Journal of Food: Microbiology, Safety & Hygiene

Research Article Open Access

Bioaerosol Formation and Bacterial Transfer from Commercial Automatic Hand Dryers

Paul Dawson*, Julie Northcutt, Michelle Parisi and Inyee Han

Department of Food, Nutrition and Packaging Science, Clemson University, Clemson, SC, USA

Abstract

Three experiments were conducted to determine to what degree hand dryers transfer bacteria. All hand dryers in public locations tested displayed transfer of aerobic microorganisms with an average transfer of 58 CFU/cycle ranging from 2-238 CFU/cycle. The 2nd experiment found the commercial hand dryer with higher exit air velocity had a greater bacterial transfer rate than the commercial brand tested with a lower air flow exit velocity. The 3rd experiment revealed that hand dryers can spread aerosolized bacteria at least 90 cm from the air exit and that foods with a rough surface such as strawberries collect significantly more microorganisms (170,000 CFU/cycle) from hand dryers compared to foods with smooth surfaces such as grapes. Overall, the series of experiments show that hand dryers aerosolize and spread microorganisms and the source of the microorganisms can be from the air in the environment immediately surrounding the dryer and from microorganisms residing on the outlet nozzle.

Keywords: Hand dryers; Aerosolized bacteria; Bioaerosol; Food contamination

Introduction

Hand hygiene is a critical factor in reducing the spread of disease-causing microorganisms [1,2] resulting in published guidelines on hand hygiene for health care workers and retail and food service workers. An essential but frequently forgotten step in adequate hand hygiene is the drying method. The importance of hand drying was demonstrated by Patrick et al. [3] who found a significantly higher degree of bacterial translocation to surfaces touched by washed, wet hands compared to those touched by washed, dry hands (max=68,000 Colony Forming Units (CFU)/mL and 655 CFU/mL respectively). Hampton [4] demonstrated that hand drying is an essential step in reducing the spread of methicillin-resistant *Staphylococcus aureus* (MRSA) in hospitals but most hand washing protocols do not stipulate a hand drying technique. While it has been shown that drying plays a significant role in the effectiveness of hand washing, the optimal drying method for microbial removal has not yet been established. Patrick et al. [3] used a hand rinsing method to compare the numbers of bacteria recovered from hands after drying with paper towels, cloth towels, or electric hand dryers. They recovered a mean of 850 CFU/mL from hands after 45 seconds of towel drying and a mean of 3700 CFU/mL from hands after 45 seconds of electric hand air drying Patrick et al. [3] Redway et al. [5] inoculated hands of volunteers with *Micrococcus luteus* and determined bacterial recovery from hands after washing and again after washing and drying with cloth towels or electric hand dryers. Results from pre to post drying showed lower reductions in bacteria after electric hand drying (1.7×10^8 cells pre-drying to 8.9×10^7 cells post drying with 51.8% *M. luteus* remaining) than after cloth towel drying (1.7×10^8 cells pre-drying to 2.6×10^7 cells post drying with 15.2% *M. luteus* remaining). Other studies have shown that the use of electric hand dryers may increase numbers of bacteria on hands and surfaces [6-9]. Knight et al. [6] asked volunteers to press their fingertips into aerobic plate count agar (PCA) before using the restroom, then wash and dry hands using paper towels, cloth towels, or electric hand dryers, and then sampled fingertips again. They reported an average increase in total aerobic microorganisms of 504% on the fingertips, with counts increasing from 28 ± 26 CFU/plate prewash to 169 ± 126 CFU/plate after drying with automatic electric hand dryers. Paper towel and cloth towel drying resulted in a 42% decrease and 10% decrease in CFU counts, respectively Knight et al. [6]. Redway et al. [7] used similar methodology to determine numbers and species of bacteria on fingertips after washing and drying using paper towels, cloth towels, and electric hand dryers. These authors also reported an increase in total bacterial counts recovered from fingertips with a 255% (83 ± 26 to 295 ± 47 CFU/plate) increase after drying with electric hand dryers, and an increase in numbers of intestinal and skin bacteria of +438% (50 ± 13 to 269 ± 44 CFU/plate). An increase in skin *staphylococci* of +169% (88 ± 36 to 237 ± 40 CFU/plate) was also reported Redway et al. [7]. Yamamoto et al. [9] determined total bacterial counts on fingertips, fingers, and palms based on 5 different independent variables: paper towel drying, electric hand dryers with UV light or without UV light while rubbing hands together, or while holding hands stationary. Rubbing hands together under warm air dryers resulted in more bacterial translocation than when hands were held stationary under warm air dryers or when hands were dried with towels (log reduction of up to 1.25 log CFU/plate on palms and fingers post electric air drying with rubbing). Yamamoto et al. [9] concluded that this may be a result of bacteria surfacing from folds or crevices in the skin during rubbing under an air dryer. Snelling et al. [9] also reported that rubbing hands together during forced air drying resulted in greater bacterial counts on hands after washing and drying. In addition Snelling et al. [10] concluded that rapid-air dryers (Airblade™ specifically) reduced bacterial populations transferred from hands after drying compared to conventional warm air hand dryers. Best et al. [11] also reported that a greater aerosolization and spread of bacteria from hands during drying occurred with hand dryers compared to towel drying. In spite of these findings, the United States' Center for Disease Control (CDC) and the United States' Food and Drug Administration's (FDA) Food Code still list warm air drying as an acceptable method of hand drying for health care and food service workers, respectively. The present study was conducted to further characterize the microbiological condition

