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Microbial Safety of Different Hand-Drying Methods: A Case Study on Electric Warm-Air Hand Dryer and Paper Towel in a Food Processing Company

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Abstract

➢ ***Background***

Electric hand dryers are installed in many food processing facilities as a low-cost and low-waste alternative to paper towels at staff hand-hygiene checkpoints. However, there is concern that these electric hand-dryers serve as reservoirs that dispersers microorganisms onto washed hands during the drying of the hands. This is a major concern because after hand-washing and drying, food handlers enter the production floor, believing their hands are free of microorganism. This study compared the microbiological safety of an electric warm-air hand dryer and a paper towel dispenser within a food processing facility.

➢ ***Method***

A total of 40 samples were collected over five consecutive periods of continuous use from January to May, 2026. After a standardized handwashing procedure, hand swabs (touch plate method) were collected following drying with each method and cultured for total viable count, yeast and mould, total coliforms, and *Escherichia coli*.

➢ ***Results***

Data collected were cleaned in Microsoft Excel 2019 and analyzed using IBM SPSS v27 and Python 3.12.3. ArcMap 10.8.2 was used to generate the sampling area. Hands dried with paper towels yielded zero recoverable colonies across all 20 samples. Hands dried with the electric warm-air dryer carried significantly higher total viable counts and yeast/mould counts (Mann-Whitney U=360, $p<0.001$, $r=-0.80$ for both), with a mean count of 578± 523 CFU/g for PCA and 1,620 ±1,888 CFU/g

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for MEA. Overall contamination for detectable growth on any medium was 80% for the electric warm-air hand dryer and 0% for paper towels.

➢ ***Conclusion***

These findings indicate that hand dryer-associated contamination accumulates predictably with dwell time after filter installation, which suggests scheduling filter replacement after every two days if the electric warm-air hand dryer is to be used and for hand-hygiene prerequisite programmes under a food safety management system (FSMS).

Keywords: *Hand-Drying Methods, Electric Warm-Air Hand Dryer, Paper Towels, Microbial Contamination, Food Safety Management*

➢ *Acronyms and Abbreviations:*

- FSMS=Food Safety Management Systems
- HACCP= Hazard Analysis Critical Control Point
- E. coli= *Escherichia coli*
- EMB= Eosin Methylene Blue
- PCA= Plate Count Agar
- VRBGA=Violet Red Bile Glucose Agar
- MEA=Malt Extract Agar

I. INTRODUCTION

➢ *Highlights*

- Compares the microbiological safety of electric warm-air hand dryers and paper towels at a food processing facility (N=40)
- Shows paper towels return zero microbial growth across the four media used: Plate Count Agar (PCA), Eosin Methylene Blue (EMB), Violet Red Bile Glucose Agar (VRBGA), Malt Extract Agar (MEA), locations, and durations tested (n=20)
- Identifies duration of use as a critical determinant of electric warm-air hand dryer microbial contamination
- Provides actionable hygiene control measures to strengthen food safety management practices in food processing facilities

The hand can be a medium or carrier of various microorganisms [1][2][3], such as bacteria, yeast, and moulds, and other microbes that can be transferred to food, surfaces, and equipment. This makes handwashing an important part of everyday life in domestic, public, community, and industrial settings. Handwashing is one of the important everyday activities that is believed to help prevent diseases [4][5]. In various homes, handwashing is done to maintain personal cleanliness [6][7][8] , household hygiene [6], [9], [10], [11][12], and to reduce contamination during food preparation and eating[13]. In the food industry, there is frequent contact by workers (production) with raw materials, processing equipment, packaging surfaces, and finished products [14][15][16]. This creates a way to transfer pathogenic and spoilage microorganisms. Insufficient hand hygiene has been linked to foodborne illness outbreaks [17][14][18], making hand hygiene an important part of food safety management systems, which prevents cross-contamination [19], [20][19] in food processing environments.

Microbial safety is key in food manufacturing and pharmaceutical companies since microorganisms cannot be seen or detected with the naked eye, making it difficult to control them. Because of this, various practices and measures, including handwashing, are put in place to ensure harmful microorganisms do not contaminate manufactured products, surfaces, equipment, the environment, or people.

In the industry setting, one cannot continue working immediately with wet hands after washing and requires drying the hands before returning to work. It has been proven that wet hands can transfer microorganisms more readily than dry hands[21][22], mainly because moisture facilitates microbial survival and transmission [23], [24], [25]. This makes proper hand drying after hand washing very important

Methods like air drying (natural), cloth towels, paper towels, and electric hand dryers [26], among others, are used to dry the hands after washing them. In our experience, paper towels and electric warm-air hand dryers are commonly used across various industries in Ghana.

The electric warm-air hand dryer operates by pulling the surrounding air into the dryer and forcing the air back out.

The paper towels are aseptically folded and transferred into a wall-mounted tissue holder or dispenser.

However, these two hand-drying methods have little data/research in Ghanaian settings to assess their microbial safety, especially in food processing establishments.

This study experimentally explored the microbial safety of paper towels and electric warm-air hand dryers in the food processing setting, with emphasis on total aerobic bacteria, E. coli, Total coliform, and yeast/moulds [27], [28], [29].

II. MATERIALS AND METHODS

➢ *Study Area*

The research was focused on a food processing facility in Sunyani. Sunyani is the capital city of the Bono Region in Ghana and functions as an agricultural and industrial center. The municipal area has a tropical climate, which produces elevated humidity levels and moderate temperature conditions that affect how microorganisms survive and multiply. The city has just a few food processing companies and many catering services that handle, package, and distribute food items and food products for public consumption. These facilities require strict hygiene and sanitation procedures to maintain food safety standards. The selected food processing company follows food safety hygiene procedures that require all workers and visitors to use handwashing facilities. The facility provides electric warm-air hand dryers, which have been installed in specific washrooms and handwashing areas throughout the production space. Hand hygiene practices are essential measures that help reduce microbial contamination risks during food production where people touch or come into contact with food-contact surfaces or food [30], [31].

