges were stored between use, Osaili et al. (2020) reported decreases in microbial counts across all categories for used sponges stored at room temperature for 3 to 10 days. These authors found that mesophilic aerobic bacteria in sponges decreased by approximately 0.4 to 1.3 log<sub>10</sub>/cm<sup>3</sup>, while coliforms decreased by approximately 0.7 to 1.4 log<sub>10</sub>/cm<sup>3</sup>, *Enterobacteriaceae* decreased by approximately 0.4 to 1.1 log<sub>10</sub>/cm<sup>3</sup>, and yeasts and molds decreased by approximately 0.6 to 1.3 log<sub>10</sub>/cm<sup>3</sup> (Osaili et al., 2020). Alternatively, Erdoğan & Erbilir (2005) recovered 3.5 log CFU/sponge of yeast and mold after day 3 of use and levels of yeast and mold increased to 7.0 log CFU/sponge after 10 days of use. Data from these studies demonstrate the difference between continuous use and decreased counts when sponges are allowed to dry.

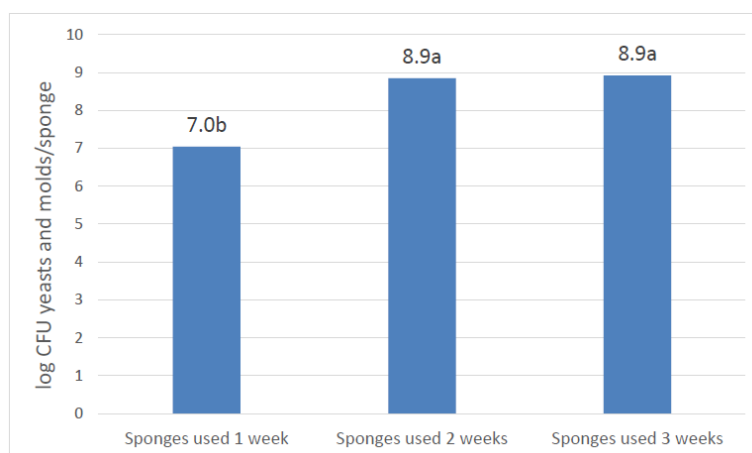


Figure 4. Log<sub>10</sub> CFU per sponge of yeast and mold per sponge used for one, two or three weeks a,b means with different superscripts are significantly different ( $p \leq 0.05$ ).  $n=14$ . Standard error = 0.47.

In the present study, levels of total aerobic microorganisms recovered from various items in student's apartments exhibited the following pattern (highest to lowest counts): kitchen sponge > kitchen sink drain > toilet seat =

kitchen countertop > refrigerator door handle. Counts for yeast and molds recovered from these same locations showed that kitchen sponge > kitchen sink drain > kitchen countertop > toilet seat = refrigerator door. Contaminated kitchen sponges are not unique to college students. In fact, numerous studies have observed elevated levels of bacteria, and sometimes even harmful pathogens in kitchen sponges (Cardinale et al., 2017; Cogan et al., 2002; Erdoğan & Erbilir, 2005; Ergönül, 2022; Evans & Redmond, 2019; Hilton & Austin, 2000; Ikawa & Rossen, 1999; Kusumaningrum et al., 2002; Marotta et al., 2018; Møretro et al., 2022; Osaili et al., 2020; Rossi et al., 2012, 2013). In a study from Turkey, kitchen sponges underwent analysis for total mesophilic aerobic bacteria, *Staphylococcus aureus*, *Salmonella spp.*, *E. coli* O157:H7, total coliform bacteria, and yeast and molds. The findings revealed that all sponges exhibited a measurable microbiological load (Ergönül, 2022). The total mesophilic aerobic bacteria count ranged from 2.3 to 8.1 log CFU/sponge, with an average count of 6.4 log CFU/sponge. Additionally, 41 out of 100 sponges contained detectable YM, averaging 2.1 log CFU/sponge. Coliform bacteria were present in 56% of the sponges, showing an average count of 1.6 log CFU/sponge and reaching a maximum level of 1.8 log CFU/sponge.

Marotta et al. (2018) found a high level of contamination in kitchen sponges, with mean values for aerobic mesophilic bacteria, *Enterobacteriaceae*, yeasts and molds, and *Micrococci* ranging from 4.82 to 8.25 log CFU/g. Among the identified enterobacteria strains, opportunistic and pathogenic agents such as *Enterobacter cloacae*, *Citrobacter freundii*, and *Cronobacter sakazakii* were found in kitchen sponges. *Cronobacter sakazakii* is commonly found in various environments as well as the intestinal tracts of humans and animals and has the potential to induce serious conditions such as necrotizing enterocolitis, bacteremia, and meningitis in infants and young children, often resulting in mortality rates ranging from 40% to 80% (Marotta et al., 2018). *Cronobacter sakazakii* was also recovered from 21 out of 78 (26.9%) of domestic kitchens in Tennessee, United States, with sinks being the most common location (44% of samples), followed by countertops (20%), dishcloths (16%), refrigerator handles (12%), meat drawers (4%), and sponges (4%) (Kilonzo-Nthenge et al., 2012). Rossi et al. (2013) found that every kitchen sponge randomly tested contained aerobic microorganisms, with levels ranging from 4.1 to 10 log CFU/sponge, averaging 6.8 log CFU/sponge. Additionally, 83.3% of the sponges were contaminated with fecal coliforms, ranging from 3 to 9.7 log CFU/sponge, with an average of 5 log CFU/sponge.