***Corresponding author:** Paul Dawson, Department of Food, Nutrition and Packaging Science, Clemson University, Clemson, SC, USA, Tel: 864-656-1138; E-mail: pdawson@clemson.edu

Received June 30, 2016; **Accepted** July 18, 2016; **Published** July 25, 2016

Citation: Dawson P, Northcutt J, Parisi M, Han I (2016) Bioaerosol Formation and Bacterial Transfer from Commercial Automatic Hand Dryers. J Food Microbiol Saf Hyg 1: 108. doi:10.4172/jfmsh.1000108

of electric hand dryers in public environments and to determine the potential of contaminated electric hand dryers to transfer bacteria to bacterial media and food.

Materials and Methods

Three experiments were performed to determine the effects of electric hand dryers on bacterial cross-contamination. First, a microbiological survey was performed on hand dryers in three types of public restroom settings including those on a college campus, in grocery stores and in gas stations to determine numbers of total aerobic microorganisms from air generated and from dryer surfaces. Secondly, a controlled experiment comparing two different types of electric hand dryers (high or low air velocity) was conducted to determine if inoculated bacteria on the hand dryer exhaust could be transferred to surfaces through air. Third, a controlled experiment was performed to determine translocation distance of bacteria inoculated in the hand dryer exhaust using different types of media placed various distances away from the dryer nozzles.

Experiment 1 survey of bacteria transmitted from public hand dryers

A microbiological survey of 60 electric hand dryers was performed using open air plating and sterile gauze swabbing of dryer surfaces. Air velocity, air temperature, and relative humidity were recorded for each dryer using a hand-held anemometer (Model 01-241, Traceable Calibrations Control Company, Friendswood, TX, 77546) and hygro-thermometer (Model 45320, Extech instruments, Melrose, MA, 02176) respectively. A Petri-dish filled with Difco Plate Count Agar (Becton Dickinson, Sparks, MD) (PCA) was positioned 15 cm (6 inches) from the end of the dryer nozzle. A distance of 15 cm was established based on hand dryer manufacturer reports that the average individual places their hands at least 10 cm away from the air exhaust Excel Dryer [12]. The dryer was activated using the start button or motion sensor on the individual units and the agar was held exposed to the air generated for 30 seconds (one cycle). A duplicate plate was held for another cycle immediately following the first. Plates were covered, placed in clean plastic bags and transported to the laboratory where they were incubated at 37°C for 48 hours before total colony forming units were counted and recorded. The button or the inlet vent of each hand dryer was also evaluated for microorganisms by swabbing with a piece of 5.5 × 5.5 cm sterile gauze previously wetted with 20 ml of 0.1% sterile Bacto Peptone water (0.1% wt/vol; Becton Dickinson, Sparks, MD) in a Whirl-Pak® bag (Weatherby/Nasco. Inc., Fort Atkinson, WI). The gauze was squeezed to remove excess peptone and removed from the Whirl-Pak bag using latex gloves. Each dryer was swabbed with a new piece of gauze using a single pass swipe before being returned to the bag and transported to the lab. Gauze samples were stomached at 250 rpm for approximately 30 seconds. The rinsate was aseptically expressed from the gauze, removed from the bag, serially diluted and plated on Difco Plate Count Agar (PCA; Becton Dickinson, Sparks, MD). Colonies were counted on dilution plates with 25 to 250 colonies after incubation at 37°C for 48 h on a Quebec colony counter and converted to colony forming units (CFU) per sample.

