



## Research Note

## Microbiological Profiles of Disposable Gloves Used for Handling Ready-to-Eat Foods



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## ABSTRACT

Hand hygiene is critical in the food service industry. Bacteria can easily be transferred between different surfaces to food during food preparation. Common hygiene practices include hand washing and usage of disposable gloves. Food handlers are often susceptible to transferring pathogenic bacteria to food, thus proper hand hygiene can limit such transmission. While gloves serve as a barrier between bare hands and food, their misuse, including reuse or lack of change, can potentially result in cross-contamination, compromising on food safety. In Singapore, strict regulations and consumer perceptions have encouraged the use of gloves in food handling. This study assessed the microbiological profile of gloves used by food handlers across fifty randomly chosen food establishments, by swabbing samples from the inner and outer surfaces of gloves. Glove samples were also subjected to a watertight test to detect significant physical damage. The results revealed that gloves with damage exhibited significantly higher mean Standard Plate Counts (SPCs), suggesting the likelihood that damaged gloves promoted the transfer of bacteria. Damaged gloves used to handle certain types of food, like noodles and rice dishes, also had significantly higher mean SPC than those used for beverages and snacks. However, gloves without visible damage showed no significant difference in mean SPC across different food types. The study highlighted that proper glove use can help in preventing bacterial transfer and consequently, maintaining food safety. Regular glove changes, particularly when damaged, are imperative. The findings underscore the importance of proper glove use in conjunction with other hand hygiene practices to uphold food hygiene and safety standards.

Hand hygiene is paramount in the food service sector. Food preparation often requires a significant degree of handling which can transfer pathogenic bacteria from nondirect food contact surfaces to ready-to-eat food in direct food contact surfaces (Lynch et al., 2005; Mattick et al., 2003; Todd et al., 2010).

To mitigate the transfer of pathogenic bacteria to food through hands, the Codex Alimentarius (General Principles of Food Hygiene CXC 1-1969, 2023) advises food handlers to practice hand washing with soap and water followed by rinsing and drying in a manner that does not recontaminate the hands. Additionally, the 2022 FDA Food Code (U.S. Food and Drug Administration, 2022) provides guidance on proper hand-washing techniques for food employees to adhere to. Proper hand washing can effectively reduce the transmission of bacteria from hands to food and food contact surfaces (Michaels et al., 2004; Montville et al., 2002).

Another common practice worldwide in hand hygiene is the use of disposable gloves (Montville et al., 2002). Gloves are intended to serve

as a barrier between food and bare hands. Glove use is especially recommended when it comes to handling ready-to-eat (RTE) food in which there is no further processing step and hence, the prevention of cross-contamination is key in minimizing the number of microbes present in the food. Albeit important, contrary to the common perception of food handlers, the use of gloves is not a substitute to handwashing (Green et al., 2006). The Codex Alimentarius (General Principles of Food Hygiene CXC 1-1969, 2023) mentions that if gloves should be worn, appropriate measures should also be taken to ensure that gloves do not become the source of contamination. In a study by Lynch et al. (2005), the authors reported instances of reuse with used gloves and lack of glove change during food preparation (Lynch et al., 2005). Such practices can compromise hand hygiene and therefore, negatively impact food safety.

In Singapore, the use of bare hands in the handling of ready-to-eat (RTE) foods is prohibited (Environmental Public Health, 2023). Together with regulatory efforts and strict enforcement, consumers'

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**Table 1**  
Breakdown on the type of food handled by the 50 pairs of gloves samples prior to collection

Type of food handled	No. of gloves swabbed (interior)	No. of gloves swabbed (exterior)
Beverages	8	8
Noodle Dishes	15	15
Rice Dishes	16	16
Snacks	11	11
Total	50	50

perception too has shaped food handlers' behavior toward the use of gloves as a common practice (Knight et al., 2007), when handling food items.

Herein, we report the findings from our study to understand the microbiological profiles of gloves used by food handlers for elucidating proper glove use behavior in Singapore. The study determined the microbiological profiles of gloves by taking swab samples of the inner and outer surfaces of gloves used by food handlers of various food types for microbiological testing. In addition, the gloves were subjected to the watertight test to determine the presence of physical damage. Findings from the study would be useful to strengthen industry, and consumers' awareness on proper glove use and hand hygiene and ultimately, to inform relevant measures to continue upholding the food hygiene and safety standards in Singapore and elsewhere.

