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CARE PRACTICES FOR ELIMINATING MICROBIAL CONTENT IN HOUSEHOLD BATH TOWELS

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ABSTRACT

Purpose: This study evaluates the impact of different washing treatments and drying methods on bacterial and fungal contamination in bath towels used by students.
Design/Methodology/Approach: Using experimental procedures, sampled towels were subjected to various washing treatments, that is, no washing, washing with soap, washing with disinfectant, and washing with soap followed by a disinfectant rinse. They were then dried indoors (room drying) or outdoors (sun drying). Bacterial and fungal loads were measured using colony-forming units (CFU). The statistical software employed to analyse the data collected was the Statistical Package and Service Solution (SPSS) for Windows version 26.
Findings: Results show sun drying significantly reduces bacterial and fungal contamination compared to room drying across all washing treatments. The most effective reduction in microbial load was achieved by combining soap washing, disinfectant rinsing, and sun drying, which reduced bacterial load to as low as $0.97 \pm 0.26 \times 10^6$ CFU/mL and fungal load to $0.593 \pm 0.217 \times 10^6$ CFU/mL. T-test analysis confirmed room and sun-drying differences were statistically significant ($p< 0.05$).
Research Limitation: The study's sample size was limited, potentially affecting the generalizability of the findings to a larger population. In addition, it focused on conventional household care practices and did not explore advanced or industrial cleaning techniques, which might yield different results in microbial elimination.
Practical Implication: These findings emphasise the critical role of sun drying in enhancing towel hygiene and minimising microbial contamination, especially when combined with proper washing methods.
Social Implication: Improved towel care can reduce infection spread, benefiting households and communities, especially vulnerable groups like the elderly and children. Public awareness campaigns can drive behavioural changes in hygiene.
Originality/Value: This study advances knowledge by identifying effective, accessible care practices for reducing microbial contamination in household bath towels. This contributes to improved hygiene, public health, and foundational research for domestic textile hygiene. It offers insights into how hygiene practices affect public health.

Keywords: *Bath towels. disinfectant. drying. microbial load. washing*

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INTRODUCTION

Infection outbreaks such as gastrointestinal (GI) infections, respiratory infections (RT), and skin, wound and eye infections in the home and other life settings continue to put a heavy burden on the health and future of the global community (Bloomfield, Exner, Signorelli, Nath, & Scott, 2011). According to Bloomfield et al. (2011), governments concerned with their citizens' well-being are under pressure to fund healthcare and look for strategies to reduce health spending. They noted that hygiene is one of the recognised methods to reduce the infectious disease burden, and inadequate infection control at home can undermine the fight against infectious diseases.

The spread of infections occurs at different points, sometimes making it difficult to trace the source. Cloth towels are commonly overlooked household items where microbes often flourish and spread (Jolade, 2017). Bath towels and sponges serve as vehicles for transporting a huge variety of microbes, and towels, in particular, have been noted to be agents of disease spreading (Abrams, 2017). Research has found that towels provide the perfect environment for bacteria and microorganisms growth since they are usually damp, absorbent and dried in dark bathrooms (Abrams, 2017; Jolade, 2017), which may pose health risks for an individual who has cuts or dry skin that can allow microbes into his/her system (Abrams, 2017). The types of bacteria noted to be common on household cloth towels include faecal coliform bacteria, which facilitates the growth of pathogenic microbes like Escherichia coli, known as E. coli (Dovey, 2016). In addition, pathogenic bacteria such as Citrobacter and Enterobacter are also found in household towels (Sifuentes et al., 2013). This suggests that individuals care for such items to reduce or eliminate microbes.