➢ *Study Design and Sampling Strategy*

- *Study Design and Sampling Strategy*

A stratified random sampling [32], [33], [34] framework was designed to capture the microbial safety of electric warm-air hand dryers and paper towels from a food handling establishment. The electric warm-air hand dryers and paper towels were first stratified based on their location: washrooms and entry protocol (where handwashing is required before you enter the processing floor). Four samples were randomly selected from each stratum for each hand drying type (electric warm-air hand dryer and paper towel). However, purposive sampling [35] was used to select five food handling establishments in Sunyani. Out of these five, only one (20%) consented to samples being collected in their company.

The sampling was done by first replacing the filters (pre verified to be free from microbes) of all the electric warm-air hand dryers that would be used for the study. Samples were then taken two months after filter replacement. The filters were changed again, and samples were taken again in a month. The same procedure was followed and samples taken in two weeks, one week, and two days. The same treatment was given to the paper towels, where the dispensers are opened and cleaned before the paper towels (pre verified to be free from microbes) were aseptically folded and transferred into them. (Sampling frequency remained the same for this too).

For the experiment, three sampling positions were identified. The first sampling was the overall air quality of the sampling environment to verify the absence of microbes in the air. Passive air sampling, where a sterile agar plate is opened and exposed to the air for 30 seconds, was the sampling method used at this position. The next sampling position was at the point where the electric warm-air dryer was used after proper handwashing. The sampling method used was the touch-plate method, in which the fingertips were pressed directly onto the agar plates. Then the last sampling point was the paper towel used after proper handwashing. Again, the touch plate method was used for this sampling.

- *Quality Assurance and Quality Control*

To ensure data reliability, the electric warm-air hand dryers selected were cleaned, and their filters were changed. The dispensers were bought by the researchers; hence, the tissue papers in them were not be used before the stipulated time (two months, one month, two weeks, one week, and two days). The tissue dispenser was also opened and cleaned before new tissues are aseptically folded and transferred into the dispenser. Sampling frequency, exposure time, conditions, and time of day were kept consistent across all sample positions. All samples taken for microbiological analysis were transported to the laboratory without delay and analyzed immediately to preserve sample integrity.

All laboratory equipment used, such as the autoclave and microwave, had been inspected and were in good shape, and glass measuring cylinders, weighing scale, water bath, and incubators were calibrated. Materials such as borosilicate glassware, a spatula, and petri dishes were all sterile. Work surfaces were disinfected before the start of analysis, and the prepared media for the microbiological analysis were sterilized. Sterilized media was poured aseptically into empty sterile petri dishes (plates). Positive and Negative controls were used during microbial culture analysis. Unexposed/untouched plates were incubated alongside test plates to detect contamination from media or handling. Replicate samples were collected at each sample position for microbial analysis to improve the accuracy and validity of the results.