Sponges from various food establishments had average counts of aerobic mesophilic bacteria varied between 7.43 and 12.44 log CFU/mm<sup>3</sup>. *Pseudomonas* (16.9%), *Bacillus* (11.1%), *Micrococcus* (10.6%), *Streptococcus* (7.8%), and *Lactobacillus* (6%) were the predominant genera identified, with additional presence of unidentified Gram-positive rods (4.9%) and Gram-negative rods (9.9%). Roughly 72.8% and 45.7% of the kitchen sponge samples had YM counts greater than 10<sup>3</sup> CFU/mm<sup>3</sup> (Wolde & Bacha, 2016). Twenty used kitchen sponges had bacterial counts up to 3.4 x 10<sup>7</sup> CFU/mL and fungal count of 3.9 x 10<sup>6</sup> CFU/mL (Paul & Gopinathan, 2022). In general, 80% of the tested sponges displayed significant bacterial proliferation. Furthermore, 60% (12 out of 20) of the examined sponges exhibited contamination with coliform bacteria

## 4. Conclusions

### 4.1 Bacterial Transfer from Sponge to Surface

Studies indicate that sponges commonly harbor a variety of microorganisms, including numerous non-pathogenic bacteria, occasionally alongside pathogenic ones, as well as viruses, Archaea, and Eukaryota (Cardinale et al., 2017; Jacksch et al., 2020; Møretro et al., 2021).

Contaminated kitchen sponges pose a significant risk of cross-contamination in kitchens by transferring large amounts of microorganisms to surfaces. Rossi et al. (2013) found that sponges used in food services were heavily contaminated and capable of transferring microorganisms to surfaces such as AISI 316 stainless steel and polyethylene. Knoll (2019) reported that 5.12% of bacteria were transferred to a hard, non-porous resin surface (specifically, a lab benchtop) from four-week-old sponges and Kusumaningrum et al. (2003) found that *S. aureus*, *S. enteritidis*, and *C. jejuni* transferred between 21% and 43% of their initial inoculums to stainless steel surfaces. Mattick et al. (2003) further demonstrated that sponges can transfer *E. coli* and *Salmonella spp.* to laminate countertop surfaces depending on the initial contamination of the sponge; higher levels of bacteria in sponges resulted in greater transfer to surfaces. Likewise, Rossi et al. (2013) found sponges with 7 to 10 log CFU/sponge transferred an average of 5.5 log CFU/cm<sup>2</sup>, while those with 4 to 6.9 log CFU/sponge transferred around 1.9 log CFU/cm<sup>2</sup> to surfaces. Hilton and Austin (2000) demonstrated that dishcloths transferred a higher percentage of bacteria compared to sponges, with 56% and 4.7% of bacteria being transferred, respectively.

### 4.2 Sponge Cleaning

Various methods to sanitize kitchen sponges have been reported with varying degrees of efficacy (Table 1). The effectiveness of some sanitizing agents is dependent upon several factors not equally controlled in the experiments

listed in Table 1. Effectiveness of sanitation may be diminished in the presence of food residue (Erdoğrul & Erbilir, 2005; Kusumaningrum et al., 2002; Sharma et al., 2009) and a key observation is that although antibacterial dish soap proves effective in laboratory experiments, its performance on used sponges in actual households fluctuates. According to Kusumaningrum et al. (2002), a concentration of 2-4% antibacterial dish soap effectively eliminated *E. coli*, *S. Enteritidis*, *Staphylococcus aureus*, and *B. cereus* when bacteria were suspended in a solution. However, when these bacteria were present on used sponges, the soap's effectiveness diminished. Additionally, the presence of food residues on the sponges enhanced the survival of all these bacteria, except for *B. cereus*, compared to sponges without food residues. Similarly, Erdoğrul & Erbilir (2005) found in a study across six households that regular dishwashing liquid, although effective in laboratory tests, failed to reduce microorganisms on used kitchen sponges. Over a two-week period, the dishwashing liquid did not decrease total mesophilic aerobic counts, *E. coli*, *Pseudomonas*, or yeast and molds, except for *Salmonella spp.* However, *S. aureus* decreased rapidly and did not survive.

Table 1. Summary of sponge sanitation methods by various researchers.