Among the common hygiene items individuals use to help improve general body care is bath towels and sponges. It is noted that there are microbes on the human body that may be transferred to these items, and depending on the conditions they are exposed to in the environment, they may multiply the microbes. These microbes may spread and cause infections in humans using the care items (sponges and towels) (Downes *et al.*, 2008). As Bloomfield et al. (2011) indicated, dirty clothing items, such as bath towels, are likely to shelter microbes, and using them can cause skin infections. Dovey (2016) indicated that bath towels are the most germ-infected items in our homes because most individuals may not handle them as they should. Tambekar *et al.* (2009), as cited in Twumwaa et al. (2020), indicated that about 80% of illnesses that affect humans in most developing countries are related to poor home environment and personal hygiene. This could be attributed to using infectious household linens such as bath towels. To have and maintain a healthy life, individuals have to maintain a high level of personal hygiene (Abdul & Hassan, 2012), which includes proper care of the items we use to assist in the general cleaning of our bodies. General observation by researchers and authors such as Twumwaa *et al.* (2020) shows that individuals usually use their bath towels for a week or more before washing them and do not observe recommended practices, which causes the growth of different microbes on bath towels.

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For instance, Twumwaa *et al.* (2020), found that most of the students they used for their study on "Toothbrush and towel handling and their microbial quality: the case of students of the university for development studies, Nyankpala campus, Ghana" did not observe recommended towel handling practices. A number of the students also dried their towels inside their rooms with the idea that doing so would help reduce the rate of the towels getting dirty due to dust settling on them. Others also held some superstitious beliefs about drying towels outside their rooms. There were, however, some students from Twumwaa et al. (2020) work who dried their towels in the sun with the mind that the practice could kill any bacteria and prevent odour, as indicated by Haider (2018), and others do not often wash their towels. It is recommended that towels should be washed every four to five days of use (Dovey, 2016). Other authors indicate washing towels three to four times a week (Bradford, 2018; Sturt, 2015). Laundering or washing (hand or machine) is one of the effective ways to control pathogenic micro-organisms in clothes (Abney et al., 2021). Some factors, however, influence the effective control or removal of microbes from clothes. The factors include usage, season, type of detergent used in washing, wash temperature, water quality and drying procedure (Abney et al., 2021).

This study seeks to determine suitable care procedure(s) that can help eliminate or reduce the microbial load on bath towels humans use to care for their bodies. These towels are cleaned using washing detergents, disinfectants, and varying drying methods.

LITERATURE REVIEW

Microbial Load of Textiles

Textiles, such as bed linens, pyjamas and uniforms, can be reservoirs for infectious agents like bacteria, viruses and fungi (Freney, & Renaud, 2012). These textiles can become contaminated during use and laundering (Fijan & Šostar-Turk, 2012; Bockmühl, Schages & Rehberg, 2019). A study in a hospital found that clean bed linen samples were contaminated 55% of the time before even coming into contact with a patient, with a mean count of 3 cfu/25 cm. The microbial load of textiles is impacted by the transfer of various microbial species from different sources. The most significant contributor is the human body, with skin contact transferring microorganisms from the skin and mucosal biota. This transfer is particularly noticeable in items like underwear and shirts, which come into direct contact with bodily excretions. Additionally, textiles like cleaning cloths, bed linen, and surgical textiles can be contaminated by dust, soil, food, and healthcare facilities (Bockmühl et al., 2019).

Research indicates that washing machines can serve as a source of microbial contamination. Biofilms are communities of microorganisms attached to surfaces, can form inside washing machines and act as reservoirs for pathogens. These pathogens can detach during the washing process and re-contaminate laundry. The microbial community composition on textiles undergoes a shift during laundering, moving from primary contaminants like skin bacteria to secondary contaminants that include biofilm-associated environmental bacteria and waterborne microorganisms (Bockmühl et al., 2019). Studies have reported that laundry items in healthcare

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environments, such as towels and sheets, can have a microbial burden of up to 104-106 cfu/cm2. The presence of microorganisms resistant to desiccation, like *Staphylococcus aureus*, is typical for healthcare settings (Bockmühl et al., 2019).

Several factors can influence the microbial load of textiles. Some key factors include the type of washing machine used. Front-loader machines, known for their water efficiency, for example, can retain residual water, creating an environment conducive to microbial growth and potential cross-contamination. This issue is less prominent in top-loader machines, which drain more effectively (Abney et al., 2021).