Experiment 2 transfer of bacteria from different models of hand dryers

A controlled study comparing two different types of hand dryers was performed. World Dryer (World Model A5-974 Dryer, World Dryer, Berkeley, Il) and Fastdry Hand Dryers (Fastdry HK1800PS Hand Dryer, Allied Hand Dryers and Baby Changing Stations, San Antonio, TX) were purchased from the manufacturer and secured onto individual camera tripods for transportability and adjustability. Hand dryer air temperature, air velocity, and relative humidity were recorded using a thermometer, anemometer and hygrometer respectively before sampling. The dryers were placed in a bio-hood for sampling where they were cleaned thoroughly around the nozzle and intake vent using a Kimwipe® (Kimberly-Clark Corp., Neenah, WI) wetted with 70% ethanol. Dryer surfaces were allowed to air dry for approximately 5 minutes with the bio-hood activated to remove incidental microorganisms present in air. Nozzles were inoculated with 0.1 mL of a culture containing 10^7 to 10^8 cells/mL of generic *Escherichia coli* (*E. coli*) suspended in 0.1% peptone buffered solution. The culture was distributed around the interior of the nozzle with a sterile loop and allowed to dry for 15 minutes. Nottermans and Kampelmacher [13] determined that bacteria attached to skin after a minimum of 12 minutes and this provided the basis for the 15 minute delay time between inoculation and dryer cycle in the current study which is also the equivalent of time for one bacterial generation. After 15 minutes, a petri-dish filled with plate count agar was placed 15.2 cm from the nozzle, the dryer was activated, and the agar was exposed to the air generated for one 30 second cycle. A duplicate plate was used for an additional 30 second cycle immediately after the first cycle. Plates were incubated at 37°C for 48 hours and total CFU were counted and recorded. This procedure was repeated 13 times for each dryer.

Experiment 3 transfer of bacteria to media or food from inoculated hand dryers

Five different types of media or food were placed at varying distances under either the World or Fastdry nozzles. Media or food included PCA, sterile water, 0.1% sterile peptone, fresh grapes and fresh strawberries. Volumes of 25 mL of sterile water or 25 mL of 0.1% peptone were measured into Petri dishes for each sampling. Prior to sampling, grapes or strawberries were rinsed with sterile water for 30 seconds and then cut in half longitudinally. One-half of each grape or one-half of each strawberry was placed in the center of an empty Petri-dish with the cut-side down and outer skin exposed. The remaining half of each grape or strawberry remained unexposed to air and was reserved for control analysis.

Before sampling, dryers were cleaned thoroughly around the nozzle and intake vent using a Kimwipe® containing 70% ethanol then allowed to dry for 5 minutes. The nozzle was inoculated with 0.1 mL of a suspension containing 10^7 to 10^8 cells per mL of generic *E. coli.* The culture was spread on the nozzle using a sterile loop and allowed to dry for 20 minutes. Petri dishes containing media or food were placed at 9 different positions around the hand dryer. The 9 positions are shown in Figure 1, and are designated as follows: Position 1 was directly under the nozzle (15.2 cm); Position 2 was at 0 degree angle and 30 cm from position 1; Position 3 was at 0 degree angle and 60 cm from position one; Position 4 was at +45 degree angle and 30 cm from position 1; Position 5 was at +45 degree angle and 60 cm from position 1; Position 6 was at -45 degree angle and 30 cm from position 1; Position 7 was at -45 degree angle and 60 cm from position 1; Position 8 was at +26 degrees and 90 cm from position 1; And position 9 was at -26 degrees and 90 cm from position 1. Petri-dish lids were removed just before dryer activation. The dryer was activated and media or food was left exposed to air for one-30 second cycle. Petri dishes were immediately covered at the conclusion of the cycle. The sampling method was performed on the World Dryer then on the Fastdry Dryer immediately following to ensure consistency in ambient environment during testing. Two cultures were prepared and used for 1 cycle of sampling on each dryer for a total of 2 cycles of data collection.