## Materials and methods

A total of fifty food establishments across Singapore were randomly recruited for the study (Table 1). Verbal permission was sought from the food handlers before the commencement of the investigation at the food premises. Sterile regular polyester swab w/ plastic applicators (COPAN™ Dry Swabs 159C) from Copan Diagnostics Inc. (California, United States), were used to swab the entire surfaces of the inner ( $n = 50$ ) and outer ( $n = 50$ ) surfaces of gloves. After swabbing, the applicators and gloves were placed into individual sterile bags and transported to the laboratory in cooler bags for the following tests. The material of the gloves was identified based on the manufacturer's information provided on the glove box purchased by the respective food establishments.

**Sample preparation** Sterile regular polyester swab w/ plastic applicators taken from the interior and exterior of gloves were suspended in 9 mL of Butterfield's phosphate buffer solution for the following microbiological tests.

**Standard plate count (SPC)** One mL of 10-fold diluted samples was inoculated onto a Petrifilm Aerobic Plate Count (3M, Minnesota, United States) and evenly distributed using a spreader. The Petrifilm was then incubated at 37°C for 48 h. The quantification of SPC was performed according to the methodology detailed in Oh et al. (2020).

**Detection and quantification of *Escherichia coli* (*E. coli*)** One mL of 10-fold diluted sample was inoculated onto a Petrifilm *E. coli*/Coliform Count Plate 3M. The Petrifilm was then incubated at 37°C for 48 h. The detection and confirmation of *E. coli* were performed according to the methodology detailed in Oh et al. (2020).

**Detection and quantification of *Bacillus cereus* (*B. cereus*)** One mL of 10-fold diluted sample was spread onto mannitol-egg yolk-polymyxin (MYP) agar (Oxoid, Hamshire, United Kingdom) and incubated at 30°C for 24 h. The detection and confirmation of *B. cereus* were performed according to methodology detailed in Oh et al. (2020).

**Detection and quantification of *Staphylococcus aureus* (*S. aureus*)** One mL of 10-fold diluted sample was equally distributed between two plates of Baird-Parker agar (Oxoid, Hamshire, United Kingdom) before incubation at 37°C for 48 h. The detection and con-

firmation of *S. aureus* were performed according to the methodology detailed in Oh et al. (2020).

**Detection and confirmation of methicillin-resistant *Staphylococcus aureus* (MRSA)** Briefly, the detection of MRSA was done via *mecA*-PCR followed by confirmation using PBP2 latex agglutination test (Oxoid, Hamshire, United Kingdom) and disk diffusion with Cefoxitin 30 ug. The detection and confirmation of methicillin-resistant *Staphylococcus aureus* (MRSA) were performed according to the methodology detailed in Aung et al. (2017).

**Detection and confirmation of *Salmonella* species** One mL of 10-fold diluted sample was inoculated onto Universal Preenrichment Broth obtained from Acumedia Manufacturers (Neogen Corporation, Michigan, United States), with dilution performed as described above, and incubated at 37°C for 18–24 h. The detection and confirmation of *Salmonella* species were performed according to the methodology detailed in Oh et al. (2020).

**Detection and confirmation of *Listeria* species (*Listeria*)** One mL of 10-fold diluted sample was spread onto Universal Preenrichment Broth obtained from Acumedia Manufacturers (Neogen Corporation, Michigan, United States), with dilution performed as described above, and incubated at 37°C for 18–24 h. The detection and confirmation of *Listeria* spp. were performed according to the methodology detailed in Oh et al. (2020).

**Detection and confirmation of *Vibrio cholerae* and *Vibrio parahaemolyticus*** One mL of 10-fold diluted sample was spread onto Universal Preenrichment Broth obtained from Acumedia Manufacturers (Neogen Corporation, Michigan, United States), with dilution performed as described above, and incubated at 37°C for 18–24 h. The detection and confirmation of *Vibrio cholerae* and *Vibrio parahaemolyticus* were performed according to the methodology detailed in Oh et al. (2020).

**Watertight test** The "watertight test" was performed with reference to ASTM D5151 (American Society for Testing and Materials, 2023), which is a standard test method used for the detection of holes in medical gloves, and used in this study to observe the presence of significant physical damage in gloves. Gloves were filled with up to 500 mL of water at room temperature, secured at the cuff and hung vertically for two minutes to observe for water leakage. The absence of water leakage from the gloves indicated the absence of significant physical damage.

**Statistical analysis** An independent samples t test was performed to compare the means SPC between inner and outer surfaces of gloves collected. Subsequently, a one-way analysis of variance (ANOVA) was performed to determine the presence of statistically significant differences between groups of gloves used to handle different types of food. All statistical tests were performed using SPSS version 26. A  $p$  value  $< 0.05$  was considered statistically significant.

