Evaluating the Effectiveness of Alcohol-based Hand Sanitizers compared to Alcohol-free Hand Sanitizers

Derek Song[1], Helen Heacock[2]
1 Lead Author, B.Tech Student, School of Health Sciences, British Columbia Institute of Technology, 3700 Willingdon Ave. Burnaby, BC V5G 3H2
2 Supervisor, School of Health Sciences, British Columbia Institute of Technology, 3700 Willingdon Ave. Burnaby, BC V5G 3H2

Abstract

Background and Purpose: Hand washing is one of the most important critical control points in public premises in preventing the spread of bacteria and viruses. There is vast research on the effectiveness of alcohol-based hand sanitizers in killing germs. However, the efficacy of alcohol-free hand sanitizers lacks real-world evidence. With little to no guidelines in which one type of hand sanitizers may be more appropriate depending on the types of public premise such as food establishments, hospitals, work place, or schools, Environmental Health Officers(EHOs)/ Public Health Inspectors(PHIs) will need to educate the public and operators on the effectiveness of these hand sanitizers and their advantages and disadvantages. The purpose of the study was to compare the effectiveness of alcohol-based hand sanitizers and alcohol-free hand sanitizers by conducting statistical analyses of the reduction in mean *E.coli* counts.

Methods: 60 pigskins were prepared (30 for alcohol-based hand sanitizers, 30 for alcohol-free hand sanitizers), which were inoculated with *E. coli*, then applied either alcohol-based hand sanitizers or alcohol-free hand sanitizers. After 48 hours of incubation for *E.coli* growth, *E.coli* was counted. The difference in mean *E.coli* counts before applying hand sanitizers and after hand sanitizers was calculated, then compared between the two hand sanitizers.

Results:

The mean *E.coli* reduction count (CFU) from alcohol-based hand sanitizers (30 samples) was 10.200; the median was 11; the standard deviation was 1.7889; the range was 5.0000.

The mean *E.coli* reduction count (CFU) from alcohol-free hand sanitizers (30 samples) was 10.233; the median was 10.5; the standard deviation was 0.8976; the range was 3.0000.

The statistical t-test resulted in p-value of 0.1034.

Conclusion: There was no significant difference between the two types of hand sanitizers. Both the alcohol-based hand sanitizers and alcohol-free hand sanitizers effectively reduced the number of *E.coli* counts (CFU) by averages of 10.2000 (92.7% reduction) and 10.2333 (93.03% reduction) respectively. While the BC Centre for Disease Control recommends 60 percent alcohol hand sanitizers to prevent the spread of germs, this research showed that alcohol-free hand sanitizers with sulfactants, allantoin, and benzalkonium chloride (SAB) formula is just as effective in killing germs. Therefore, EHOs/PHIs can educate the public and operators on the advantages and disadvantages on the two types of hand sanitizers in preventing the spread germs during the flu season and give practical advice or guidance on which type of hand sanitizers would be most appropriate in restaurants for example.

Key words: Alcohol-free hand sanitizers, alcohol-based hand sanitizers, benzalkonium chloride, *E. coli*

Introduction

The simple act of washing your hands correctly could protect you from the spread of disease. According to the British Columbia Centre for Disease Control (BCCDC), eighty percent of common infections are spread by hand, and washing your hands five times a day could drastically decrease the frequency of influenza (flu) and nosocomial infections (BCCDC, 2014). The main pathogens of concern are *Salmonella, Staphlococcus aureus, Streptococi, E.coli, and protozoa* (Fazlar & Ekhtelat, 2012). However, not everyone has frequent access to water and soap, which is why the more convenient hand sanitizers, which some companies claim to kill "99.9% of germs" (Purell, 2015) are increasing in popularity. Even the BCCDC recommends the use of hand sanitizers to supplement hand washing, which will increase its efficacy (BCCDC, 2014).

However, with different types of sanitizers being used in different public premises, the public may not be aware of why one type is preferred over the other, specifically comparing alcohol-based hand rubs (ABHR) and alcohol-free hand sanitizers. There are advantages of using either type of sanitizer but according to the Wall Street Journal, there is insufficient real-world evidence to demonstrate that the alcohol-free hand sanitizer works as well in the real world as it does in laboratory testing (Johannes, 2013).