The sources of microbes underscore the public health implications of microbial contamination in textiles, particularly for vulnerable individuals (Quao et al., 2024). According to Bockmühl et al. (2019), textiles can act as vectors for transmitting infections, posing a risk to various groups, including Healthcare workers, Patients in healthcare facilities, Infants, Elderly people, Pregnant women and People with compromised immune systems. Studies have documented outbreaks linked to contaminated laundry, with bacterial pathogens like *Bacillus cereus*, *Acinetobacter* spp., and *Aspergillus flavus* being frequent culprits. In healthcare settings, inadequate laundry hygiene can contribute to healthcare-associated infections (HAIs) (Ayub et al., 2024). For instance, the spread of multidrug-resistant organisms like methicillin-resistant *Staphylococcus aureus* (MRSA) and extended-spectrum beta-lactamase (ESBL)-producing species through contaminated laundry is a growing concern (Ayub et al., 2024; Bockmühl et al., 2019).

Laundry Effectiveness in Microbial Reduction in Textiles

The main objective of laundering is to ensure hygienically clean textiles by effectively reducing microbial presence. This involves removing visible stains and soils and achieving a safe level of microorganisms on the fabric (Bockmühl et al., 2019). Various factors contribute to this hygienic cleanliness, including temperature, chemical inactivation, and physical removal.

Temperature

According to Bockmühl et al. (2019), temperature plays a crucial role in microbial reduction during laundering. Temperatures of 60°C or above are widely recognised for their ability to inactivate microorganisms, ensuring a high level of hygiene. However, a growing trend towards lowering washing temperatures to conserve energy can impact antimicrobial efficacy. Studies suggest temperatures above 50°C can significantly reduce a wide range of microorganisms, even without bleach (Bockmühl et al., 2019). For heat-resistant strains like *Enterococcus faecium*, high temperatures are still necessary for effective inactivation (Bockmühl et al., 2019). Lower temperatures can be partially compensated for by extending the wash cycle time or increasing the chemical component, such as using bleach-containing detergents**.** However, even with bleach, lower temperatures and shorter washing cycles may not achieve the desired antimicrobial effect, particularly for immunocompromised individuals (Bockmühl et al., 2019).

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Chemical Inactivation
The chemical composition of laundry detergents and additives significantly influences antimicrobial efficacy. Bleach is considered the most crucial component for antimicrobial activity. While chlorine bleach has been traditionally used in some regions, activated oxygen bleach (AOB) is more prevalent in others. Based on perborate or percarbonate, AOB releases hydrogen peroxide in aqueous solutions, requiring higher temperatures or bleach activators for optimal efficacy. Studies consistently show that AOB significantly enhances the antimicrobial efficacy of laundering, effectively reducing bacteria and viruses. However, complete inactivation, especially for non-enveloped viruses like Norovirus, is typically achieved only at temperatures above 60°C (Bockmühl et al., 2019).

Other chemical agents contributing to microbial reduction include:
- **Surfactants:** These primarily enhance cleaning efficacy by removing hydrophobic soil, indirectly aiding in the physical removal of microbial cells.
- **Quaternary ammonium compounds (QACs):** These increase antimicrobial activity, particularly against gram-positive bacteria. However, their use should be considered carefully as they may contribute to biocide and antibiotic resistance (Bockmühl et al., 2019).

Physical Removal
According to Bockmühl et al. (2019), the mechanical action of the washing machine plays a significant role in physically removing microbial cells from textiles. While the assumption of the mechanical impact on microbial reduction is mainly based on laboratory data, some studies support this notion. Factors influencing the mechanical action include:

- **Washing machine type and construction:** European households and industrial settings primarily use horizontal-axis washing machines, while vertical-axis machines are common in other regions. The type of machine likely influences the mechanical force applied during washing.
- **Liquor ratio:** Water to laundry ratio may also affect the efficiency of physical removal.

Other Contributing Factors
Additional factors impacting the antimicrobial performance of laundering include:

Microbial species: Different microorganisms exhibit varying susceptibility to temperature, chemical inactivation, and physical removal.

Soil type and amount: The presence of organic soil can impact the effectiveness of bleach and other antimicrobial agents.

Textile characteristics: Fabric composition, thickness, and weave can influence the ability of microorganisms to attach and persist on textiles, affecting their removal during laundering (Abney et al., 2021).