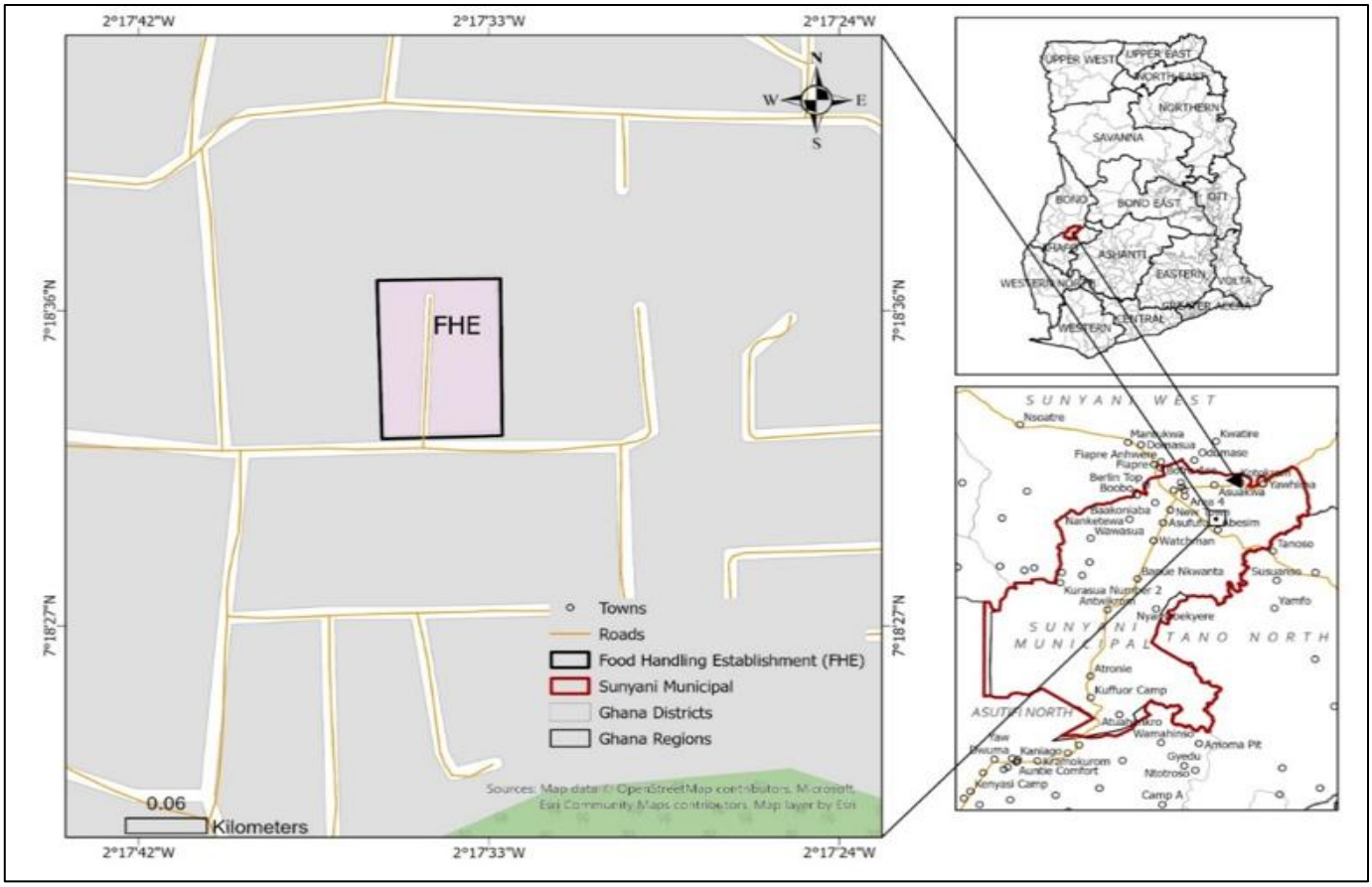


Fig 1 A Map Showing the Sampling Area

- *Microbiological Analysis*

Total Viable Count (TVC), Total Coliform (TC), E. coli, and Fungal Counts were the parameters analyzed. Plate Count Agar (PCA) was used to identify bacterial growth for TVC, Violet Red Bile Glucose Agar (VRBGA) was used to detect coliform bacteria for TC, Eosin Methylene Blue (EMB) Agar was used to identify faecal bacteria growth for E. coli counts, and Malt Extract Agar (MEA) was used to identify yeast/moulds growth for fungal counts. Media (PCA, VRBGA, EMB, and MEA) were prepared according to the ISO 4833: 1991(E), NMKL 44; 2004, ISO 4832, and ISO 21527-1; 2008 analysis method, respectively. PCA, VRBGA, and EMB plates were incubated at 37°C for 24hours before enumeration, while the MEA plates were incubated in a dark place at room temperature for 72hours before enumeration. The results were expressed in CFU/g.

➢ *Statistical and Predictive Modeling*

Data collected were cleaned in Microsoft Excel 2019 and analyzed using IBM SPSS v27 and Python 3.12.3. ArcMap 10.8.2 was used to generate the sampling area.

III. RESULTS AND DISCUSSIONS

➢ *Descriptive Profile of Microbial Counts*

Table 1 Descriptive Microbial Counts (CFU/g) on Hands After Drying by Method (n=20 per Drying Method) on Plate Count Agar (PCA), Malt Extract Agar(MEA), Violet Red Bile Glucose Agar(VRBGA), and Eosin Methylene Blue(EMB)

Parameter	Dryer mean ± SD	Dryer median (range)	Towel mean ± SD	Towel median (range)	% positive (dryer/towel)
PCA (total viable count)	578 ± 523	415 (0-1860)	0 ± 0	0 (0-0)	80% / 0%
MEA (yeast & mould)	1620 ± 1888	1075 (0-5300)	0 ± 0	0 (0-0)	80% / 0%
VRBGA (total coliforms)	2.0 ± 5.2	0 (0-20)	0 ± 0	0 (0-0)	15% / 0%
EMB (E. coli)	0 ± 0	0 (0-0)	0 ± 0	0 (0-0)	0% / 0%
Total count (sum of 4 media)	2200 ± 2393	1525 (0-7110)	0 ± 0	0 (0-0)	80% / 0%

Across all the sampling points, hands dried with paper towels showed zero colonies on all four media used. Hands dried using the electric hand dryer showed detectable total viable count and yeast/mould counts in 16 out of 20 samples (80%), 3 out of the 20 samples showed counts for coliforms (15%), and there were no counts for *E. coli* in all the samples.

Table 2 Hand Dryer-Associated Microbial Counts by Duration on Plate Count Agar(PCA), and Malt Extract Agar(MEA)

Duration of use	PCA mean ± SD (CFU/g)	MEA mean ± SD (CFU/g)	Total count mean ± SD (CFU/g)
2 days	0 ± 0	0 ± 0	0 ± 0
1 week	288 ± 91	100 ± 41	388 ± 122
2 weeks	410 ± 132	1125 ± 253	1540 ± 362
1 month	768 ± 131	1875 ± 427	2648 ± 565
2 months	1425 ± 299	5000 ± 324	6425 ± 567

Counts were categorized by duration for the electric hand dryer. The total viable and yeast/mould counts rose from 0 at 2 days to their highest at 2 months.

Table 3 Pearson Correlation Coefficient Among Microbial Parameters and Duration Score for Hand Dryer, with Spearman rho in Parenthesis for Plate Count Agar(PCA), Malt Extract Agar(MEA(, and Violet Red Bile Glucose Agar(VRBGA)

	PCA	MEA	VRBGA	Duration score
PCA	1.00	.96 (.98)	.10 (.19)	.92 (.96)
MEA	.96 (.98)	1.00	.05 (.22)	.91 (.98)
VRBGA	.10 (.19)	.05 (.22)	1.00	.14 (.11)
Duration score	.92 (.96)	.91 (.98)	.14 (.11)	1.00

The Pearson and Spearman correlation matrices computed on the dryer showed that total viable count and yeast and mould counts were strongly intercorrelated (Pearson r=0.96, Spearman rho=0.98). Both correlated strongly with duration score (Pearson r=0.92 and 0.91; Spearman rho=0.96 and 0.98) for total viable count and yeast/mould counts respectively.