## Results

**Physical damage** Out of the gloves collected, 66% ( $n = 33/50$ ) were made of polyethylene (PE) and 34% ( $n = 17/50$ ) were made of polyvinyl chloride (PVC) material. A total of 20 PE and seven PVC

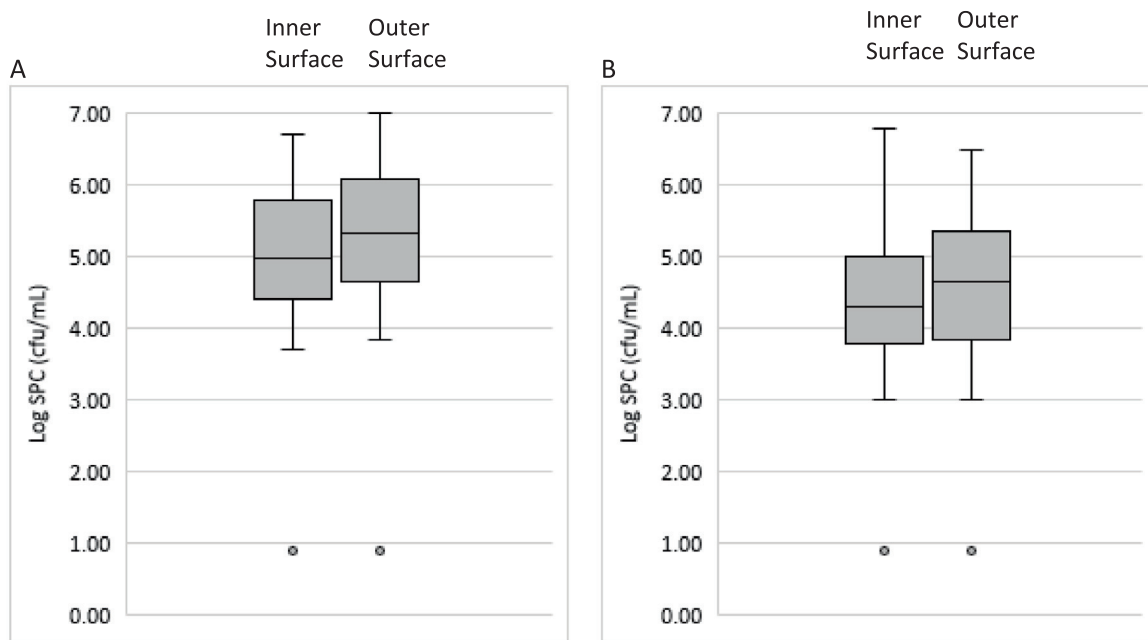


Fig. 1. SPCs for inner and outer surfaces of (A) damaged gloves and (B) gloves without visible damage. Top and bottom of boxes in plots indicate the 25th and 75th percentiles, horizontal lines indicate the medians, and the whiskers indicate minimum and maximum values. Circles indicate outliers.