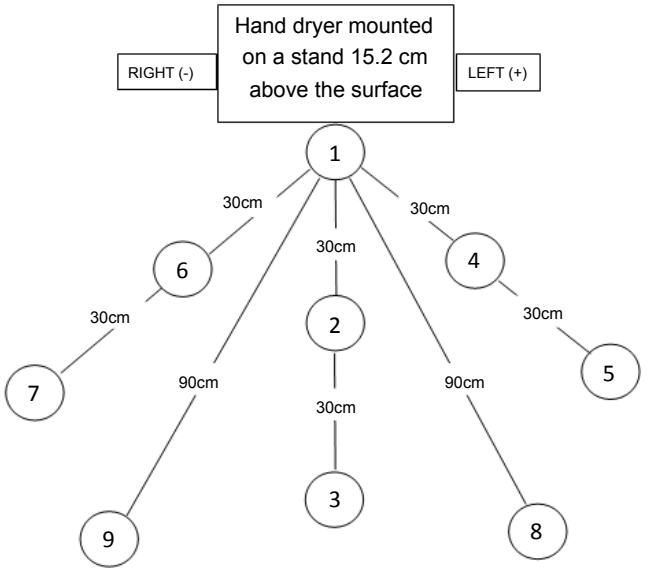

Figure 1: Positions of contact surfaces relative to the hand dryer outlet for Experiment 3: Position 1 – 15.2 cm directly below the dryer nozzle, position 2–30 cm from position1, 0 degree angle from the nozzle; position 3–60 cm from position 1, 0 degree angle from the nozzle; position 4–30 cm from position 1, 45 degree angle to the left of the hand dryer; position 5–60 cm from position 1, 45 degree angle to the left of the hand dryer; position 6–30 cm from position 1, 45 degree angle to the right of the hand dryer; position 7–60 cm from position 1, 45 degree angle to the right of the hand dryer; position 8–90 cm from position 1, 26 degree angle to the left of the hand dryer; position 9–90 cm from position 1, 26 degree angle to the right of the hand dryer.

One-tenth of mL of exposed sterile water and 0.1 mL peptone were placed onto PCA for enumeration immediately after the 30 second cycle. Treatment samples of grapes and strawberries were aseptically removed from the Petri-dish, transferred to sterile WhirlPak® bags and vigorously agitated for 1 min in 20 ml of 0.1% peptone. Rinsates were serially diluted and 0.1 mL of each dilution plated onto PCA. Control samples of grapes and strawberries were analyzed using this same method. All plates were incubated at 37°C for 48 hours before CFU were determined.

Statistical analysis

Total CFU were analyzed using the general linear model procedure of the SAS/STAT program (2000). For experiment 1, public bathroom location, bathroom gender, and dryer air velocity were the main effects of the model. For experiment 2, dryer type, run (first run or duplicate run immediately following) and treatment (inoculated or control) were the main effects of the model. For experiment 3, dryer type, position under dryer exhaust (15, 30, 60, or 90 cm from position 1 and 0, +45, -45, +26 and -26 degree angles) and media or food (PCA, sterile water, 0.1% sterile peptone, strawberries and grapes) were the model main effects (SAS, 2000). All first order interactions were tested for statistical significance ($p<0.05$) using the residual error mean square. Because no significant replication or interaction effects were detected, the analysis was repeated after pooling the data over replicate and main effects.

Results

Experiment 1 Survey of bacteria transmitted from public hand dryers (Table 1)

Twenty-five dryers (42%) were in restrooms in various buildings on a college campus. Fourteen dryers (23%) were sampled in gas station restrooms and 21 dryers (35%) were sampled from grocery store restrooms of the total number of dryers sampled, 29 dryers (48%) were from men's restrooms, and 31 dryers (52%) were from women's restrooms. Buttons from 23 of the 60 dryers (38%) were swabbed and inlet vents were swabbed on the remaining 37 dryers (62%). Average air velocity and temperature was 18.7 m/sec (ranging from 6.8 – 40 m/sec) and 108.2°C (ranging from 88 - 130°C), respectively.

Open air plate collection showed that 100% of dryers transferred microorganisms through air. Total numbers of microorganisms ranged from 2 to 238 CFU/cycle with a mean of 58 CFU/cycle. Differences in the numbers of microorganisms collected from hand dryers in men's restrooms compared to those recovered from women's restrooms for open-air samples approached but did not achieve statistical significance (**p**=0.06). Mean CFU from open air samples from dryers located in men's restrooms were 125 CFU/cycle and ranged from 11 to 238 CFU/cycle. For dryers located in women's restrooms, numbers of microorganisms from open-air sampling of hand dryers ranged from 2 to 160 CFU/cycle with a mean of 81 CFU/cycle. No statistical differences in microbial populations on open-air plate samples were identified between dryers sampled in restrooms on a college campus, in grocery stores, or in gas stations. Numbers of microorganisms on open air plates collected from dryers in gas station restrooms ranged from 2 to 126 CFU/cycle with a mean of 64 CFU/cycle, while those collected from grocery store restroom dryers ranged from 6 to 160 CFU/cycle with a mean of 83 CFU/cycle. Microbial populations recovered from dryers in restrooms on college campuses ranged from 10 to 238 CFU/cycle with a mean of 53 CFU/cycle.