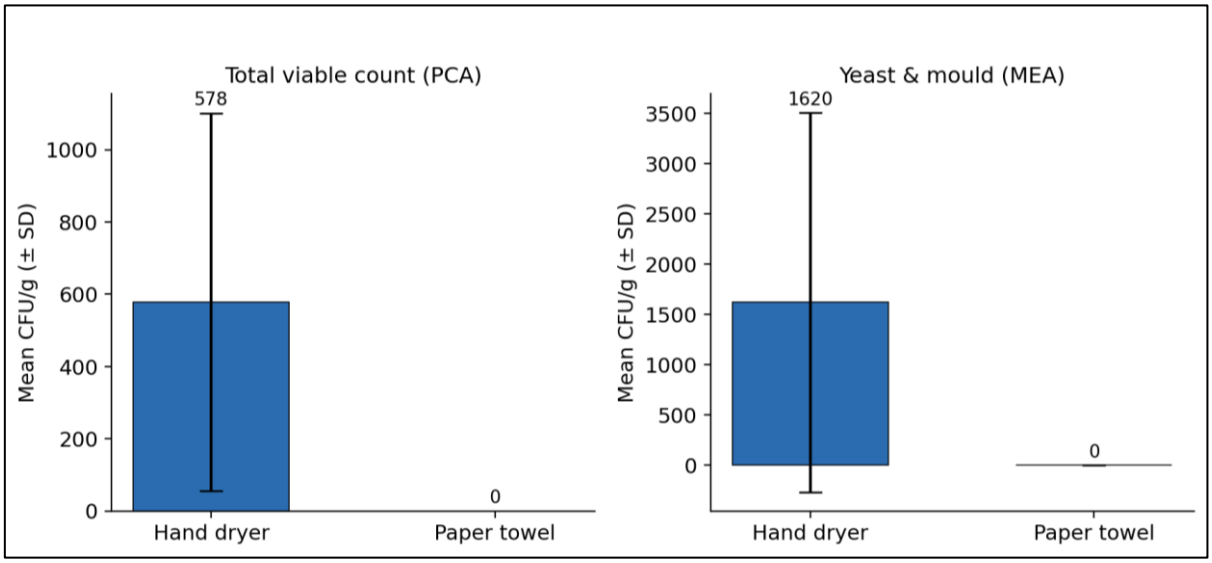


Fig 2 Mean ± SD Total Viable Count on Plate Count Agar (PCA) and Yeast/Mould Count on Malt Extract Agar (MEA) on Hands After Drying

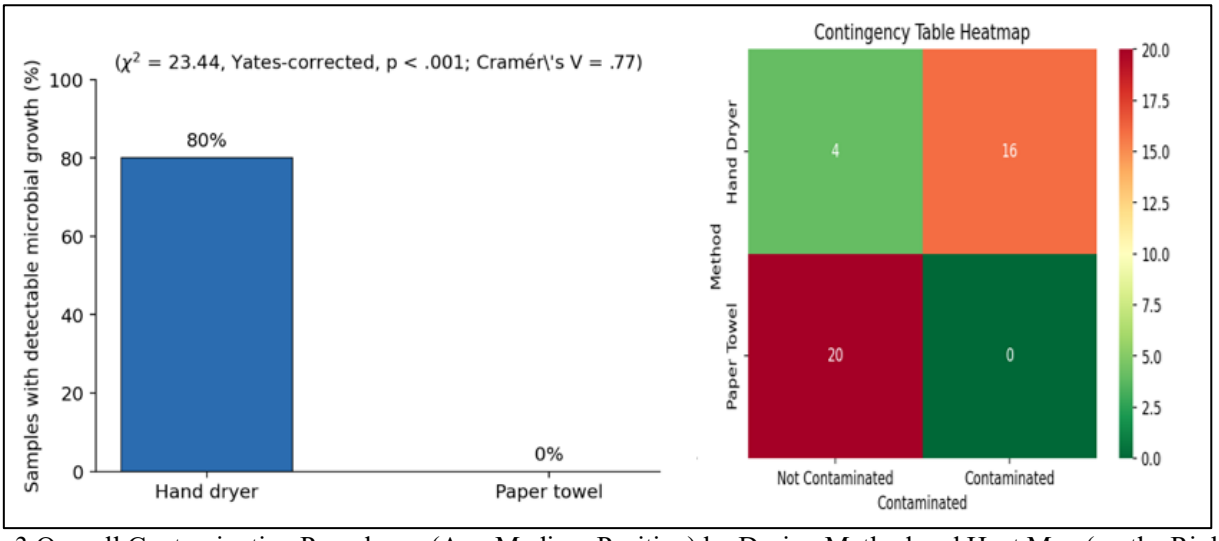


Fig 3 Overall Contamination Prevalence (Any Medium Positive) by Drying Method and Heat Map (on the Right)