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Washing machine biofilm: Washing machines can harbour biofilms that may detach during washing, potentially contaminating laundry. These biofilms can also contribute to malodor formation (Bockmühl et al., 2019).

Drying: Drying temperature and duration contribute to the microbial reduction achieved during laundering. High-temperature drying reduces microbial numbers as an additional barrier to transmission and survival (Abney et al., 2021).

By appreciating the intricate interplay of these factors, individuals can ensure hygienically effective and safe laundering processes for their textiles. Continued research is essential to advance our understanding and optimise laundering practices for sustainability and infection control.

MATERIALS AND METHODS

The study employed an experimental design with laboratory testing to assess the microbial load of bath towels used by students.

Sample and Sampling Procedure

A purposive and convenient sampling technique was used to select fifty undergraduate female students living alone in hostels with built-in bathrooms. This was to avoid inconveniencing roommates when the individual was asked to dry the towel in the room. The fifty new bath towels were microbiologically examined, and those contaminated were treated. Each of the 50 participants selected was given one of the bath towels, 250 mL of antiseptic, and a bar of soap. Each of the 50 participants selected was asked to use and expose the bath towels to different treatments each week. However, only seventeen were regularly present for the research work.

The Collected towel samples were kept in containers and transported to the laboratory. At the laboratory, each towel was swabbed using sterilised swab sticks. This was done to pick specimens from the towels before and after exposure to care treatments. After each week, the towels were treated to ensure they were free from microbes and returned to them for the subsequent treatment. The data collection process spanned nine months. Further details on the test treatment are provided in Table 1.

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Table 1: Exposure of each bath towel sample by each selected individual to care treatments

Group	Care treatment Number/week	Care Treatment
A *Room Treatment*	1	Used for a week, unwashed, dried in the room after every use
	2	Used for a week, dried in the room after every use, washed with soap at the end of the week and dried in the room
	3	Used for a week, dried in the room after every use, rinsed with disinfectant at the end of the week and dried in the room
	4	Used for a week, dried in the room after every use, washed with soap and rinsed with disinfectant at the end of the week and dried in the room
B *Sun Treatment*	5	Used for a week, unwashed, dried in the sun after every use
	6	Used for a week, dried in the sun after every use, washed with soap at the end of the week and dried in the sun
	7	Used for a week, dried in the sun after every use, rinsed with disinfectant at the end of the week and dried in sun
	8	Used for a week, dried in the sun after every use, washed with soap and rinsed with disinfectant at the end of the week and dried in the sun

Sample Preparation, Inoculation and Incubation

The swabbed samples were kept in labelled test tubes containing 9 mL of tryptone soya broth while constantly swirling for five (5) minutes. Tenfold serial dilutions were performed for each processed sample. An aliquot of 1 mL of 10^{-6} dilutions was taken aseptically and inoculated on prepared Mannitol salt agar (MSA) and MacConkey agar plates for the isolation of *Staphylococcus aureus* and *Escherichia coli*, respectively. The inoculated plates were incubated for 24 hours at 37ºC for MSA and 44.5ºC for MacConkey agar, respectively.

Data Analysis and Presentation

The means of the microbial load of the bath towels exposed to different care conditions were determined. Inferential statistics (Independent Samples t-test at 0.05 alpha level) were employed to test the hypotheses and determine whether differences existed between and among the variables under study.

Ethical Clearance

Ethical clearance was sought from the University of Cape Coast Institutional Review Board. Standard tests were conducted at the laboratory to ensure quality measures.

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RESULTS AND DISCUSSION

Microbial Load of used towels before and after wash and drying treatments

The control group represents the baseline where the towels were neither used nor washed. As expected, the bacterial load is 0.0 for room and sun-drying conditions. The unwashed towel samples dried in the room have a very high bacterial load (177.3 ± 46.0 x10^6 CFU/mL), indicating significant bacterial contamination accumulation after use. However, the bacterial load for the sun-dried samples used but not washed is much lower (25.46 ± 8.25 x 10^6 CFU/mL) than room drying. Sunlight reduces bacterial growth on the used, unwashed towels (Table 2).