As a result, it is important to analyze the efficacy of both types of hand sanitizers to determine which is appropriate in different public premises and to educate the public in deciding which type to use during this flu season. This in turn may increase hand washing in general. The purpose of this research will be to determine the effectiveness of alcohol-based hand sanitizers and alcohol-free hand sanitizers by conducting statistical analyses of the reduction in microbes. In particular, the means of *E. coli* counts from using alcohol-based hand sanitizers and from using alcohol-free hand sanitizers will be compared by conducting inferential statistics. There has been extensive research analyzing the effectiveness of alcohol-based hand sanitizers. In particular, the Fraser Health clinical practice guideline concludes that alcohol-based hand rubs (ABHR) of concentration of at least seventy percent inactivates microorganisms and temporarily stops the growth of pathogens (Fraser Health, 2012). However, there is a lack of empirical data of how long the alcohol-free hand sanitizers last on the hands before they become ineffective against bacteria (Johannes, 2013).

Literature Review

The advantages of alcohol-based hand sanitizers and alcohol-free hand sanitizers in different public premises are discussed first below. Depending on the types of public premise such as food establishments, hospitals, work place, or schools, one type of hand sanitizer may be better than the other. Finally, the lack of real-world evidence of the efficacy of alcohol-free hand sanitizers is discussed for comparison.

Hand sanitizers in Food Establishments

Hand washing is one of the most important critical control points in a food premise or establishment in preventing the spread of bacteria and viruses, which ultimately cause foodborne illnesses. However, could any method of hand washing, whether soap and water or alcohol-based or alcohol-free hand sanitizer, be appropriate for food establishment employees? According to the *BC Food Premise Regulation Division 5 Section 21(3)(4)*, each employee must wash his or her hands as often as necessary and the operator of the establishment must supply and maintain adequate number of hand washing stations (FPR, 2008). The *Food Retail and Food Services Code (FRFSC) Section 5 (a)* from the Canadian Food Inspection Systems Implementation Group also gives guidelines on washing hands, vigorously for 20 seconds and then rinsed with clean warm water (FRFSC, 2004). The Food and Drug Administration (FDA) states that hand sanitizers do not replace hand washing with soap and water by food retail workers because hand sanitizers do not reduce fatty and proteinaceous materials that pathogens can survive on (Minnesota Department of Health, 2009). Also, these fatty materials reduce the effectiveness of hand sanitizers and these sanitizers are ineffective against viruses such as norovirus, which can be transmitted from person-to-person (U.S. Food and Drug Administration, 2014). The FDA recommends that hand sanitizers with at least 60 percent alcohol be used after hand washing with soap and water (U.S. Food and Drug Administration, 2014). No further information is available for alcohol-free hand sanitizers and whether these can also be used. All food establishments should therefore have guidelines on hand sanitizers in employee hygiene policy that adhere to the Food Premise Regulations (FPR). It may also be advisable to offer hand sanitizers to customers during the flu season as a further precaution in preventing the spread of germs.

Improved hand hygiene in healthcare settings by using Alcohol-Based Hand Sanitizers

According to the World Health Organization, 1.4 million people around the world acquire infections at hospitals and health-care associated infections (HAI) incur additional 5.7 billion dollars and 90,000 deaths in the United States (World Health Organization, 2007). Therefore, hand hygiene is a fundamental solution to decrease the spread of diseases. Research has shown that multimodal, multidisciplinary strategies that include promoting hand hygiene adherence and alcohol-based hand sanitizer are essential in ensuring patient safety (World Health Organization, 2007). According to the Fraser Health clinical practice guideline, alcohol-based hand rubs (ABHR) of concentration of at least 70 percent inactivates microorganisms and temporarily stops the growth of pathogens and should be available in all areas of the hospital (Fraser Health, 2012). Some of the benefits of using ABHR are quicker application, no need for soap or water, more readily available, and effective in reducing microorganisms on hands (Fraser Health, 2012). Research done by Hilburn et al. studied the efficacy of alcohol-based hand sanitizer in an acute-care facility and determined that the primary infection types were urinary tract and surgical site infection (Hilburn J, 2003). The use of hand sanitizer resulted in 36.1% decrease in infection rates for the 10-month period of the study and recommends its use ABHR in acute care facilities and hospitals (Hilburn J, 2003).