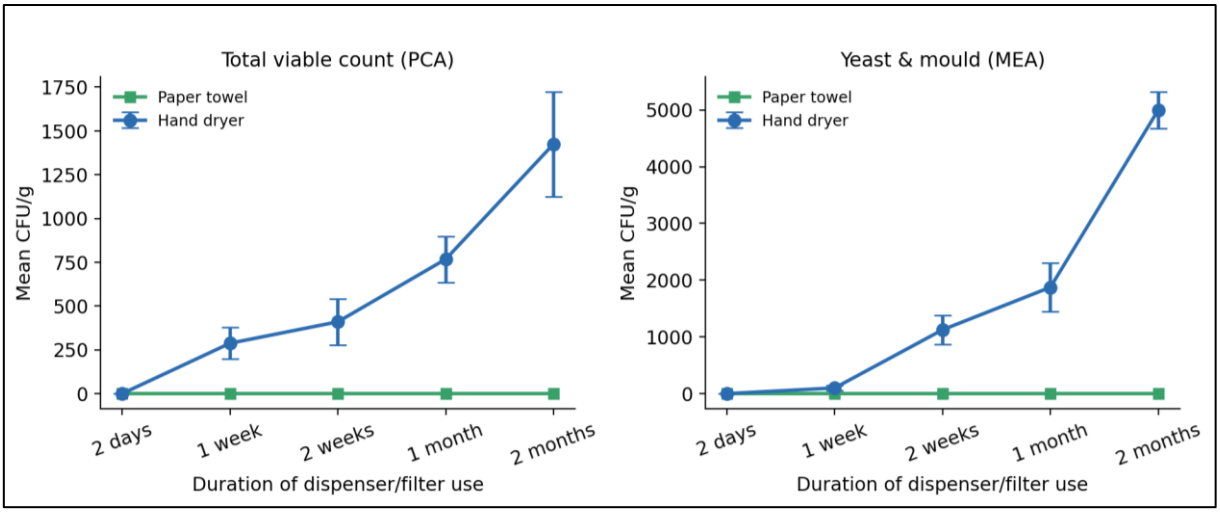


Fig 4 Contamination Trend of the Hand Drying Method with the Duration of Use on Plate Count Agar(PCA) and Malt Extract Agar(MEA)

➢ *Microbial Safety Between the Two Drying Methods (Electric Warm-Air Hand Dryer vs Paper Towel)*

From the microbial analyses, there was no growth from paper towel-dried hands throughout the experiment. Every paper towel sample, regardless of location or duration, showed a count of 0, which is not a marginal statistical difference but a categorical one. However, using the electric warm-air hand dryer to dry hands showed several thousand CFU/g.

Paper towel, as a hand drying method, removes residual moisture and any transient microorganisms it carries by direct absorption and mechanical friction. This happens without recirculating air drawn from the surrounding environment [36]. Electric warm-air dryers, in contrast, direct a continuous stream of air, drawn from the ambient washroom or facility atmosphere, through ducting, filters, and nozzles onto the hand surface. Any organism resident on these internal surfaces or suspended in the entrained air is potentially deposited back onto the hands during the drying process [37]. Prior comparative work has consistently found that warm air and jet air dryers disperse substantially more bacteria into the surrounding air and onto the hands of the user than paper towels, and this dispersal effect scales with air velocity and dryer design [37], [38], [39]. Results from this study under routine operating conditions at a working food processing facility, rather than a controlled laboratory chamber, extend this evidence base to an industrial hand-hygiene checkpoint in which humidity and residual moisture from adjacent washing and production activity may favor microbial persistence within the electric warm-air hand dryer.

Mann-Whitney comparisons confirmed that hands dried with the electric warm-air dryer had significantly higher total viable count, yeast/mould count, and total count than hands dried with paper towels, with large effect sizes across all comparisons ($U=360$, $p<0.001$, $r = -0.80$ for PCA, MEA, and total count). This pattern was the same for the two sampling locations (entry protocol area: $U=90$, $p=0.00075$, $r = -0.80$; Washroom: $U=90$, $p=0.00075$, $r = -0.80$), indicating that the method effect was not driven by a single sampling point. Coliform counts were higher on average in the electric warm-air hand dryer group but showed no significant difference in the pooled values ($U=230$, $p=0.081$, $r = -0.15$), reflecting the low overall detection frequency. E. coli counts were zero throughout both sampling groups and were therefore not statistically testable. When all four media were grouped into a single binary outcome (any detectable growth versus none), it showed that 16 out of the 20 dryer samples (80%) were contaminated, compared with 0 out of the 20 paper towel samples (0%). A chi-square test of independence with Yates' continuity correction confirmed that this difference was highly significant and large in magnitude (chi-square (1)=23.44, $p<0.001$, Cramer's $V=0.77$). These results are illustrated in Fig. 3. These findings indicate that the electric warm-air hand dryer can be safely used as a prerequisite programme for food safety system management when the filters are changed after two days of continuous use. However, this frequent filter change may not be practical in many settings, and it will also not be cost-effective. The paper towel is a safer and more reliable method for hand drying among food handlers to prevent contamination and cross-contamination.

➢ *Duration-Dependent Contamination*

From the laboratory analysis and results, it was observed that there was a rise in both total viable count and yeast/mould count as the duration of usage of the electric warm-air hand dryer increased after the filter was changed. A freshly installed microbiologically verified filter began at zero recoverable counts. After two months of continuous use, the mean count for yeast/mould rose to 5,000 CFU/g, which exceeds the threshold set by the Ghana Standards Authority of 1,000 CFU/g. This threshold in particular is used because no specific recognized standard exists for microbial limits on hands. However, manufactured food is required not to exceed a yeast/mould count of 1,000 CFU/g [40]. This high yeast/mould value may result from progressive biofilm colonization of the moist, nutrient-enriched internal surface of the hand dryer. This can cause initially sparse microbial populations from ambient air to accumulate and proliferate [41]. Restricted to the electric warm-air dryer, Kruskal-Wallis tests showed a significant

effect of duration on total viable count ($H(4)= 17.73$, $p=0.0014$, $\varepsilon^2=0.92$). The effect of duration on yeast/mould count was also significant ($H(4)=18.22$, $p=0.0011$, $\varepsilon^2=0.95$). Spearman's correlation confirmed a strong positive (near-monotonic) association between duration score and CFU count for total viable count ($rho=0.96$, $p<0.001$) and yeast/mould ($rho=0.98$, $p<0.001$), as shown in Table 3. From an operational standpoint, this study does not frame the electric warm-air hand dryer as a fixed-risk device, but as a system whose microbiological burden is a function of time.

Only the one-week (mean 100 CFU/g) and two-days (no growth) durations fell below the 1,000 CFU/g threshold. The total viable counts were lower than the GSA standard of 100,000 CFU/g [40] throughout. However, the one-week result of 100 CFU/g is not entirely safe since these microbes proliferate under ideal conditions that support their growth. The best handwashing and drying should eliminate all microbes on the hands, as observed over the two-day duration. With the paper towels, duration does not affect microbial load. This was evident in the results, showing no counts throughout.