Table 2: Total bacteria load from bath towels dried in the room and the sun used by students

Method of Washing	Room Drying (x10^6 cfu/mL)	Sun Drying (x10^6 cfu/mL)
Control	0.0	0.0
Used and Unwashed	177.3±46.0[a]	25.46±8.25[a]
Washed with soap	92.8±15.1[ab]	3.39±1.48[b]
Washed with disinfectant	56.6±15.3[b]	10.69±4.81[ab]
Washed with soap and rinsed with disinfectant	104.66±9.95[ab]	0.969±0.26[b]

Mean Values with the same alphabet in a column are not significantly different.

To the samples washed with soap only and dried in the room, the results in Table 2 show that washing the towels with the soap reduces the bacterial load to 92.8 ± 15.1 x 10^6 CFU/mL, but there is still a significant bacterial presence. However, the bacterial load drops significantly to 3.39 ± 1.48 x 10^6 CFU/mL when the towels are washed with soap only and are dried in the sun, showing the effectiveness of sun drying in reducing bacterial contamination.

Concerning the samples washed with disinfectant, samples dried in the room have a lower bacterial load (56.6 ± 15.3 x 106 CFU/mL) than those washed with soap only. This shows that disinfectant has a more potent antibacterial effect. However, for sun drying, the bacterial load is 10.69 ± 4.81 x 10^6 CFU/mL, higher than soap + sun drying, but still a reduction compared to room drying, showing sun drying's contribution in reducing bacteria in the used towel samples.

For the towel samples washed with soap and rinsed with disinfectant, those dried in the room show a bacterial load of 104.66 ± 9.95 x 10^6 CFU/mL, higher than when only disinfectant is used. This suggests that combining soap and disinfectant does not offer better results than using disinfectant alone. However, the sun-dried samples show extremely low load (0.969 ± 0.26 x 10^6 CFU/mL) (Table 2), indicating that this is the most effective method for reducing bacterial contamination.

The results in Table 2 highlight the significant role of drying methods in controlling bacterial contamination on bath towels. Towels dried in the sun consistently had lower bacterial loads than indoors. Sunlight, which provides UV radiation and heat, acts as a natural disinfectant,

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considerably reducing bacterial load, even on unwashed towels. This shows the importance of sun drying as an additional step in maintaining hygiene in fabrics.

When comparing the effectiveness of washing methods, towels washed with soap followed by sun drying had a lower bacterial load than when disinfectant was used alone. However, combining soap and a disinfectant rinse yielded the best results when sun drying was applied, almost eliminating bacterial presence (Table 2). It is also evident that washing with disinfectant, whether the towels are dried indoors or outdoors, is more effective at reducing bacterial load than soap alone. Nevertheless, combining sun drying with washing methods, particularly disinfectant, produces the best outcomes.

Fungal Load of used towels before and after wash and drying treatments

Table 3 provides the mean total fungal load on bath towels used by students, whether indoors (room drying) or outdoors (sun drying). The fungal load is expressed as mean colony-forming units (CFU). Mean Values with the same alphabet in a column are not significantly different.

Table 3: The mean total fungal load from bath towels dried in the room and the sun used by students

Method of Washing	Room Drying ($x10^6$ cfu/mL)	Sun Drying ($x10^6$ cfu/mL)
Control	0.0	0.0
Used and Unwashed	208.8 ± 32.7^a	49.79 ± 4.34^a
Washed with soap	49.59 ± 8.33^b	2.929 ± 0.932^b
Washed with disinfectant	94.7 ± 41.8^b	2.079 ± 0.630^b
Washed with soap and rinsed with disinfectant	64.78 ± 6.44^b	0.593 ± 0.217^b

No fungal growth is observed in the control group, where towels were neither used nor washed, indicating no contamination (Table 3). The fungal load on used, unwashed towels is high at $208.8 \pm 32.7 \times 10^6$ CFU/mL, suggesting significant fungal contamination due to towel use. However, there is a sharp reduction in fungal load to $49.79 \pm 4.34 \times 10^6$ CFU/mL (Table 3) when these towels are dried in the sun, indicating that sunlight significantly inhibits fungal growth compared to room drying.