Effectiveness of Alcohol-free hand Antiseptic Hand Wash among podiatric physicians and healthcare personnel

Healthcare workers are at a greater risk of contacting dermatitis due to constant hand washing and glove changing (Moadab A, 2001). Alcohol-based hand sanitizers can irritate the skin with cuts and chops, dry the skin with overuse, and cause dermatologic changes. As a result, alcohol-free hand sanitizers that contain sulfactants, allantoin, and benzalkonium chloride (SAB) have been studied for their efficacy in immediate and residual disinfecting power (Reichel, 2014). The study followed the Food And Drug Administration (FDA) protocol in evaluating the two solutions and determined that the SAB formula not only killed the microbes after the first wash, but also maintained its residual disinfectant power after ten washes (Moadab A, 2001). This surpassed the minimum FDA standard for antiseptic hand sanitizer and showed that SAB sanitizers are appropriate for podiatric physicians and healthcare personnel (Moadab A, 2001). However, the limitation of this study is that it did not test SAB products in different vehicles as surgical scrubs (Moadab A, 2001) and therefore is not appropriate for hospitals.

Effectiveness of Alcohol-free hand sanitizers in Schools

The use of hand sanitizers should be emphasized in schools where children are in close proximity to each other and there are many factors that could pose increased spread of diseases. These factors include many objects as vehicles of transmission, lack of hand washing facilities, inadequate time requirement for proper hand washing, and education (White CG, 2001). ABHR can be poisonous if children ingest them, can irritate skin with cuts and eyes, and are flammable, which make them hazardous at a school setting (White CG, 2001). As such, alcohol-free hand sanitizers may be a good option. The controlled study that used elementary school students' absenteeism as an indication of effectiveness of alcohol-free hand sanitizer showed that in conjunction with at will hand washing with soap and water, alcohol-free hand sanitizers were just as effective as alcohol-based sanitizers and reduced absenteeism by 31% (White CG, 2001). At school settings, especially among small children who are likely to become ill four or more times a year, hand hygiene is a crucial practice in and outside of school. With the benefits of alcohol-free hand sanitizers, it should be recommended that children use this type of hand sanitizer compared to alcohol-based hand sanitizers.

Use of alcohol-based hand sanitizers in open, nonclinical workplace setting

Acute infectious respiratory and gastrointestinal diseases are among the most common diseases in schools, universities, and workplace settings (Hübner NO, 2010). The crowdedness of the working space, the number of close person-to-person interactions, and constant sharing of public space make transmission of diseases easy. As a result, productivity is greatly diminished due to absenteeism from work (Hübner NO, 2010). According to a prospective, controlled study that followed a cohort for 1230 person months and recorded the use of hand disinfectant, there was a reduced number of illnesses for the majority of gastrointestinal symptoms when using alcohol-based hand sanitizers, thus a reduced absenteeism (Hübner NO, 2010). The use of hand sanitizers, whether alcohol-based or non-alcohol based, should be part of all workers' hand hygiene and company health support programs.

Public Health Significance

No matter which type of public premise, hand washing has been proven to prevent the transmission of diseases between people. Most Health Authorities and Centers for Disease Control recommend using hand sanitizers to fight nosocomial infections and pathogens such as *Salmonella, Staphlococcus aureus, Streptococi,* and *E.coli.*

After reviewing various research studies that examined alcohol-based hand sanitizers and non-alcohol hand sanitizers, there still needs objective empirical evidence of the efficacy of non-alcohol hand sanitizers compared to alcohol-based hand sanitizers. Extensive research shows that alcohol-based hand sanitizers at 70% or higher effectively kills pathogens and reduce infection rates at hospitals (Hilburn J, 2003). However, it may not be suitable for children at elementary schools due to some of the hazards of alcohol-based hand sanitizers such as being poisonous if ingested, flammable, and irritation to the cut skins (White CG, 2001).

Hand sanitizers are a great supplement to hand hygiene practice and people should be educated in the different types of hand sanitizers, their advantages and disadvantages, and their efficacy in different public premises such as food establishments, schools, hospitals, and workplaces. Although non-alcohol based hand sanitizers seem favorable due their effectiveness, less irritation to the skin, and non-flammable properties, there is still a lack of empirical evidence that shows its effectiveness compared to the vastly researched alcohol-based hand sanitizers. It is still a good idea to be aware of the different types of hand sanitizers.