➢ *Washroom-Specific Coliform Detection*

Total coliforms were detected only in dryer samples collected in the washroom over one-month and two-week durations (time points). It can therefore be argued that coliform contamination is not a device-intrinsic, but environmental in origin. This is because samples were taken for the same device at the same duration for the entry protocol area, which showed no coliform growth throughout. The detected coliforms from the washrooms, however, showed a weak correlation to duration ($r=0.14$). This might be because the washroom air entrained by the dryer periodically carries enteric organisms aerosolized from toilet flushing. This phenomenon has been directly demonstrated for electric dryers in the immediate aftermath of a flush [42], [43], [44], [45]. The dryer in this regard functions less as a reservoir for coliforms and more as an intermittent sampler and redistributor of ambient washroom bioaerosols. The absence of any *E. coli* even in coliform-positive samples shows that the contamination is environmental rather than a strictly faecal source. Total coliforms include a range of non-faecal, soil and water-associated genera that are common in washroom environments [4], [46], [47], [48].

➢ *Operational and Food Safety Implications*

First, the overall contamination prevalence observed for the electric warm-air hand dryer is a food safety issue. 80% of hands dried using the hand dryer carried detectable microbial growth on at least one of the media used, against 0% for the paper towels. This difference is both statistically large (Cramer's $V=0.77$) and directly interpretable by a non-statistical audience. Regulatory and guidance frameworks for food handling treat hand hygiene, including drying, as a prerequisite programme (PRP), which underpins a facility's HACCP-based food safety management systems (FSMS). The Codex Alimentarius Commission's General Principles of Food Hygiene and the European Union's Regulation (EC) No 852/2004 on the hygiene of foodstuffs form part of these regulatory frameworks. A hand-drying step that reintroduces microbes (contamination) right before food handlers enter the production floor stops being a minor convenience and becomes a food safety issue [48], [49], [50], [51], [52], [53], [54]. The handwashing, including the hand-drying step, should serve as a control point.

➢ *Limitations*

Although this study provides a microbial safety comparison between paper towel and electric warm-air hand dryer as a hand-drying method, it did not take into account different dryer modules and brands. The study was also specific to one food manufacturing facility.

Future work should incorporate a confirmatory test and research across various food handling facilities.

IV. CONCLUSION

This study found that the use of paper towel and electric warm-air dryer for hand drying is not microbiologically equivalent at a food processing facility's hand hygiene checkpoint. Paper towels returned every hand swab to a state indistinguishable from a sterile control across 20 samples, two locations, and five durations of dispenser use. The electric warm-air dryer returned significantly elevated total viable count, yeast/mould count, and total count that rose in a strong, near-monotonic fashion with duration since filter installation ($rho = 0.96$-0.98; a linear time-score model explained 84% of the variance in total count, at a rate of roughly 1,511 CFU/g per duration step). Collapsed to a single presence/absence outcome, overall contamination prevalence was 80% for the dryer against 0% for paper towels (Yates-corrected chi-square $= 23.44$, $p < .001$, Cramer's $V = 0.77$), and this conclusion converged across parametric and non-parametric tests alike. Total coliforms were detected sporadically and only in the washroom-located dryer, correlating only weakly with total viable count, yeast/mould, or duration, consistent with an intermittent, environmentally sourced rather than device-intrinsic contribution. *E. coli* was not recovered under any condition tested. Taken together, these findings support two evidence-based recommendations consistent with HACCP-based prerequisite programme logic: that paper towels remain the more conservative choice for hand drying at safety-critical entry protocol areas and other food handling zones, and that where electric warm-air dryers are retained, a filter or unit servicing schedule informed by the duration-count relationship identified here, rather than by visual inspection alone, is a reasonable and readily implementable safeguard. Replication across additional dryer units, installation sites, and with direct genus-level identification of recovered coliforms would strengthen the generalizability of both conclusions.

➢ *Credit Authorship Contribution Statement*

Richard Selasi Freeman: Writing-review & editing, Writing-original draft, Validation, Methodology, Formal analysis, Data curation, Investigation, Visualization, Data analysis, Project coordination. Audrey Ameley Armah:

Writing-review & editing, Writing-original draft, Validation, Methodology, Formal analysis, Data curation. Eric Adom: Writing-review & editing, Methodology. Anita Owusu Asantewaa: Writing-review & editing, Methodology. Joseph Kofi Senade: Writing-review & editing, Data analysis. David Annor Sakyi: Writing-review & editing, Methodology.

- *Declaration of Generative AI and AI-Assisted Technologies in the Writing Process*

  No Generative AI tool was used

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- *Declaration of Competing Interest*

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

- *Data Availability*

  Data will be made available on request.

REFERENCES

[1.] R. A. Ataee, M. H. Ataee, A. M. Tavana, and M. Salesi, "Bacteriological aspects of hand washing: a key for health promotion and infections control," International journal of preventive medicine, vol. 8, no. 1, p. 16, 2017.

[2.] M. Kirchner et al., "The role of hands in cross-contamination of kitchen surfaces during meal preparation," American journal of infection control, vol. 51, no. 11, pp. A44--A57, 2023.

[3.] M. Erdoğan and Ş. Pamuk, "Microbial contamination in food, food-handlers' hands and surfaces and evaluation of contamination sources by the similarity between isolates," Ankara Universitesi Veteriner Fakultesi Dergisi, vol. 67, no. 1, pp. 73–79, 2020, doi: 10.33988/auvfd.599367.

[4.] D. Fonn and L. Jones, "Hand hygiene is linked to microbial keratitis and corneal inflammatory events," Contact Lens and Anterior Eye, vol. 42, no. 2, pp. 132–135, 2019.