Table 3 also shows that under room drying, washing with soap reduces the fungal load to $49.59 \pm 8.33 \times 10^6$ CFU/mL, but there is still a notable presence of fungi. When the same towels are dried in the sun, the fungal load decreases drastically to $2.929 \pm 0.932 \times 10^6$ CFU/mL, highlighting the effectiveness of sun drying in reducing fungal contamination.

About the use of disinfectant, room drying resulted in a fungal load of $94.7 \pm 41.8 \times 10^6$ CFU/mL. This is higher than the fungal load after washing with soap, indicating that disinfectant alone may not be as effective for fungi. However, the fungal load drops to 2.079 ± 0.630 x 106 CFU/mL for sun drying, a slightly lower result than soap and sun drying. Sunlight still plays a significant role in reducing fungal load when used in conjunction with disinfectant.

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For towel samples washed with soap and rinsed with disinfectant, room-dried samples recorded a fungal load of 64.78 ± 6.44 x 10^6 CFU/mL, lower than when disinfectant is used alone but higher than soap alone. The fungal load recorded for sun dry samples is extremely low at 0.593 ± 0.217 x 10^6 CFU/mL, showing that this method, combined with sun drying, is the most effective for reducing fungal contamination.

The results in Table 3 indicate a clear difference in fungal contamination based on both washing methods and drying conditions. Room-dried towels consistently showed higher fungal loads across all methods, while sun-drying significantly reduced fungal contamination. This suggests that sunlight is a powerful antifungal agent, likely due to its UV radiation and heat inhibiting fungal growth. The extremely high fungal load in unwashed towels highlights the importance of regular washing, as fungal organisms can thrive on damp and frequently reused towels. Sun drying reduces fungal load, but washing is essential to remove the bulk of contamination. Washing towels with soap significantly reduces fungal load compared to unwashed towels, especially when followed by sun drying. The combination of soap and sun drying resulted in a very low fungal load (2.929 ± 0.932 x 10^6 CFU/mL), a highly effective strategy for maintaining towel hygiene.

Surprisingly, towels washed with disinfectant alone had higher fungal loads when dried in the room than those washed with soap. This may suggest that the disinfectant used was less effective at targeting fungal organisms or that its antifungal action diminishes over time. However, when disinfectant-washed towels were sun-dried, the fungal load dropped dramatically, illustrating the complementary role of sun drying. The combination of soap washing and disinfectant rinsing yielded the best results when towels were dried in the sun, with a very low fungal load of 0.593 ± 0.217 x 10^6 CFU/mL. This suggests that using cleaning agents and sun exposure is the most effective way to control fungal growth on towels. The infrequent washing of bath towels is suggested to play a role in the transmission of dermatitis (Abney et al., 2021).

In a study by Twumwaa et al. (2020), it was found that the infrequent washing of towels and the choice of disinfectant contributed to the high microbial count on student's towels. It was noted that most students were using only soap in washing towels without disinfectants, a procedure that Bloomfield et al. (2011) indicated as ineffective in killing bacteria. In this study, the disinfectant was introduced to determine how effective it is likely to eliminate bacteria on the used towels. The results presented in Table 2 under room drying confirm that even disinfectant alone is likely to aid in reducing the microbial content of a used towel.

Washing towels with soap and disinfectant, followed by sun drying, offers the most effective combination for reducing bacterial and fungal loads. When followed by sun drying, the combination of soap and disinfectant rinse nearly eliminates bacterial presence (0.97 CFU), indicating this is the most hygienic method for cleaning towels. Towels dried indoors retain higher bacterial and fungal contamination levels, even after washing with disinfectant. This suggests that drying towels indoors may create conditions conducive to microbial survival, possibly due to moisture retention and the lack of UV exposure.

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Generally, the most dominant microbial isolates identified through selective medium were *Escherichia coli*, *Pseudomonas erogenous Enterococcus, and yeast species (Table 4). The presence of these microorganisms is indicative of faecal contamination and yeast infection. Regularly cleaning* these bath towels will significantly improve hygiene.