Methods and Materials

The experiment involved preparation of the *E. coli* dilution (10^{-6}), preparation of 60 pigskins (30 for alcohol-based hand sanitizer, 30 for alcohol-free hand sanitizer), the inoculation of *E. coli* on the pigskin pieces before applying hand sanitizers, and applying the hand sanitizers on the pigskin pieces. The experiment was conducted in the Food Microbiology Laboratory at BCIT Burnaby Campus, under the supervision of Helen Heacock (Environmental Health Program Instructor, BCIT), with guidance and feedback from Melinda Lee (Technical Staff II, BCIT) and Ken Keilbart (Assistant Instructor, BCIT), and with the approval for lab use from Erin Friesen (Food Program Head, BCIT). The procedures were taken from Sophia Yip but altered for the purpose of this research experiment (Yip, 2003)

Description of Materials

***One Step Hand Sanitizer* (236ml, 62% ethyl alcohol)** meets the recommended alcohol concentration by Fraser Health to inactivate the microbes. It is inexpensive at $4.72 CAD, and is widely available at retail stores such as *Walmart*.

***X3 Clean Foaming Hand Sanitizer* (Benzalkonium chloride 0.13%)** contains benzalkonium chloride, a quaternary ammonium compound that is used widely as antiseptic agents due to their cationic amphiphilic property and destabilizing the pathogen's surface (Campanac, Pineau, Payard, Baziard-Mouysset, Baziard-Mouysset, & Roques, 2002). Also, it is inexpensive at $5.79 CAD, and is widely available at retail stores such as *Walmart*.

E. coli is mostly harmless bacteria found in the intestines of humans and animals but some strains such as *E. coli 0157:H7* can cause severe abdominal pain, diarrhea and vomiting (Public Health Agency of Canada, 2015). It makes up 97% of fecal materials in human excretion and is used as an indicator for fecal contamination and unsanitary practices. It can be detected by the enumeration method by using lactose fermentation (U.S. Food and Drug Administration, 2002). *E. coli* culture is available at the BCIT microbiology lab (Food Microbiology Laboratory at BCIT) or can be purchased online.

Pigskin is anatomically similar to human skin in terms of color, hair follicles, sweat glands, and subcutaneous fat (Herron, 2009). Also, since pigs are considered food source, it is widely accepted by the public for its use as laboratory animals. It is also readily available at butcher shops and is relatively inexpensive. Thus, it is frequently used as a model of human skin (Herron, 2009).

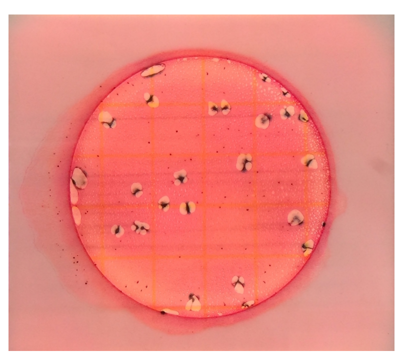
***E. coli* 3M Petrifilms**

3M Quickswabs

Preparation of *E. coli* culture: *E. coli* culture was obtained from the Food Microbiology Laboratory at BCIT. *E. coli* was transferred into nutrient broths so that it can be diluted to 10^{-6} (Yip, 2003).

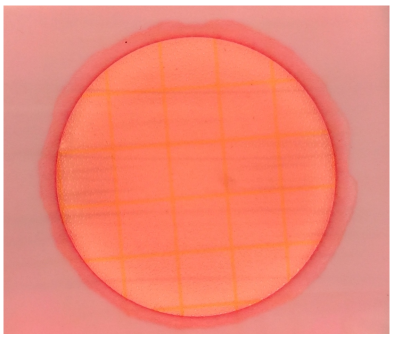
Negative Control: This was done to verify the swabs and Petrifilm were sterile by pouring an unused Quickswab onto the Petrifilm. **Preparation of Controls:** Thoroughly washed the pigskins with tap water to ensure there was no dirt or other debris. Cut into five 10cm x 5cm pieces. Inoculate the pigskin pieces with *E. coli* by swabbing. Incubated all five petrifilm plates for 48 hours at 35C. This was the counted *before data* (Colony Forming Unit). Confirmed *E.coli* coliforms were blue colonies with associated gas bubbles (3M Corporation, 2015) as seen in figures 1.

