1 Impact of Soap Type—Foaming vs. Gel-based—on Handwashing Time

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Abstract

Handwashing (HW) is used daily in the food service industries to prevent disease transmission. Limited published research into the efficacy of foaming handsoap exists when compared to gel-based handsoap. Understanding how foaming soap may affect HW behavior as represented by time is critical to maximize HW effectiveness and minimize transmission of foodborne pathogens. Here, 12 participants completed a baseline HW, and then applied a known amount of Glo Germ (GG) fluorescent lotion and washed their hands with the assigned handsoap. Hands were then swabbed to quantify the amount of GG remaining on hands. Hand wash and hand rinse times were also recorded. No significant difference in efficacy between soap types was observed 1) in terms of GG remaining ($p = 0.35$) nor 2) in hand wash and rinse times ($p = 0.77$ and $p = 0.48$, respectively). However, consistently longer time (4.5 s on average) in both wash time and rinse time for gel-based handsoap did occur when compared to foaming handsoap. This may indicate a possible benefit to using gel-based handsoap as opposed to foaming types for better protection of public health; however, more research is needed to elucidate these differences.

KEY WORDS: foaming handsoap; gel-based handsoap; handwashing; fluorescing compound; handwashing time

1. Introduction

Handwashing (HW) is one of the primary means to prevent transmission of infectious diseases. While the general population uses HW as a daily tool to limit the spread of disease, it is especially critical within a food service environment (Todd, Michaels, Smith, Greig, & Bartleson, 2010). Throughout the production and preparation of food, food workers are presented with a variety of scenarios in which hand contact (e.g. direct or indirect) can result in the contamination of food with harmful microorganisms (Todd, Grieg, Bartleson, & Michaels, 2008, 2009; Todd et al., 2010). Despite the focus on HW in the food industry and the establishment of clear guidelines for proper HW via the U.S. Food and Drug Administration (USFDA) *Food Code 2013* (USFDA, 2013) as well as the European Commission (EC) General Food Law Regulation 178/2002 (ECR No, 2002), food workers are still implicated in the transfer of harmful pathogens to food resulting in a significant contribution to the incidence of foodborne illnesses (Green et al., 2006; Hall, 2012; Scallan, Griffin, Angulo, Tauxe, & Hoekstra, 2011; Todd, Grieg, Bartleson, & Michaels, 2007).

The USFDA *Food Code 2013* (section 2-301.12) states that food employees must wash hands as well as exposed portions of the arm for 20 s, designating at least 10 to 15 s of this HW process to vigorously rubbing the hands together (USFDA, 2013). Similarly, EC guidelines on hand hygiene specifically state that hands must be washed for 30 s dedicating 20 s to rubbing 'soap-smear' hands together and 10 s to rinsing the hands while rubbing together under running water (Bonne, Wright, Camberou, & Boccas, 2005). Guidelines for when food employees should wash their hands are fairly standard including after 1) using the toilet room, 2) coughing, sneezing, blowing nose, etc., 3) handling soiled equipment or utensils, and 4) handling specific types of food to prevent cross-contamination. Additional

actions that warrant HW include when moving from raw food production areas to cooked food product areas and before placing gloves on hands to work with food. Although food safety regulatory bodies as well as many other organizations—World Health Organization, the Mayo Clinic, and U.S. Centers for Disease Control and Prevention—recommend at least a 20 s handwash, numerous studies have reported that food service workers as well as the general population often complete the HW process in 15 s or less (Bonne et al., 2005; Burton et al., 2011; Soap and Detergent Association, 2007; Strohbehn Sneed, & Paez, 2008). Reasons for lack of compliance with the recommended HW time vary; however, a recent study by Seimetz, Boyayo, & Mosler (2016) indicate that psychosocial factors (self-efficacy, action planning, and remembering to perform a specified behavior) were most important for understanding hygiene behaviors including deviance from recommended HW times.