Swab samples collected from individual dryers in grocery stores had significantly higher levels of microorganisms than those from dryers on a college campus (p=0.02). This may reflect a greater number of users in these public areas. Mean populations obtained from swabbing grocery store dryers was 931 CFU/mL while gas station and college campus dryer swabs had a mean of 202 CFU/mL and 108 CFU/mL respectively. Bacterial numbers recovered from buttons and inlets of dryers in men's restrooms were higher (p=0.004) compared to buttons and inlets on dryers in women's restrooms with means of 933 CFU/mL and 221 CFU/mL respectively. Combined results for microorganisms found on both inlet vent and ignition button ranged from 1 to 1860 CFU/mL with a mean of 176 CFU/mL. When individually analyzed, counts from inlet vents were higher (p=0.04) than those from buttons, likely because of larger surface area as well as location (mean for vents=230 CFU/mL, mean for buttons=83 CFU/mL,) because inlet vents tended to be underneath the dryer units, often in close proximity to the garbage cans.

Mean and range of Colony Forming Units (CFU) recovered from public hand dryers based on gender and location						
	Overall	**Men**	**Women**	**CC[1]**	**GAS[2]**	**GS[3]**
Open-Air (CFU/cycle)	58 (2-238)	125 (11-238)	81 (2-160)	53 (10-238)	64 (2-126)	83 (6-160)
Swabbing (CFU/mL)	176 (1-1860)	933 (5-1860)	221 (1-440)	108 (2-440)	202 (3-400)	931 (1-1860)
Average Velocity (m/sec)	18.7	18.2	19.2	19	26.1	11.1
Average outlet temperature (°C)	108.6	108.3	108.2	108.2	118.3	103.4

Table 1: Evaluation of Microorganism Contamination of Automatic Hand Dryers in Public Restrooms; [1]CC refers to hand dryers located in 20 restrooms on a college campus; [2]GAS refers to hand dryers located in 20 restrooms in gas stations; [3]GS refers to hand dryers located in 20 restrooms in grocery stores.

	Cycle 1 CFU/dryer cycle	Cycle 2 CFU/dryer cycle	Pooled cycle1 and cycle 2 CFU/dryer cycle
[1]WD Treatment	25 (3-47)	24 (6-41)	25 (3-47)
[2]FD Treatment	6 (0-12)	7 (0-13)	5 (0-9)

Table 2: Transfer of microorganisms aerosolized from automatic hand dryers inoculated with generic *E. coli* to plate count agar plates placed 15.2 cm directly in front of the nozzle during a 30 sec dryer cycle; [1]WD refers the World Dryer electric hand dryer, Model A5, Berkeley, IL (high velocity dryer) Mean air velocity =151 m/s and air temperature =60.4°C; [2]FD refers the Fastdry Dryer electric hand dryer, Model L: HK1800PS, New Taipei City, Taiwan (low velocity dryer). Mean air velocity =125 m/s and air temperature =51.0°C

Experiment 2 Transfer of bacteria from different models of hand dryers (Table 2)

Dryer cycle data (CFU for run 1 and CFU for run 2/duplicate plate) were pooled for statistical analysis because there were no differences (p=0.37) in number of microorganisms recovered between cycles. Counts of bacteria recovered from the World Dryer was significantly higher (p=0.0009) than the counts of bacteria recovered from the Fastdry hand dryer although levels in both instances were low (mean=25 CFUs/mL and mean=5 CFUs/mL respectively). Results from pooled t-test showed differences (p=0.0009) in mean velocity and air temperature for the World Dryer versus the Fastdry dryer. Mean air velocity was 151 m/s for the World Dryer and 125 m/s for the Fastdry Dryer. Mean air temperature was higher, 60.4°C for the World Dryer compared to 51.0°C for the Fastdry Dryer (p=0.01). Linear regression was performed to determine if there was a relationship between air velocity and recovery of bacteria. Statistically significant but relatively weak correlations were found between CFU recovery and dryer air velocity (r^2=0.315, p=0.0001). No significant relationship was found between bacterial counts and dryer air temperature (r^2=0.19, p=0.0012).

Experiment 3 Transfer of bacteria to media or food from inoculated hand dryers (Table 3)

Microorganisms were detected on 100% of the PCA media samples at all distances from the contaminated dryer nozzles for both the World Dryer and the Fastdry model dryers. This suggests that the hand dryers aerosolized microorganisms as far as 90 cm away from the nozzle exhaust. Minimal transfer was detected in sterile water and 0.1% peptone samples at all positions and may be due to an inability to attach or for damaged cells to survive in the liquids. Differences in bacterial counts from pre to post exposure was calculated and used for statistical analysis for strawberries and grapes. Statistical differences (p=0.0001) were found in the number of bacteria recovered from strawberries compared to all other forms of media or food. Microorganism populations averaged 170,000 CFU/cycle higher on strawberries compared to other surfaces. An unexpected decrease in total CFU from non-inoculated to inoculated dryers was found in fresh grapes exposed to air generated from both dryers with decrease in mean CFU at 8 out of the 9 different positions around the World Dryer, and 7 out of 9 positions around the Fastdry dryer. This may be due to the smooth surface of the grape providing minimal access for surface attachment. It is also possible that the heat from the dryers may have reduced or eliminated bacteria. No statistically significant differences were found in CFU between the 9 different positions or between the 2 types of dryers.