Figure 1: Blue colonies are the confirmed *E.coli* counts used for *Before Data* (CFU)



Preparation of Sixty pigskin pieces for hand sanitizers application: After inoculating the pigskin pieces *with E.coli,* two types of hand sanitizers were applied for 30 samples each. The pigskins were incubated for 48 hours at 35C. This was the counted *after data* (Colony Forming Unit). Confirmed *E.coli* coliforms were blue colonies with associated gas bubbles (3M Corporation, 2015) as seen in figures 2.

Figure 2: After applying hand sanitizers, most of the blue colonies were eliminated.



Inclusion and Exclusion criteria

The alcohol-based hand sanitizers used in this experiment was *One Step Hand Sanitizer* (236ml, 62% ethyl alcohol) and the alcohol-free hand sanitizer was *X3 Clean Foaming Hand Sanitizer*. The specific breed of pigskin used was Yorkshire pig. The exclusions were any other types or brands of hand sanitizers on the market.

Results

The hypotheses generated are as follows:

H_o: The reduction mean *E. coli* counts on pigskin that is cleaned with alcohol-based hand sanitizers is the **same as or less than** the reduction mean *E. coli* counts on pigskin that is cleaned with alcohol-free hand sanitizers. $\bar{y}_{Alcohol-based} \leq \bar{y}_{Alcohol-free}$

H_a: The reduction mean *E. coli* counts on pigskin that is cleaned with alcohol-based hand sanitizers is **greater** than the reduction mean *E. coli* counts on pigskin that is cleaned with alcohol-free hand sanitizers. $\bar{y}_{Alcohol-based} > \bar{y}_{Alcohol-free}$

Inferential Statistics

The hypothesis test that was used by SAS and Microsoft Excel was one-tailed two-sample t-test. The two-sample t-test was able to compare the two mean reductions in *E. coli* counts and assessed which group was more effective in reducing the *E. coli* counts. After calculating the p-value, if the p-value is less than 0.05, we reject the null hypothesis and conclude that there is statistical significant difference between the two groups. If the p-value was greater than 0.05, we fail to reject the null hypothesis and conclude there is not statistically significant difference between the two groups.

Description of Data

The data for this research was both nominal and numerical data. The type of hand sanitizers (*One Step Hand sanitizer* or *X3 Clean Foaming Hand Sanitizer*) is the nominal data. The *E. coli* count in CFU is the numerical (discrete) data. The mean reduction in *E. coli* count after applying alcohol-based hand sanitizer ($\bar{y}_{DA}$) and that of alcohol-free hand sanitizer ($\bar{y}_{DF}$) was compared to determine if there was significant evidence that the reduction mean *E. coli* counts on pigskin that was cleaned with alcohol-based hand sanitizers was greater than the reduction mean *E. coli* counts on pigskin that was cleaned with alcohol-free hand sanitizers. The mode and the median were not used in this research for statistical analysis, although they may aid in determining how effective hand sanitizers were in reducing the pathogen. The ranges of the mean reduction *E. coli* counts allowed for the determining of the extremes. The standard deviation, which showed how data is spread about the mean, also showed the variation in mean reductions. Table 1 summarizes the descriptive statistics. Table 2 shows the mean reduction *E.coli* counts.

Table 1: Descriptive Statistics

	Variable 0 (Alcohol-based hand sanitizer) (CFU)	Variable 1 (Alcohol-free hand sanitizer) (CFU)
Mean ($\bar{y}$)	10.2000	10.2333
Median	11	10.5
Standard Deviation	1.7889	0.8976
Variance	3.2002	0.8057
Samples	30	30
Minimum	3.0000	8.0000
Maximum	11.0000	11.0000
Range	5.0000	3.0000

Table 2: Mean reduction of *E. coli* count (CFU) (before and after using *One Step Hand*

Sanitizer sanitizer $(\overline{y}_{DA})$ **and *X3 Clean Foaming Hand Sanitizer*** $(\overline{y}_{DF})$**)**