In order for HW to be as effective as possible, it is essential to understand how all of the different variables associated with the actual HW process will affect the end result. As reviewed in Conover & Gibson (2016a), the primary factors influencing the efficacy of the HW process include soap volume, HW time, plain vs. antimicrobial soap, and drying technique. However, it should be noted that results related to the significance of each of these factors on HW are inconsistent in the published literature. Another variable recently explored is the difference in hand soap types—foaming and gel-based—in the level of microbial reduction (Conover & Gibson, 2016b). The primary differences between foaming and gel-based handsoaps are the level of surfactant and additional salt compounds. Foaming soaps generally have lower levels of surfactants and salts compared with gel-based soaps. As a result, foaming soaps do not form micelles as readily as gel-based handsoap (personal communication provided by M. Caetta, VCI Formulation Specialist at

GOJO Industries, Inc.) thus possibly reducing the removal of dirt and oils as well as microorganisms.

In comparison to gel-based handsoaps, foaming handsoaps are relatively new with the first appearance on the market in 1999 (Deb Group Ltd, 2014). Therefore, it is important to determine if the efficacy of foaming handsoaps is equal to that of traditional, gel-based handsoaps. One aspect of this is to understand how people respond to these foaming handsoaps with respect to total HW time—a primary factor influencing HW efficacy (Conover & Gibson, 2016a). The primary objectives of this study were 1) to determine if handsoap type (foaming versus gel-based) affects HW time and 2) to investigate whether a fluorescing compound remaining on hands after HW could be quantified and correlated with HW time differences between soap types. The use of the fluorescing compound, Glo Germ, is more commonly used to qualitatively observe HW behavior (Biran et al., 2009; Ling & How, 2012). Typically, participants rub the fluorescent lotion onto their hands, wash their hands, and then participants view their hands under a blacklight in order to visualize where the fluorescent compound is remaining, thus indicating the areas missed during HW. Therefore, the potential quantitative application for evaluating various HW variables, specifically HW time, is a novel aspect of the present study.

2. Materials and Methods

2.1. Study design

Studies were arranged in a paired t-test design. To account for any possible confounding factors, two blocking factors were incorporated into the statistical model.

These included sequence and participant. Two experimental sequences occurred to alternate exposure of participants to soap type and to adjust for any possible confounding factors (e.g., learning by either the researchers or the study participants over the two weeks of the study). The study was completed over a two-week period in November 2015 with one-week in between visits for different soap types.

2.2. Participant recruitment

Twelve participants (six men and six women) from the University of Arkansas (Fayetteville, Arkansas) community were recruited to wash their hands. Participant age ranged from 19 to 72 years with an average age of 30 years old. Participants were required to have no known conditions of the skin nor any broken skin (ASTM, 2013). University of Arkansas Institutional Review Board approval was obtained prior to participant recruitment, and informed consent was received for all participants.

2.3. Selection of soaps

Two unscented, non-antimicrobial soaps were chosen for use in the study. The soaps did not have identical formulations, but were selected as surrogates for handsoaps widely available on the market and used daily. Two automatic dispensers, one foaming (GOJO Industries, Akron, OH) and one gel-based (Epare, Staten Island, New York), were chosen to standardize the soap volume. One dispense of foaming soap was 0.9 mL (after foaming subsided), and one dispense of gel-based handsoap was 1.5 mL. Based on preliminary, unpublished data on average soap volume at 68 food service locations in Washington County, Arkansas, the soap dispensers selected for this study were determined

to be representative of the average soap volume used in the patron-accessible restrooms of food service facilities.

2.4. Baseline handwash

On each study day, participants completed a preliminary handwash to remove any possible physical contamination (e.g., residues from hand lotions, organismic materials, etc.) present on their hands. Participants did not receive any direction as to how to complete the handwash since the objective of the study was to detect differences in the time spent washing and rinsing hands by soap type. The following steps were performed: 1) wetting hands, 2) provided with designated handsoap, 3) dispensed the desired amount of soap (number of pumps recorded), 4) lathered hands for desired amount of time (time recorded), and 5) asked researcher to turn on faucet and rinsed hands for desired amount of time (time recorded). After completion of these steps, participants were instructed to flick their hands 10 times to remove excess water and then air-dry at ambient temperature. Hands were then immediately swabbed in the three locations as discussed in Subsection 2.6, and the swabs were then processed as described in Subsection 2.7. Swabs from this step were considered “baseline” swabs.