[5.] D. M. Conover and K. E. Gibson, "A review of methods for the evaluation of handwashing efficacy," Food Control, vol. 63, pp. 53–64, 2016, doi: 10.1016/j.foodcont.2015.11.020.

[6.] D. W. Kanwal, D. C. A. Edwin, D. A. Ahmad, and U. Rafaqat, "Creating Awareness about Cleanliness and Hand Hygiene among Students at Primary Level," J Manag Pract Humanit Soc Sci, vol. 6, no. 1, pp. 40–48, 2022.

[7.] Y. T. Maigari, "The relevance of the Islamic principles on cleanliness to contemporary times: focus on hand washing," Ilorin Journal of Religious Studies, vol. 6, no. 2, pp. 91–104, 2016.

[8.] B. Satish Kumar et al., "Importance of understanding the need of personal hygiene: A comprehensive review," Int J Res Pharm Pharm Sci, vol. 5, pp. 56–61, 2020.

[9.] J. Wolf et al., "Handwashing with soap after potential faecal contact: global, regional and country estimates," International journal of epidemiology, vol. 48, no. 4, pp. 1204–1218, 2019.

[10.] B. C. Mbakaya, F. W. Kalembo, and M. Zgambo, "Use, adoption, and effectiveness of tippy-tap handwashing station in promoting hand hygiene practices in resource-limited settings: a systematic review," BMC public health, vol. 20, no. 1, p. 1005, 2020.

[11.] R. Aunger, K. Greenland, G. Ploubidis, W. Schmidt, J. Oxford, and V. Curtis, "The determinants of reported personal and household hygiene behaviour: A multi-country study," PloS one, vol. 11, no. 8, p. e0159551, 2016.

[12.] M. Moffa, R. Cronk, L. Fleming, and J. B. Tidwell, "Measuring household hygiene access and handwashing behaviors: Findings from 14 low-and middle-income countries," International Journal of Hygiene and Environmental Health, vol. 237, p. 113810, 2021.

[13.] A. Hadaway, "Handwashing: clean hands save lives," Journal of Consumer Health on the Internet, vol. 24, no. 1, pp. 43–49, 2020.

[14.] H. Allam, M. Al-Batanony, A. Seif, and E. Awad, "Hand Contamination among Food Handlers," British Microbiology Research Journal, vol. 13, no. 5, pp. 1–8, 2016, doi: 10.9734/bmrj/2016/24845.

[15.] P. Dudeja and A. Singh, "Food handlers," in Food safety in the 21st century, Elsevier, 2017, pp. 269–280.

[16.] M. M. Tadele, A. Dagnaw, and D. Alamirew, "Food handling practice and associated factors among food handlers in public food establishments of Ethiopia: A systematic review and meta-analysis," BMJ Open, vol. 12, no. 3, pp. 1–8, 2022, doi: 10.1136/bmjopen-2021-051310.

[17.] J.-C. Augustin et al., "Contribution of foods and poor food-handling practices to the burden of foodborne infectious diseases in France," Foods, vol. 9, no. 11, p. 1644, 2020.

[18.] S. P. Tappes, D. C. C. Folly, G. da Silva Santos, C. de Aquino Feijó, and M. Pustiglione, "Food handlers and foodborne diseases: grounds for safety and public and occupational health actions," Revista Brasileira de Medicina Do Trabalho, vol. 17, no. 3, p. 431, 2020.

[19.] A. Robinson, H. J. Lee, J. Kwon, E. Todd, F. P. Rodriguez, and D. Ryu, "Adequate hand washing and glove use are necessary to reduce cross-contamination from hands with high bacterial loads," Journal of food protection, vol. 79, no. 2, pp. 304–308, 2016.

[20.] M. Ebert, "Hygiene principles to avoid contamination/cross-contamination in the kitchen and during food processing," in Staphylococcus aureus, Elsevier, 2018, pp. 217–234.

[21.] S. J. Pitt, S. L. Crockett, and G. M. Andreou, "The contribution of hand drying in prevention of transmission of microorganisms: comparison of the