Sample	Difference (CFU) $\overline{y}_{DA}$	Difference (CFU) $\overline{y}_{DF}$
1	**11**	**9**
2	**11**	**9**
3	**11**	**10**
4	**10**	**11**
5	**11**	**10**
6	**11**	**11**
7	**11**	**9**
8	**10**	**10**
9	**11**	**8**
10	**11**	**11**
11	**10**	**10**
12	**11**	**9**
13	**11**	**10**
14	**10**	**11**
15	**10**	**9**
16	**11**	**11**
17	**11**	**10**
18	**11**	**10**
19	**11**	**11**
20	**11**	**11**
21	**11**	**11**
22	**10**	**11**
23	**3**	**11**
24	**6**	**11**
25	**11**	**11**
26	**7**	**11**
27	**10**	**11**
28	**11**	**9**
29	**11**	**11**
30	**11**	**10**

Interpretation

Using SAS software (SAS University Edition, 2015), the normality was tested for the data, which showed p-values all less than 0.05, confirming that the data is not normally distributed, thus a nonparametric test was performed (the Wilcoxon rank sum test). From the Wilcoxon rank sum test, the p-value was 0.1034, which was greater than 0.05, thus we failed to reject the null hypothesis and concluded that there was no significant difference between the two types of hand sanitizers.

Discussion

Both the alcohol-based hand sanitizers and alcohol-free hand sanitizers effectively reduced the number of *E.coli* counts (CFU) by averages of 10.2000 (92.7% reduction) and 10.2333 (93.03% reduction) respectively. There have been many research studies to show the effectiveness of alcohol-based hand sanitizers and alcohol-free hand sanitizers such as the separate studies done by Hilburn et al., Hübner NO et al., Reichel et al, and White CG et al. as mentioned earlier in the literature review. However, none of the studies compared the two types of hand sanitizers and which one has greater effectiveness in reducing *E.coli* counts. Some of these studies used indirect correlation between absenteeism among children at schools (White CG, 2001) and workers at jobs (Hübner NO, 2010) and the effectiveness of hand sanitizers to determine if hand sanitizers significantly contributed to preventing communicable pathogens and thus reducing absenteeism. This research confirmed that each type of hand sanitizers effectively reduced *E.coli* counts through microbiological lab experiment, although the Food and Drug Administration (FDA) protocol for testing sulfactants, allantoin, and benzalkonium chloride (SAB) formula-based hand sanitizers may be more stringent (Moadab A, 2001).

Furthermore, this research compared the two types with statistical analysis, which showed no difference in their effectiveness. While the BC Centre for Disease Control measure (BCCDC, 2014), Fraser Health Authority (Fraser Health, 2012), and the FDA recommend hand sanitizers with at least 60 percent alcohol to supplement hand washing with soap and water at different public premises such as restaurants, hospitals, and schools (U.S. Food and Drug Administration, 2014), this research, using statistical analysis derived from microbiological testing, showed that alcohol-free hand sanitizers can be just as effective as 60 percent alcohol-based hand sanitizers. However, this research did not test for the residual effect of the hand sanitizers, which should be considered to determine which one is more effective in reducing communicable pathogens in the real world and testing on human hands with regular activities such as shaking hands, touching door nobs, and using the computer.

Recommendations

We failed to reject the null hypothesis and concluded that there is no significant difference between the two types of hand sanitizers. There is some practical significance with respect to the field of public health. As discussed in the literature review, with different types of hand sanitizers being used in different public premises, the public may not be aware of why one type is preferred over the other, specifically comparing alcohol-based hand rubs (ABHR) and alcohol-free hand sanitizers. This research study showed, with microbiological evidence, that the effects of hand sanitizers are the same for both alcohol based and alcohol free. For public premises such as food establishments, all employees are required to wash hands with soap and hot water (FPR, 2008). Whether they use alcohol-based or alcohol-free hand sanitizers is the operators' choice, factoring in the fact that alcohol-free hand sanitizers are slightly more expensive but have other benefits such as no irritation to the skin. The practical significance would be to use the cheaper sanitizers, as it is more cost effective for operators. Neither the *Food Premise Regulation (FPR)* nor the *Food Retail and Food Services Code (FRFSC)* used by health inspectors mentions the effectiveness of hand sanitizers whether alcohol-based or alcohol-free (Canadian Food Inspection System, 2004); there is potential for educating the food establishment operators in the FPR or the FRFSC of the effectiveness of the different types of hand sanitizers and to offer hand sanitizers to customers during the flu season as a further precaution in preventing the spread of germs.