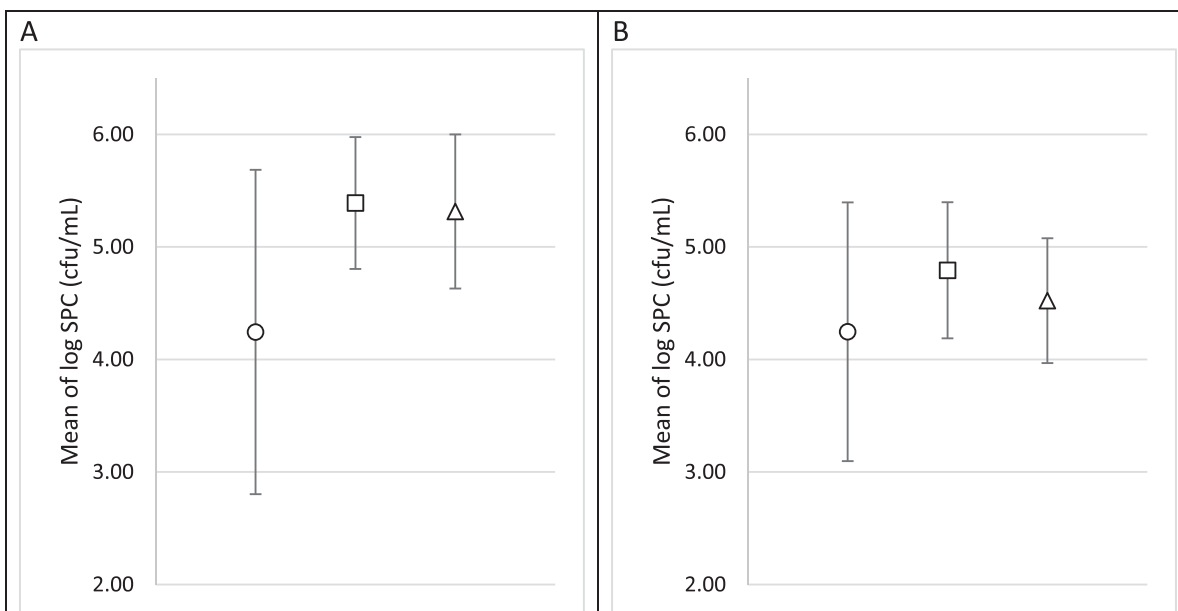


Fig. 2. A means plot showing the differences in mean log SPC between groups of gloves used to handle Beverages and Snacks (circle), Noodle Dishes (square), and Rice Dishes (triangle) for (A) damaged gloves and (B) gloves without visible damage. Error bars indicate standard deviation. A statistically significant difference in mean log SPC was observed between groups of *damaged* gloves used to handle different types of food ( $p < 0.05$ ) but not for gloves *without visible damage* ( $p > 0.05$ ).

gloves failed the watertight test, which correspond to a damage proportion of 61% and 41% respectively for PE and PVC gloves, respectively.

**Standard plate count** An independent samples t test showed that there was no statistically significant difference in SPC (cfu/mL) between the inner and outer surfaces of the gloves observed for both damaged ( $t(52) = 0.97, p > 0.05$ ) and gloves without visible damage ( $t(44) = 0.62, p > 0.05$ ) gloves (see Fig. 1). However, our analysis showed that gloves with visible damage exhibited significantly higher

mean SPC ( $t(48) = 2.52, p < 0.05$ ) on both the inner and outer surfaces of the gloves, compared to gloves without damage.

Furthermore, there was significant difference in mean SPC between groups of damaged gloves used to handle different types of food (see Fig.2), as demonstrated by one-way ANOVA ( $F(2,24) = 3.80, p < 0.05$ ). A Tukey posthoc test showed that damaged gloves used to handle beverages and snacks had significantly lower SPC than damaged gloves used to handle noodles and rice dishes (.03 and .04, respectively). There was no significant difference between gloves used

**Table 2**  
Proportion of samples positive for pathogens and hygiene indicators on inner and outer surfaces of gloves

Condition of gloves	No. of samples tested	Surface of gloves	% (no.) of positive samples		
			<i>E. coli</i>	<i>B. cereus</i>	<i>S. aureus</i>
Damaged	27	Inner	22.2 (6)	3.7 (1)	18.5 (5)
		Outer	14.8 (4)	11.1 (3)	18.5 (5)
Intact	23	Inner	4.3 (1)	8.7 (2)	21.7 (5)
		Outer	8.7 (2)	13.0 (3)	17.4 (4)

to handle noodles and rice dishes ( $p = 0.98$ ). However, for gloves without visible damage used to handle different types of food, one-way ANOVA revealed no significant difference ( $F(2,20) = 0.61$ ,  $p > 0.05$ ) in the mean SPC.

**Proportion of samples detected with pathogens and hygiene indicators** The proportion of samples detected with pathogens and hygiene indicators on the inner and outer surfaces of damaged and gloves without visible damage is given in Table 2. Out of 50 inner surfaces of all gloves samples, none were detected with *Listeria* spp., *Salmonella*, *V. cholerae*, and *V. parahaemolyticus* while of 50 outer surfaces of all gloves samples, none were detected with *Salmonella*, *V. cholerae*, and *V. parahaemolyticus*.

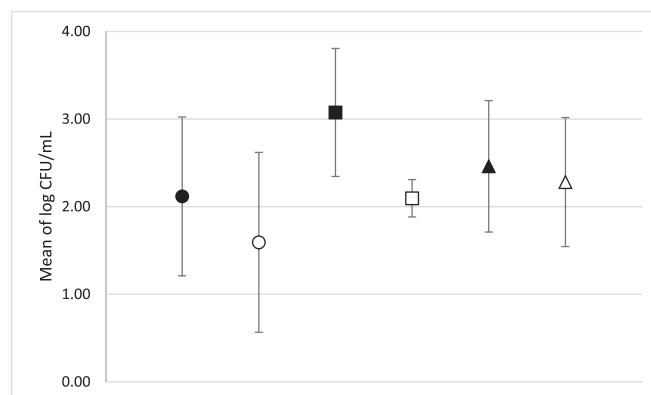
No significant difference in the detection of *B. cereus*, *E. coli*, and *S. aureus* between inner and outer surfaces of the gloves samples was observed ( $p > 0.05$ ) for both damaged and gloves without visible damage. The mean CFU/mL of damaged and gloves without visible damage detected with *B. cereus*, *E. coli*, and *S. aureus* is shown in Fig.3. The mean log CFU/mL of the damaged gloves detected with *B. cereus* was statistically significantly higher ( $p < 0.05$ ) than the mean log CFU/mL of gloves without visible damage.