2.5. Fluorescing Compound Handwash

Following the preliminary HW and air-drying, hands were air-dried for an additional 30 s or until hands appeared visibly dry. Participants were then provided with Glo Germ (GG) lotion (Glo Germ Company, Moab, UT) that contains a fluorescing compound with individual units approximately the size of a bacterial cell (about 5 microns) (Kilbride,

Wirtsschafter, Powers, & Sheehan, 2003). Participants were provided with 1.0 ± 0.01 g (i.e. approximately the size of a quarter) of GG lotion as recommended by the manufacturer. Next, the participants thoroughly rubbed the lotion into their hands (both palmar and dorsal sides) for 1 min until evenly distributed and absorbed. Hands were air-dried for 30 s or until hands appeared visibly dry. Once dry, participants completed a second handwash as described previously in Subsection 2.4.

2.6. Swabbing Participant Hands

Based on the findings of Taylor (1978), the skin between the thumb and index finger was chosen for swabbing as well as the lower nail bed/skin region of the middle finger and the palmar side of the wrist. To quantify the amount of GG remaining on hands after washing, sterile, foam tipped swabs (VWR, Radnor, PA) were placed in a 15 mL centrifuge tube containing 2 mL of 95% ethanol, and both hands were swabbed in 3 locations (Figure 1a-c) using one swab for each location (i.e. 3 swabs total for each participant).

2.7. Determination of Sample Absorbance

Three swabs each from the baseline handwash and GG handwash were placed in their respective tubes containing 2 mL of 95% ethanol and vortexed for 60 s. The sample was placed in a disposable acrylic cuvette (VWR), and the absorbance of each swab was measured at an optical density of 370 nm by a DU® 640 spectrophotometer (Beckman Coulter, Inc., Brea, CA). The values from each of the three swabs were combined to create a total fluorescence concentration for each participant after baseline handwash and GG handwash. As previously described by Gibson et al. (2013), a standard curve of the GG

fluorescent lotion was created by preparing a two-fold dilution of the fluorescent lotion in 95% ethanol and subsequently measuring the absorbance at 370 nm with a DU® 640 spectrophotometer (Beckman Coulter, Inc.). Concentration (y) of fluorescent compound remaining on participants' hands was determined by using the absorbance (x) measurement for each participant, and the slope (m) and intercept (b) of the fit line of the standard curve through use of the slope intercept equation ($y = mx + b$). The r^2 value of the fit line was determined to be 0.996, and the slope-intercept equation used for further calculations was $y = 0.012x + 0.0001$.

2.8. Statistical Analysis

JMP® Pro 11 (SAS, Cary, NC) statistical analysis software was used for all data analysis. Difference in concentration between the post GG handwash and the baseline handwash was calculated by first subtracting the total absorbance for the baseline absorbance from the total absorbance for the post GG handwash. This value was then inserted into the slope-intercept equation ($y = 0.012x + 0.0001$) to solve for the total concentration. As the study was based on a paired t test design, a fit model was used to test for significant differences in total concentration of GG remaining as well as hand wash and rinse times and number of pumps used. Sequence and week were incorporated into the model to account for any variance that may have occurred due to learning by either the participants or researchers throughout the study. Gender was also added as an effect in the model. Results were considered statistically significant at $p \leq 0.05$.

3. Results

All participants completed the study within a two-week period. Overall, the experimental sequence was determined to have no effect on the fit model. With respect to concentration of GG fluorescent compound remaining on hands, no significant difference between foaming and gel-based handsoap occurred when the mean differences of the concentration of GG remaining between the post GG and baseline handwash were compared in the fit model (Table 1). Gender also did not have a significant impact on the difference of the concentration of GG remaining between the post GG and baseline handwash ($p = 0.40$).