Discussion

Findings from experiments 1 and 2 of this study are in agreement with work completed by Redway et al. [5,7], Knights et. al. [6], and Taylor et al. [8] and demonstrate that electric hand dryers may promote bacterial transfer to surfaces. Experiment 1 was limited in the number of locations sampled (60) with 20 for each location (college campus, gas stations and grocery stores). There was a 100% incidence of microorganism recovery from both open plate collection and sterile gauze swabbing methods in public restrooms in experiment 1 from the current study. This indicates that dryer buttons and inlet vents of dryers in public restrooms are highly contaminated, even without a source of nutrients for survival and growth. Moreover, findings from experiment 2 demonstrate that bacteria are transferred through air generated from electric hand dryers was spread and that bacteria was spread in nearly equal levels from a second dryer cycle. Thus, multiple users may be receiving bacteria residing on or in the dryer. In fact Best et al. [11] found that bacteria was spread to the body of the user from their hands using both a jet-air and warm-air (lower velocity) dryer. Whether the source of the microorganisms is from the nozzle, intake vent and other unit components or is simply drawing in and redistributing airborne microorganisms remains to be determined. Ultimately, findings from experiment 2 demonstrate that these units transfer bacteria whether directly contaminated at the nozzle or contaminated via circulating air from the environment. While correlations between air velocity and air temperature were weak in the current study, total CFU differed considerably between the high and low velocity dryers suggesting a need for further research using a wider range of velocity settings to identify differences.

From experiment 1, levels of contamination were highest in grocery store restrooms suggesting a particular need to determine if the use of electric hand dryers in food retail and processing establishments is the most appropriate method to minimize cross-contamination. Cross-contamination to clean hands, worker clothes or surrounding surfaces is likely to occur through hand dryers. This may increase the spread of foodborne illness and disease-causing microorganisms to individuals and foods prepared and consumed in these environments and even higher levels of contamination could occur from workers that are ill or carriers of infection. The World Union of Wholesale Markets at the European Tissue Symposium European Union [14] recommended that air dryers or roller towels not be used in food preparation rooms as they may induce microbiological contamination. With a 90 cm minimum spread of aerosolized bacteria found in experiment 3, workers and surfaces are at risk for contamination, even if they are not directly using these dryers. Best et al. [11] compared the Airblade™, conventional warm air dyer and paper towel drying of inoculated hands for the spread of bacteria in the vicinity of hand drying and reported greater spread of bacteria in the air both close to the dryer and up to 1 m away. Experiment 3 from the current study also demonstrated the translocation of bacteria to foods, specifically those foods with rough surface characteristics like strawberries. Conversely, foods with smooth surfaces and lower moistures and water activity may have a lower risk of contamination from air sources. Further investigation on the transfer of aerosolized bacteria to hands, food processing surfaces, and food is needed to determine the true nature of these risks.

Conclusions from the results of this study highlight the importance of appropriate drying methods in food processing and retail establishments. In addition to the concern of the potential spread of microorganisms via air hand dryers, observation studies have found that the average drying time for men (17 sec) and women (13.3 sec) are not adequate and do not meet the designated 30 sec for the dryer cycle Patrick et al. [3]. Furthermore, hand wetness was found to play a significant role in transfer of bacteria for