## Discussion

Gloves usage can limit or prevent the transfer of pathogens from hands to food and food contact surfaces and vice versa. When the gloves are damaged, the barrier is breached and transient microflora including pathogens present on the food handlers' hands may transfer to foods. This could possibly lead to microbiological contamination and would pose a significant food safety risk if the contamination occurs particularly in ready-to-eat food.

In this study, more than half of the gloves collected, 54% (27/50 pairs) showed indication of physical damage. Out of these damaged gloves, the rate of gloves that did not pass the watertight test was higher in PE gloves (61%) than in PVC gloves (41%). While PE gloves may be of a more popular option among food handlers observed in this study likely due to their lower cost and flexible fit, they might be more prone to damage than PVC gloves. Therefore, PE gloves may require more regular changes compared to PVC gloves to prevent the transfer of bacteria between the inner and outer surfaces of the gloves. This is supported by our analysis which showed that the mean SPC on outer surfaces of gloves was significantly higher ( $p < 0.05$ ) than on inner surfaces, between damaged and intact gloves. Hence, gloves should be changed frequently, especially with contamination or physical damage (Todd et al., 2010). Although contamination might not impact the physical condition of gloves, it still poses a risk for the transfer of pathogens. Additionally, the wearer's perception plays an important role in determining the damage in gloves, as they may not always be able to recognize damages, especially subtle ones.

Our analysis also showed that damaged gloves used to handle beverages and snacks had statistically significantly lower mean SPC than gloves used to handle noodles and rice dishes ( $p < 0.05$ ). The observed difference in mean SPC could possibly be attributed to the increased frequency of ingredient handling and subsequent contact with gloves during the preparation of noodles and rice dishes, as com-



**Fig. 3.** A means plot showing the differences in mean log CFU/mL of damaged gloves (filled symbol) and gloves without visible damage (open symbol) detected with *E. coli* (circle), *B. cereus* (square), and *S. aureus* (triangle). Error bars indicate standard deviation. A statistically significant difference in mean log CFU/mL was observed between damaged gloves and gloves without visible damage detected with *B. cereus* ( $p < 0.05$ ) but not for gloves detected with *E. coli* and *S. aureus* ( $p > 0.05$ ).

pared to beverages and snacks, which typically require fewer interactions with ingredients. However, this interpretation is speculative, and further study would be needed to confirm this hypothesis. This difference was not found in gloves without visible damage, again suggesting that the damage present on gloves may increase the transfer of bacteria between surfaces. Therefore, disposable gloves used in the preparation of food dishes should be changed more frequently to prevent possible contamination of food (World Health Organization, 2006).

While proper glove use can offer a form of protection against microbiological contamination when handling food, gloves should be considered an adjunct and not an alternative to handwashing (Todd et al., 2010). A study by Price (1938) demonstrated that recommended washing procedures could significantly remove transient microorganisms from the hands. This further affirms the need for hand washing to prevent continuous exposure to pathogens in conjunction with practicing proper glove use in the preparation and handling of food. Furthermore, based on their observations, the authors of Lynch et al. (2005) opined that glove wearers tend to be complacent and neglect sanitary procedures such as handwashing. Gloves create an occlusive environment, sealing off the skin and potentially promoting the growth of microorganisms due to the increased warmth and humidity (Nørreslet et al., 2021). Consequently, the World Health Organization (WHO) emphasizes the importance of hand hygiene in food safety, recommending that food handlers wash their hands with soap and water before and during handling of food (World Health Organization, 2006). Therefore, glove users in the food service sector should practice proper handwashing along with glove use to mitigate the risk of bacterial growth that may be present with glove use.

In summary, to the best of our knowledge, this is the first cross-sectional study attempted to demonstrate the microbiological quality

of gloves and glove use behavior in food handlers, while handling ready-to-eat food, in Singapore's retail food establishments. Our study, though limited by the number of samples collected, provides scientific evidence for increasing awareness and reiterates the importance of proper glove usage while handling ready-to-eat foods in the food service sector.

### 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.

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