No significant difference between foaming and gel-based handsoap occurred in terms of the mean wash times for both the baseline and the post GG handwash (Table 2). Gender did not have a significant impact on wash time for the baseline ($p = 0.89$) or the post GG handwash ($p = 0.53$). As shown in Table 3, no significant difference between foaming and gel-based handsoap occurred in terms of rinse time for either the baseline or the post GG handwash. Similar to wash time, gender did not have a significant impact on wash time for the baseline rinse ($p = 0.48$) or the post GG hand rinse ($p = 0.34$).

The minimum number of pumps dispensed for the baseline handwash for both foaming and gel-based handsoap was 1 pump, while the maximum was 2 pumps. The minimum number of pumps dispensed for the post GG handwash for foaming and gel-based handsoap was 1 pump, while the maximum was 3 and 2 pumps, respectively. No significant difference between foaming and gel-based handsoap occurred with respect to the number of pumps of soap for either the baseline ($p = 0.35$) or the post GG handwash (p

= 0.29) (data not shown). Gender did not have a significant impact on the amount of soap dispensed in the baseline ($p = 0.072$) or in the post GG handwash ($p = 0.29$).

4. Discussion

Comparison of foaming and gel-based handsoap, especially concerning HW time, or behavior in general, in response to soap type, is extremely limited in the published literature. The results of the present study indicate that no significant difference exists between foaming and gel-based handsoap with respect to GG remaining, HW time, rinsing time, and amount of soap dispensed. Despite the finding that no significant difference appears to exist in HW time and rinsing time between foaming and gel-based handsoap, in the present study, participants consistently washed and rinsed hands for a longer amount of time with gel-based handsoap as compared to foaming handsoap.

While the lathering of soap in hands is a large component of the removal of microorganisms from hands, rinsing adds additional physical removal of bacteria through the water flow, primarily for transient microorganisms (Price 1938; Todd, Michaels, Smith, Greig, & Bartleson, 2010). Miller et al. (2011) conducted a study on reduction of *Escherichia coli* on skin with three different methods of HW: 1) running water; 2) running water and friction; and 3) running water with friction and soap. The authors found that simply holding contaminated hands passively under running water was ineffective, but the friction from energetically rubbing hands together while holding hands under water improved the decontamination of hands (Miller et al., 2011). Although the additional reduction in microorganisms resulting from the rinsing of hands is unclear, the difference in rinsing time between foaming (8.5 s) and gel-based (11 s) handsoaps could present an

251 opportunity for increased removal of microorganisms from hands; therefore, additional
252 investigation into the impact of soap type on rinse time and resulting microbial reduction is
253 warranted.

254 One of the primary objectives here was to use GG as an indicator to determine if HW
255 efficacy—based on remaining concentration of GG—was impacted by soap type (foaming
256 versus gel-based) and if this would be associated with HW time. Establishment of a
257 standard curve allowed for determination of the concentration of GG remaining on
258 participants' hands. However, the remaining GG on hands proved to be a difficult tool to use
259 as a measure of HW behavior as represented by time since concentrations of GG remaining
260 on participants' hands were rather low, and the concentration remaining varied greatly
261 from person to person. These low concentrations were likely a result of the small surface
262 areas that were selected from sampling.

263 Gibson et al. (2013) used GG powder fluorescent compound in a mock retail deli
264 environment to understand the impact of workers on cross-contamination as well as to
265 identify critical areas of contamination. Similar to the present study, the results were
266 rather variable for each participant, but the researchers were able to determine the areas
267 within the deli environment that were more likely to be impacted by cross-contamination
268 (Gibson et al., 2013). More recently, Benoit et al. (2015) also used GG to quantitatively
269 determine the spread of *Listeria monocytogenes* between deli meats and product contact
270 surfaces. In this study, GG was spread on deli meats, and the transfer to product contact
271 surfaces was measured by photographing surfaces under UV-light and using image
272 processing software to quantitatively analyze the photos. These data were then compared
273 to *L. monocytogenes* transfer data collected under equivalent conditions. The authors found

that GG was a reasonable surrogate to rapidly quantify simulated *L. monocytogenes* cross-contamination (Benoit, Marks, Ryser, Jeong & Crandall, 2015). While GG can serve as a beneficial tool in HW training, based on the present study, it appears to be much more useful as a qualitative tool rather than as a quantitative tool, especially considering the large amount of variance that can occur between participants. Time spent washing and rinsing hands proved to be more reliable measurements in the present study.