Sanitizing Treatment	Parameters	Relative Effectiveness <sup>1</sup>	Reference
Ginger extract	15 min	*	Paul & Gopinathan, 2022
Lemon juice	15 min	*	Paul & Gopinathan, 2022
Vinegar	15 min	*	Paul & Gopinathan, 2022
3% H <sub>2</sub> O <sub>2</sub>	15 min	****	Paul & Gopinathan, 2022
0.1% Phenol	15 min	****	Paul & Gopinathan, 2022
100% Ethanol	15 min	***	Paul & Gopinathan, 2022
Lysol™	15 min	**	Paul & Gopinathan, 2022
Microwave	1 min high setting	***	Knoll, 2019
Dishwasher	1 cycle	*	Knoll, 2019
10% hypochlorite	1 min immersion	***	Knoll, 2019
70% Ethanol	1 min immersion	***	Knoll, 2019
55°C soapy water	1 min immersion	*	Knoll, 2019
45°C soapy water	1 min immersion	*	Cardinale et al., 2017
10% hypochlorite	3 min immersion	**	Sharma et al., 2009
Lemon juice (pH= 2.9)	1 min immersion	*	Sharma et al., 2009
Microwave	1 min high setting	****	Sharma et al., 2009
Dishwasher	1 cycle	***	Sharma et al., 2009
Microwave	30 sec	*	Tate., 2006
Microwave	1 min	**	Tate, 2006
Dishwasher	1 cycle	***	Ikawa & Rossen, 1999
0.02 % hypochlorite	10 min	****	Rossi et al. 2012
Antimicrobial liquid	Held 24 hr	****	Nielsen et al., 2002

<sup>1</sup> The number of stars represent the relative log reduction for each study compared to control as judged by the author from \* ~0-1 log reduction, \*\* ~1-2 log reduction, \*\*\* ~ 3-4 log reduction, \*\*\*\* ~ 5-6 log reduction.

Josephson et al. (1997) highlighted that targeted use of antimicrobial agents, specifically addressing potential contamination sources, was more effective in reducing bacterial contamination compared to sporadic or non-specific use. According to Møretro et al. (2021) brushes are a good dishwashing alternative, as they dry faster, reducing the risk of *Salmonella* and *Campylobacter* growth compared to sponges. Additionally, their handles prevent direct hand contact with water, allowing for higher cleaning temperatures. This reduces the risk of hand contamination, unlike with sponges. Furthermore, brushes are easily cleaned in dishwashing machines, ensuring consistent hygiene practices. These authors also recommend cleaning sponges and brushes using either chlorine (4000 ppm chlorine for 16-20 hours), a dishwashing machine, or submersion in boiling water (Møretro et al., 2021).

In another study by Møretro et al. (2022), bacterial levels and microbiological diversity, as well as *Salmonella* survival, were investigated in used dish washing sponges and brushes. Portuguese sponges exhibited a median of 10.3 log CFU/item, while Norwegian items had lower levels, with 7.3 and 7.0 log CFU/item for sponges and brushes, respectively. Additionally, common non-pathogenic bacteria like *Acinetobacter*, *Chryseobacterium*, *Enhydrobacter*, *Enterobacteriaceae*, and *Pseudomonas* were identified in both brushes and sponges. Brushes generally harbored lower bacterial levels compared to sponges, and *Salmonella* was observed to die more rapidly on brushes. The study suggests that drying brushes effectively eliminates bacteria, including *Salmonella*, whereas

sponges present challenges for thorough drying, potentially increasing the risk of bacterial contamination.

When compared to other areas within a college student's apartment, the present study found that kitchen sponges contained the highest level of total aerobic microorganisms and YM. This is not surprising because the sponge is used to clean multiple surfaces containing microorganisms, and yet sponges are rarely cleaned between uses. Based on the findings of the present study, consumers, including college students, should clean or replace their kitchen sponges to prevent transfer of microorganisms from their sponges to other surfaces. This also raises concerns about using sponges to clean dishes that will subsequently be in contact with food. The microbial contamination residing in the sponge could also be very dangerous considering one might use the sponge to clean cutting boards that are used for raw meats and vegetables. Contrary to popular belief, the toilet seat showed some of the lowest microbial contamination levels along with the refrigerator door handle. There are many reasons for this, including limited access to one's personal bathroom so there is less human contact compared to other surfaces and there are less "nutrients" to support. Another location of concern, in addition to the sponge, is the kitchen sink drain. The high moisture environment and contact with raw and contaminated rinse water make the drain an ideal location for biofilms development and shedding of bacteria. Additionally, kitchen sink drains may not be cleaned as often as other surfaces (Xiong and Olson, 2017). Results from the present study demonstrate that there is room for improvement in the household sanitation practices among college students.

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### **Authors contributions**

Dr. Buyukyavuz, Dr Northcutt and Dr. Dawson were responsible for study design and revising. Dr. Buyukyavuz was responsible for overseeing data collection. Drs. Buyukyavuz, Northcutt and Dawson all drafted the manuscript and revised it. All authors read and approved the final manuscript.

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The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

### **Informed consent**

Obtained.

### **Ethics approval**

The Publication Ethics Committee of the Canadian Center of Science and Education.

The journal's policies adhere to the Core Practices established by the Committee on Publication Ethics (COPE).

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### **Data availability statement**

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

### **Data sharing statement**

No additional data are available.

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