In regards to hand sanitizers at schools, it may be recommended that schools use alcohol-free hand sanitizers since children are more sensitive to skin irritation, have weaker immune systems, and can contract sickness up to four times a year (White CG, 2001). Such benefits of alcohol-free hand sanitizers include less irritation to the skin, non-flammable properties, and not being poisonous to children. The practical significance is educating the children and staff of the proper hand hygiene practice in and outside of school with soap and water, while supplementing the practice with alcohol-free hand sanitizers. Although non-alcohol based hand sanitizers seem favorable due their same effectiveness as alcohol-based sanitizers, there is still a lack of empirical evidence that shows its effectiveness compared to the vastly researched alcohol-based hand sanitizers. It is still a good idea to be aware of the different types of hand sanitizers.

Limitations

Improvements to Study: The validity of the experiment depended heavily on the experimenter's lab techniques and skills. Due to the cost issue, two experimenters with differing microbiological lab experience and techniques performed the experiment and shared the data for alcohol-based hand sanitizers, thus leading to potential human errors. To improve the experiment even further, one experimenter could have performed the entire experiment.

Possible Errors or Bias: Human errors cannot be fully eliminated as this experiment relies heavily on the accuracy of the experimenter (both performing the experiment and counting the *E. coli* colony counts), but can be minimized by having an experimenter who is well trained on laboratory techniques and instruments.

There was no Type I error since the difference was not significant but Type II error could be decreased by increasing the number of samples. However, Type II error occurs when the p-value obtained is only slightly greater than 0.05 (ex. between 0.05 and 0.1). Thus, a p-value as high as 0.1034 suggested that there was simply no difference between the two types of hand sanitizers, regardless of the size.

Due to the vastly researched effectiveness of alcohol-based hand sanitizers such as the studies done by Hübner NO et al. and Hilburn J et al., as well as the recommendation of using 60 percent alcohol-based hand sanitizers by BCCDC, the Fraser Health Authority, and the FDA, there was initial bias towards the alcohol-based hand sanitizers. However, both types of hand sanitizers were applied on the pigskins in the same method and analyzed using the same materials, thus minimizing any bias.

Future Research

This research compared the two types of hand sanitizers by analyzing the mean reduction in *E.coli* counts (CFU). However, it did not measure the residual effect of alcohol-based and alcohol-free hand sanitizers, which is an important property in the real world. The residual effect of hand sanitizers is how long it kills germs after the initial application. For future research, this residual effect, particularly of alcohol-free hand sanitizers, could be studied to show how effective alcohol-free hand sanitizers are in terms of having long or short residual effect. Having long residual effect could be more effective in preventing communicable diseases such as *Salmonella, Staphlococcus aureus, Streptococi, E.coli,* and *protozoa* as compared to short residual effect. There are many studies that show the residual effect on alcohol-based hand sanitizers such as the one by Hilburn et al. but more studies should be conducted using alcohol-free hand sanitizers. Indeed, there is a limited real-world evidence of the efficacy of non-alcohol based hand sanitizers outside the clinical studies before they become ineffective against bacteria (Johannes, 2013).

Conclusion

The p-value was 0.1034, which was greater than 0.05, thus we failed to reject the null hypothesis and concluded that the reduction mean *E. coli* counts on pigskin that was cleaned with alcohol-based hand sanitizers is the same as or less than the reduction mean *E. coli* counts on pigskin that was cleaned with alcohol-free hand sanitizers. In other words, there is no difference between the types of hand sanitizers.

Acknowledgements

The authors thank the British Columbia Institute of Technology – Environmental Health for supporting this research and providing funding for the project. The authors also thank the instructors and technicians from the BCIT Food Technology program for additional help, providing necessary equipment, and allowing the use of their lab.

Competing Interest

The authors declare that they have no competing interests.

References

3M Corporation. (2015, September 1). *3M™ Petrifilm™ E.coli/Coliform Count Plates*. Retrieved November 9, 2015, from 3M: http://solutions.3m.com/wps/portal/3M/en_US/Microbiology/FoodSafety/product-information/product-catalog/?PC_Z7_RJH9U523003DC023S7P92O3O87000000_nid=C0WJ62882Vbe29BDXSBJ7Fgl

BCCDC. (2014, November 20). *Hand Hygiene*. Retrieved October 13, 2-15, from BC Centre for Disease Control: An Agency of the Provincial Health Services Authority: http://www.bccdc.ca/prevention/HandHygiene/default.htm

British Columbia Regulation 210/99. 1999. *Health Act – Food Premises Regulation*. Retrieved 15 October 2015, from http://www.bclaws.ca/Recon/document/ID/freeside/11_210_99

Campanac, C., Pineau, L., Payard, A., Baziard-Mouysset, Baziard-Mouysset, G., & Roques, C. (2002). Interactions between biocide cationic agents and bacterial biofilms. *Antimicrob Agents Chemother. , 46* (5), 1469-1474.