One limitation of the present study is that it is an observational study. While participants were not informed as to what researchers would be observing and recording prior to their participation, it is entirely possible that participants inferred what was being studied and then altered their HW behavior accordingly. It is known that people are responsive to the presence of an outside observer (Ram, 2013). Ram et al. (2010) embedded acceleration sensors within soap to assess the reactivity of participants to structured observation. Results of the study indicated that on days participants were observed, the use of the sensed soap increased by approximately 35%. Ram et al. (2010) concluded that individuals substantially alter HW behavior in the presence of an observer. However, structured observation is still a commonly used method in HW research (Ram, 2013). Additionally, although this cannot be determined, the possibility exists that if behavior changed because of the presence of an observer, that behavior would be equally changed for both soap types, negating the effect.

An additional limitation of the present study is that of sample size. Although a significant difference in HW time was not found, a nearly 4.5 s increase occurred in total HW time for gel-based handsoaps. However, because of sample size, the statistical power of this study was around 0.65 with a corresponding alpha and standard deviation of 0.50 and

1, respectively. Therefore, it is highly probable that an increased sample size would result in reduction of variance and subsequently greater statistical power and in turn the likelihood of detecting a significant difference in HW time between soap types if one truly does exist. Irrespective, we still feel that these data are important and provide the foundation for future studies in this area of HW research.

5. Conclusions

Despite recommendations that HW should occur for a minimum of 20 s and strict guidelines established by the USFDA in the Food Code, these guidelines are often not being met, and people in daily life as well as in the food industry wash their hands for less time than the recommended 20 s handwash (Burton et al., 2011; Meengs et al., 1994; Soap and Detergent Association, 2007; Strohbehn et al., 2008). Foaming handsoap is relatively new, and limited research comparing the efficacy of foaming and gel-based handsoap exists (Conover & Gibson, 2016). Additionally, no studies have been conducted on the impact of soap type on total HW time. It is essential to understand if HW time changes in response to the type of soap used, as a significant change could decrease the efficacy of soap in the removal of microorganisms during HW. Based on the present study, more research is warranted on the impact of soap type with respect to HW time and behavior in general.

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<http://www.fda.gov/downloads/Food/GuidanceRegulation/RetailFoodProtection/FoodCode/UCM374510.pdf>.

431 Table 1. Total Glo Germ concentration remaining by soap type.

		Concentration (units)	
		Foaming	Gel-based
GG Remaining	Range	-0.0030 – 0.0062	-0.0021 – 0.00062
	Mean	0.00027	-0.00034
	Std Dev	0.0021	0.00084
	p value	0.35	

432 GG = Glo Germ

433

434 Table 2. Time spent washing hands by soap type.

		Time (s)	
		Foaming	Gel-based
Baseline Hand Wash	Range	5 - 18	6 - 24
	Mean	11.2	13.8
	Std Dev	3.9	7.3
	p value	0.29	
Post GG Hand Wash	Range	7 - 30	6 - 24
	Mean	13.3	14.2
	Std Dev	6.2	7.7
	p value	0.77	

435 GG = Glo Germ

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437 Table 3. Time spent rinsing hands by soap type.

		Time (s)	
		Foaming	Gel-based
Baseline Hand Rinse	Range	3 - 15	6 - 19
	Mean	7.4	10.8
	Std Dev	3.3	4.3
	p value	0.056	
Post GG Hand Rinse	Range	5 - 20	4 - 24
	Mean	9.6	11.3
	Std Dev	4.1	5.8
	p value	0.48	

438 GG = Glo Germ

439

440 Figure Legend

441 **Figure 1: Areas of the hand swabbed with standard templates.** Locations of the hand
442 swabbed with standard templates. (a) depicts the palmar side of the wrist; (b) depicts the
443 lower half of the nail/upper portion of the middle finger; and (c) depicts the skin between
444 the thumb and index finger on both the palmar and dorsal sides of the hand.

Figure 1: Areas of the hand swabbed with standard templates

(a)

(b)

(c)