Table 4: Dominant microbial isolates from the bath towels

Microbial Isolates	Room Drying (x10^6 cfu/mL)	Sun Drying (x10^6 cfu/mL)
Escherichia Coli	33.6±2.82	3.72±0.92
Staphylococci sp	28.1±3.59	8.68±1.97
Pseudomonas aeroginosa	21.3±3.41	1.2±0.48
Enterococcus	31.8±4.67	8.1±0.69
Yeasts	18.4±1.56	1.29±0.87

Comparison of wash and drying treatments on microbial load

There is a statistically significant difference between room drying and sun drying in unwashed towels, with sun drying leading to a lower bacterial load. Washing with soap and sun drying significantly reduces the bacterial load compared to room drying. Fungal load is significantly lower in sun-dried towels than in room-dried ones for unwashed towels, and sun drying leads to a significantly lower fungal load when towels are washed with soap than when room drying. Compared to drying in a room, bacterial load is significantly reduced when towels washed with disinfectant are sun-dried. Additionally, the combination of soap, disinfectant, and sun drying is highly effective at reducing bacterial load, as evidenced by the significant difference between room and sun drying (Table 5).

Table 5: Effect of drying conditions on the microbial load (x10^6 cfu/mL) after different washing methods

Treatment	N	Drying methods		T-Value	P-Value
		Room	Sun		
Used and Unwashed (Bacteria)	17	177±46	25.5±8.2	2.95	0.006*
Used and Unwashed (Fungi)	17	209±33	63.5±5.6	3.98	0.000*
Used and washed with Soap (Bacteria)	17	92.8±15	3.39±1.5	5.50	0.000*
Used and washed with Soap (Fungi)	17	49.6±8.3	2.93±0.93	5.20	0.000*
Washed with only disinfectant (Bacteria)	17	56.6±15	10.7±4.8	2.86	0.008*
Washed with soap and disinfectant (Bacteria)	17	104.7±10	0.97±0.26	10.41	0.000*

**Significant $p \leq 0.05$*

The results from the *t*-test (Table 5) show a clear and statistically significant difference between room drying and sun drying in terms of both bacterial and fungal loads on bath towels. Across all treatments, sun drying consistently reduces microbial contamination more effectively than room drying. The bacterial load for sun-dried samples is significantly lower, regardless of whether they are washed or unwashed. The heat from the sun quickly dries out the dampness

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from the bath towels to prevent a conducive environment that enables microorganisms to thrive (Møretrø et al., 2022). This highlights the importance of sun drying as a powerful method for reducing bacterial contamination due to its antimicrobial effects, likely from UV light exposure. For example, unwashed towels dried in the sun had a mean bacterial load of 25.5 CFU compared to 177 CFU for room drying, showing a substantial reduction. Similar trends are observed for fungal contamination, where sun drying significantly lowers the fungal load compared to room drying. This is particularly evident in unwashed towels, where fungal load decreased from 209 CFU with room drying to 63.5 CFU with sun drying.

CONCLUSION

These findings highlight the crucial role of sun drying in reducing both bacterial and fungal contamination on towels, even when different washing methods are used. Sun drying is particularly effective when combined with thorough washing using soap and disinfectant, making it the optimal approach for maintaining hygiene. The significant differences demonstrated by the t-test emphasise that room drying alone is insufficient for effectively reducing microbial loads.

These findings suggest that sun drying, combined with appropriate washing practices (especially disinfectants), is crucial for minimising bacterial contamination for students who may reuse towels frequently. This has practical implications in environments where hygiene is important, such as schools or shared living spaces, where proper towel care can prevent the spread of bacteria and reduce the risk of infection.

Implications For Research, Practice, And Society

Research on eliminating microbial content from household bath towels has key implications for public health, sustainability, and the economy. Proper towel care can reduce microbial contamination and prevent health risks like skin infections and respiratory issues. It also promotes innovation in antimicrobial textiles and fosters healthier household habits. Public health campaigns can raise awareness about the importance of towel hygiene, especially for vulnerable groups. The findings may lead to improved and sustainable cleaning methods for laundry services and home washing. Societally, better towel care can lower infection rates, reduce healthcare costs, and support environmental sustainability, driving demand for hygienic and eco-friendly products.

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