Mean CFUs, standard deviations, minimum and maximum CFUs for world dryer and fast-dry dryers by position and contact surface									
	World Dryer					**Fast-Dry Dryer**			
*pos/ **surface	Mean	Std dev	min	max	*pos **surface	Mean	Std dev	Min	max
1/1	76.3	31.2	54.0	112.0	1/1	27.3	27.0	7.0	58.0
1/2	150.3	172.9	0.0	300.0	1/2	1.3	1.0	0.0	2.0
1/3	1.0	0.8	0.0	2.0	1/3	1.3	2.3	0.0	4.0
1/4	**§ 110000**	**231617.4**	**-24129.5**	**566282.0**	**1/4**	**§ 290000**	**460406.0**	**-16634.1**	**926178.1**
1/5	-2947.0	4631.5	-8066.7	3151.2	1/5	8620.5	14220.8	-5481.3	27414.1
2/1	55.3	48.3	25.0	111.0	2/1	45.3	58.6	10.0	113.0
2/2	77.8	148.2	0.0	300.0	2/2	2.0	1.8	0.0	4.0
2/3	75.5	149.7	0.0	300.0	2/3	0.3	0.6	0.0	1.0
2/4	**§ 780000**	**1233297.3**	**-23268.8**	**2476730.3**	**2/4**	**§ -32000**	**48800.8**	**-117347.8**	**-42.3**
2/5	-3900.6	4158.6	-10849.9	0.0	2/5	-1409.7	3190.5	-5481.3	1415.4
3/1	205.3	313.4	13.0	567.0	3/1	15.0	15.4	2.0	32.0
3/2	0.8	0.5	0.0	1.0	3/2	7.3	6.8	1.0	15.0
3/3	5.3	8.6	0.0	18.0	3/3	101.0	172.3	1.0	300.0
3/4	**§ 560000**	**879942.6**	**-14144.6**	**1762046.9**	**3/4**	**§ -130000**	**224808.5**	**-572841.4**	**-1157.5**
3/5	-2398.2	2708.5	-5481.3	0.0	3/5	-1642.3	2996.9	-5481.3	939.0
4/1	86.3	89.9	22.0	189.0	4/1	19.7	16.7	10.0	39.0
4/2	83.8	144.4	0.0	300.0	4/2	6.0	6.9	0.0	12.0
4/3	19.3	32.6	0.0	57.0	4/3	16.0	30.0	0.0	61.0
4/4	**§ 270000**	**477837.2**	**-10845.8**	**1117597.0**	**4/4**	**§ 430000**	**1154617.4**	**-182400.9**	**2779953.4**
4/5	-3098.9	2803.5	-6000.0	-142.9	4/5	-1825.7	2832.2	-5481.3	55.4
5/1	67.7	89.6	11.0	171.0	5/1	12. 7	3.2	9.0	15.0
5/2	8.0	14.0	0.0	29.0	5/2	3.0	3.5	1.0	7.0
5/3	7.0	8.1	0.0	18.0	5/3	1.5	1.9	0.0	4.0
5/4	**§ 360000**	**601140.3**	**-22462.8**	**1353406.7**	**5/4**	**§ 98000**	**177188.4**	**-22305.1**	**430857.8**
5/5	-3937.2	6526.1	-16528.9	811.4	5/5	-1698.3	2946.7	-5481.3	597.0
6/1	171. 7	147.8	10.0	300.0	6/1	34. 7	23.9	18.0	62.0
6/2	7. 7	6.7	2.0	15.0	6/2	109.5	139.0	5.0	300.0
6/3	3.5	2.6	0.0	6.0	6/3	4.3	0.6	4.0	5.0
6/4	**§ -86000**	**167821.8**	**-385781.6**	**481.9**	**6/4**	**§ -120000**	**1263632.4**	**-2365328.5**	**1567056.7**
6/5	-2750.7	2650.7	-5481.3	241.8	6/5	-1944.1	2719.6	-5481.3	192.3
7/2	8.8	8.1	2.0	20.0	7/2	1.3	0.6	1.0	2.0
7/3	5.0	4.6	0.0	9.0	7/3	4.5	5.3	0.0	12.0
7/4	**§ 690000**	**710220.5**	**-368.5**	**1714114.1**	**7/4**	**§ 230000**	**368551.3**	**-121567.2**	**889269.7**
7/5	-3703.3	2095.3	-5851.3	-1562.5	7/5	-1802.4	2852.0	-5481.3	210.5
8/1	36. 7	42.4	6.0	85.0	8/1	20.0	11.5	9.0	32.0
8/2	6. 7	8.3	0.0	16.0	8/2	2.8	2.5	0.0	6.0
8/3	2.0	1.6	0.0	4.0	8/3	13.0	14.7	0.0	29.0
8/4	**§ 380000**	**706136.1**	**-24462.8**	**1759829.5**	**8/4**	**§ 970000**	**1533644.0**	**-21307.0**	**3272078.1**
8/5	1894.5	3573.0	-1401.3	7255.1	8/5	-1785.2	2807.6	-5455.9	430.8
9/1	75.7	110.4	6.0	203.0	9/1	116.3	159.2	19.0	300.0
9/2	24. 7	29.8	6.0	59.0	9/2	0.5	0.6	0.0	1.0
9/3	2.3	2.1	0.0	4.0	9/3	2.0	1.0	1.0	3.0
9/4	**§ -80000**	**258022.4**	**-549575.4**	**-139.1**	**9/4**	**§ 530000**	**836222.3**	**-21226.6**	**1663065.1**
9/5	-3411.1	3642.5	-6818.2	1595.8	9/5	186.1	5151.1	-5450.0	6618.7
*position 1=0°,15 cm; position 2=0°,30 cm; position 3=0°,60 cm; position 4=+45°,30 cm; position 5=+45°,60 cm; position 6=-45°,30 cm; position 7=-45°,60; position 8=+26°, 90 cm; position 9= -26°,90 cm; **contact surface 1=PCA; contact surface 2=sterile water; contact surface 3=0.1% sterile peptone water; contact surface 4=strawberries; contact surface 5=grapes; §indicates statistically significant difference from contact surfaces 1, 2, 3 and 5.									