Canadian Food Inspection System. 2004. *Food Retail and Food Services Code. CFISIG*. Retrieved 15 October 2015, from http://foodsafe.ca/resources/Food_Services_Code2004.pdf

Fazlar, A., & Ekhtelat, M. (2012). The Disinfectant Effects of Benzalkonium Chloride on Some Important Foodborne Pathogens . *American-Eurasian Journal of Agricultural & Environmental Sciences* , 23-29 .

Fraser Health. (2012, March 1). *Hand Hygiene*. Retrieved October 14, 2015, from Fraser Health: https://www.fraserhealth.ca/media/StudentPractice_HandHygiene.pdf

Hübner NO, H. C. (2010, August 24). Effectiveness of alcohol-based hand disinfectants in a public administration: Impact on health and work performance related to acute respiratory symptoms and diarrhoea. *BMC Infectious Diseases* , 250.

Herron, A. (2009). *Pigs as Dermatologic Models of Human Skin Disease.* Houston: Baylor College of Medicine.

Hilburn J, H. B. (2003). Use of alcohol hand sanitizer as an infection control strategy in an acute care facility. *Am J Infect Control , 31* (2), 109-116.

Johannes, L. (2013, Feburary 11). *How Hand Sanitizers Sans Alcohol Hold Up*. Retrieved October 13, 2015, from The Wall Street Journal: http://www.wsj.com/articles/SB10001424127887324900204578286354195382458

Minnesota Department of Health. (2009, December 1). *Hand Sanitizers: Not a Replacement for Handwashing in Food Service Settings*. Retrieved October 15, 2015, from Hand Hygiene: http://www.health.state.mn.us/handhygiene/food/handsanifs.pdf

Moadab A, R. K. (2001). Effectiveness of a nonrinse, alcohol-free antiseptic hand wash. *J Am Podiatr Med Assoc. , 19* (6), 288-293.

Public Health Agency of Canada. (2015, October 20). *E. coli*. Retrieved November 8, 2015, from Public Health Agency of Canada: http://www.phac-aspc.gc.ca/fs-sa/fs-fi/ecoli-eng.php

Purell. (2015, January 1). *ILLNESS OUTBREAK FREQUENTLY ASKED QUESTIONS*. Retrieved October 15, 2015, from Purell: http://www.purell.com/fighting-germs/

Reichel, M. S. (2014, May 28). Efficacy of surface disinfectant cleaners against emerging highly resistant gram-negative bacteria. *BMC Infectious Diseases* , 292.

U.S. Food and Drug Administration. (2002, September 1). *BAM: Enumeration of Escherichia coli and the Coliform Bacteria*. Retrieved November 8, 2015, from U.S. Food and Drug Administration: http://www.fda.gov/Food/FoodScienceResearch/LaboratoryMethods/ucm064948.htm

U.S. Food and Drug Administration. (2014 , November 26). *FDA Fact Sheet on Hand Hygiene in Retail & Food Service Establishments.* Retrieved October 14, 2015, from U.S. Food and Drug Administration: http://www.fda.gov/Food/GuidanceRegulation/RetailFoodProtection/IndustryandRegulatoryAssistanceandTrainingResources/ucm135577.htm

White CG, S. F. (2001). Reduction of illness absenteeism in elementary schools using an alcohol-free instant hand sanitizer. *The Journal of School Nursing , 17* (5), 258-265.

World Health Organization. (2007, May 1). *Improved Hand Hygiene to Prevent Health Care-Associated Infections*. Retrieved October 14, 2015, from WHO Collaborating Centre for Patient Safety Solutions: http://www.who.int/patientsafety/solutions/patientsafety/PS-Solution9.pdf

Yip, S. (2003). *One Step Hand Sanitizer vs. CAREX Liquid Soap with Hand Washing.* British Columbia Institute of Technology . Burnaby: British Columbia Institute of Technology .