efficacy of three hand drying methods in the removal and distribution of microorganisms," Journal of Infection Prevention, vol. 19, no. 6, pp. 310–317, 2018.
[22.] R. Vandegrift et al., "Cleanliness in context: reconciling hygiene with a modern microbial perspective," Microbiome, vol. 5, no. 1, p. 76, 2017.
[23.] N. Lotfinejad, A. Peters, E. Tartari, C. Fankhauser-Rodriguez, D. Pires, and D. Pittet, "Hand hygiene in health care: 20 years of ongoing advances and perspectives," The Lancet infectious diseases, vol. 21, no. 8, pp. e209--e221, 2021.
[24.] H. K. Lee, H. Abdul Halim, K. L. Thong, and L. C. Chai, "Assessment of food safety knowledge, attitude, self-reported practices, and microbiological hand hygiene of food handlers," International journal of environmental research and public health, vol. 14, no. 1, p. 55, 2017.
[25.] J. Holah, H. L. M. Lelieveld, and D. Gabric, Handbook of hygiene control in the food industry. Woodhead Publishing, 2016.
[26.] C. Huang, W. Ma, and S. Stack, "The Hygienic Efficacy of Different Hand-Drying Methods: A Review of the Evidence," Mayo Clin. Proc., vol. 87, no. 8, pp. 791–798, Aug. 2012, doi: 10.1016/j.mayocp.2012.02.019.
[27.] B. C. Britton, I. Sarr, and H. F. Oliver, "Enterobacteriaceae, coliform, yeast, and mold contamination patterns in peanuts compared to production, storage, use practices, and knowledge of food safety among growers in Senegal," International journal of food microbiology, vol. 360, p. 109437, 2021.
[28.] S. A. 'Ainaa' Idris, M. M. Hanafiah, M. Ismail, S. Abdullah, and M. F. Khan, "Laboratory air quality and microbiological contamination in a university building," Arabian Journal of Geosciences, vol. 13, no. 13, p. 580, 2020.
[29.] A. H. Dinço\uglu, Z. Çal\i\cskan, and G. Gürcan, "Determination of the Hygiene Quality of Food Workers, Equipment, Surface Areas, and Ambient Air in Mass Catering Places," Current Perspectives on Health Sciences, vol. 6, no. 1, pp. 31–38, 2025.
[30.] C. O. R. Okpala and I. M. Ezeonu, "Food Hygiene/Microbiological Safety in the typical Household Kitchen: Some basic 'must knows' for the general public," J. Pure Appl. Microbiol., vol. 13, no. 2, pp. 697–713, 2019, doi: 10.22207/JPAM.13.2.06.
[31.] E. Akanele, S. Mgbo Otu Chukwu, and C. Mary Ahudie, "Microbiological Contamination Of Food: The Mechanisms, Impacts And Prevention," INTERNATIONAL JOURNAL OF SCIENTIFIC & TECHNOLOGY RESEARCH, vol. 5, no. 03, 2016, [Online]. Available: www.ijstr.org
[32.] L. Boschetti, S. V Stehman, and D. P. Roy, "A stratified random sampling design in space and time for regional to global scale burned area product validation," Remote sensing of environment, vol. 186, pp. 465–478, 2016.
[33.] R. Iliyasu and I. Etikan, "Comparison of quota sampling and stratified random sampling," Biom. Biostat. Int. J. Rev, vol. 10, no. 1, pp. 24–27, 2021.
[34.] T. D. Nguyen, M.-H. Shih, D. Srivastava, S. Tirthapura, and B. Xu, "Stratified random sampling from streaming and stored data," Distributed and Parallel Databases, vol. 39, no. 3, pp. 665–710, 2021.
[35.] F. Nyimbili and L. Nyimbili, "Types of purposive sampling techniques with their examples and application in qualitative research studies.," 2024.
[36.] K. Redway and S. Fawdar, "European Tissue Symposium Prepared by," Symposium A Quarterly Journal In Modern Foreign Literatures, no. November, 2008.
[37.] E. L. Best, P. Parnell, and M. H. Wilcox, "Microbiological comparison of hand-drying methods: the potential for contamination of the environment, user, and bystander," Journal of Hospital Infection, vol. 88, no. 4, pp. 199–206, 2014.
[38.] P. T. Kimmitt and K. F. Redway, "Evaluation of the potential for virus dispersal during hand drying: A comparison of three methods," Journal of Applied Microbiology, vol. 120, no. 2, pp. 478–486, 2016, doi: 10.1111/jam.13014.
[39.] E. Margas, E. Maguire, C. R. Berland, F. Welander, and J. T. Holah, "Assessment of the environmental microbiological cross contamination following hand drying with paper hand towels or an air blade dryer," Journal of Applied Microbiology, vol. 115, no. 2, pp. 572–582, 2013.
[40.] Ghana Standards Authority, "Microbiological analysis of foods - Sampling plans and microbiological criteria (GS 955:2019, 3rd ed.)," 2019.
[41.] L. del C. Huesca-Espitia, J. Aslanzadeh, R. Feinn, G. Joseph, T. S. Murray, and P. Setlow, "Deposition of bacteria and bacterial spores by bathroom hot-air hand dryers," Applied and Environmental Microbiology, vol. 84, no. 8, pp. e00044--18, 2018.
[42.] J. Cooper, "the Role of Hospital Toilets in Microbial Dissemination and," no. August, 2017.
[43.] D. L. Johnson, K. R. Mead, R. A. Lynch, and D. V. L. Hirst, "Lifting the lid on toilet plume aerosol: A literature review with suggestions for future research," American Journal of Infection Control, vol. 41, no. 3, pp. 254–258, 2013, doi: 10.1016/j.ajic.2012.04.330.
[44.] K. McLennan, "Electric Hand Dryers as a Source of Bacterial," British Columbia Institute of Technology, 2006.
[45.] K. A. N. Aithinne, Bowl Water Clearance and Bioaerosol Generation in a Toilet Contaminated with Clostridium Difficile Spores. The University of Oklahoma Health Sciences Center, 2017.
[46.] N. Da Silva, M. H. Taniwaki, V. C. A. Junqueira, N. Silveira, M. M. Okazaki, and R. A. R. Gomes, Microbiological examination methods of food and water: a laboratory manual. CRC Press, 2018.

[47.] G. E. Flores et al., “Microbial biogeography of public restroom surfaces,” PloS one, vol. 6, no. 11, p. e28132, 2011.
[48.] N. D. Fortin, “Global governance of food safety: the role of the FAO, WHO, and Codex Alimentarius in regulatory harmonization,” in Research handbook on international food law, Edward Elgar Publishing, 2023, pp. 227–242.
[49.] G. Rusconi, “Food safety and policy in the European Union,” in International food law and policy, Springer, 2017, pp. 451–483.
[50.] C. O. F. Practice, “I N T E R N AT I O N A L F O O D S TA N D A R D S GENERAL PRINCIPLES,” 2022.
[51.] M. Hasani et al., “Development of an online food safety toolbox based on the Codex Alimentarius General Principles of Food Hygiene: engaging users through mapping, chunking, and learning-by-asking,” Food Quality and Safety, vol. 8, p. fyae030, 2024.
[52.] T. H. E. Commission, O. F. The, and E. Communities, “(Acts whose publication is obligatory),” vol. 2002, no. March, pp. 1–13, 2001.
[53.] W. H. O. (WHO et al., “Process: hygiene, traceability and recall,” International food law and policy, vol. 42, no. 2, pp. 451–483, 2020, doi: 10.1016/j.ajic.2012.04.330.
[54.] W. H. O. (WHO and others, “General principles of food hygiene,” 2023.