Table 3: Bacteria[1] recovered from inoculated hand dryers using contact surfaces positioned at various distances from dryer nozzles; [1]Mean values for colony forming units (CFUs), standard deviation of mean, minimum and maximum CFU recovered.

food Patrick et al. [3], Snelling et al. [10] and hospital settings Merry et al. [15]. Hygiene education is critical prompting new strategies for motivating workers to comply with proper hand washing and drying techniques. While cleaning and sanitizing electric hand dryers may reduce the risk of aerosolizing potentially harmful microorganisms, we were unable to demonstrate effectiveness of cleaning in the current study. This warrants the removal or discontinued use of electric hand drying units in environments such as grocery stores, cafeterias and food processing plants to reduce the potential spread of pathogens via aerosols resulting in possible foodborne illness. Lastly, data from the present study indicate that air hand dryers may not be appropriate for food handling environments a conclusion previously suggested by Best et al. [11] for healthcare settings.

References

1. FDA (2009) U.S. Food and Drug Administration Food Code.
2. CDC (2016) Handwashing: Clean hands save lives.
3. Patrick DR, Findon G, Miller TE (1997) Residual moisture determines the level of touch-contact-associated bacterial transfer following hand washing. Epidemiol Infect 119: 319-325.
4. Collins F, Hampton S (2005) Hand-washing and methicillin-resistant Staphylococcus aureus, British Journal of Nursing 14: 703-707.
5. Redway K, Knights B, Johnson K, (1995) A comparison of the anti-bacterial performance of two hand drying methods (textile towels and warm air dryers) after artificial contamination and washing of hands. A study by the Applied Ecology Research Group, University of Westminster for ELIS.
6. Knights B, Redway K, Edwards V (1997) Hand washing habits in public toilets and the bacterial contamination of the hands before and after washing: a study by the Applied Ecology Research Group, University of Westminster for DEB Hygiene.
7. Redway K, Knights B, Bozoky Z, Theobald A, Hardcastle S (1994) Hand drying: a study of bacterial types associated with different hand drying methods and with hot air dryers. A study by the Applied Ecology Research Group, University of Westminster for the Association of Makers of Soft Tissue Papers.
8. Taylor JH, Brown KL, Toivenen J, Holah JT (2000) A microbial evaluation of warm air hand driers with respect to hand hygiene and the washroom environment. J Appl Microbiol 89: 910-919.
9. Yamamoto Y, Kazuhiro U, Takahashi Y (2005) Efficiency of hand drying for removing bacteria from washed hands: Comparison of paper towel drying with warm air drying. Infect Control Hosp Epidemiol 26: 316–320.
10. Snelling AM, Saville T, Stevens D, Beggs CB (2010) Comparative evaluation of the hygienic efficacy of a ultra-rapid hand dryer vs conventional warm air hand dryers. J Appl Microbiol110:19-26.
11. Best EL, Parnell P, Wilcox MH (2014) Microbiological comparison of hand-drying methods: the potential for contamination of the environment, user and bystander. J Hosp Infect 88:199-206.
12. Excel Dryer Inc (2011) Rapid drying electric hand dryer.
13. Nottermans S, Kampelmacher EH (1974) Attachment of some bacterial strains to the skin of broiler chickens. British Poultry Science 15: 573-585.
14. European Union (2009) Community guide to good hygienic practices specific to whole market management in the European Union. Obtained through the internet.
15. Merry AF, Miller TE, Findon G, Webster CS, Neff SP (2001) Touch contamination levels during anesthetic procedures and their relationship to hand hygiene procedures: a clinical audit. Br J Anaesth 87: 291-294.

Citation: Dawson P, Northcutt J, Parisi M, Han I (2016) Bioaerosol Formation and Bacterial Transfer from Commercial Automatic Hand Dryers. J Food Microbiol Saf Hyg 1: 108. doi:10.4172/jfmsh.1000108