Journal of Food Protection, Vol. 64, No. 6, 2001, Pages 845–849

Glove Barriers to Bacterial Cross-Contamination between Hands to Food

REBECCA MONTVILLE, YUHUAN CHEN,† AND DONALD W. SCHAFFNER*

Food Risk Analysis Institute, Rutgers University, 65 Dudley Road, New Brunswick, New Jersey 08901-8520, USA

MS 00-258: Received 24 July 2000/Accepted 31 August 2000

ABSTRACT

Human hands are an important source of microbial contamination of foods. However, published data on the effectiveness of handwashing and glove use in a foodservice setting are limited. Bacterial transfer through foodservice quality gloves was quantified using nalidixic acid-resistant *Enterobacter aerogenes* (a nonpathogenic surrogate with attachment characteristics similar to *Salmonella*). Five transfer rates were determined: chicken to bare hand, chicken to hand through gloves, bare hand to lettuce, hand to lettuce through gloves (with low inoculum on hands), and hand to lettuce through gloves (with high inoculum on hands). At least 30 observations were made for each percent transfer rate using 30 individual volunteers. The logarithm of percent transfer data were then fit to distributions: chicken to bare hand, normal (0.71, 0.42); chicken to hand through gloves, gamma (5.91, 0.40, −5.00); bare hand to lettuce, logistic (1.16, 0.30); hand to lettuce through gloves (low inoculum), normal (0.35, 0.88); hand to lettuce through gloves (high inoculum), normal (−2.52, 0.61). A 0.01% transfer was observed from food to hands and from hands to food when subjects wore gloves and a 10% transfer was observed without a glove barrier. These results indicate that gloves are permeable to bacteria although transfer from hands to food through a glove barrier was less than without a glove barrier. Our results indicate that gloves may reduce both bacterial transfer from food to the hands of foodservice workers and in subsequent transfer from hands back to food.

Glove use has recently become popular in foodservice establishments because of the intuitive assumption that a physical barrier will prevent the food handler from contaminating food. Food handlers and poor handwashing practices have been implicated as the source of foodborne disease outbreaks *(13)*. However, some have argued that mandatory glove use can cause overall hygiene to decline and that gloves are commonly misused *(5, 8, 23)*. In September 1999, the Food and Drug Administration asked the National Advisory Committee for the Microbial Criteria for Foods to examine this issue. The committee determined that there were insufficient data on gloves to mandate their use in the model food code *(1, 20)*.

The majority of data on glove effectiveness originate from the healthcare literature *(6, 9, 15, 17, 26)*. These studies have limited foodservice application because they evaluate surgical gloves that typically are of a better quality than foodservice gloves. These studies also utilize the static watertight test, which is not generally indicative of how gloves fare while in use *(16)*.

Some studies have examined gloves in a foodservice setting, focusing primarily on attachment characteristics and contamination on the outer part of the glove. In a study by Bardell *(3)*, droplets of saliva containing herpes simplex virus were placed on the outside of latex disposable gloves and touched to lettuce or ham at 0, 30, and 60 min. The virus was isolated from the food in all five trials for each group. Fendler et al. *(11)* asked volunteers to handle ground beef containing *Escherichia coli* and showed that the outside of the glove was highly contaminated at the end of a 3-h period regardless of whether gloves had been changed or hands washed. Other studies also provide data on the transfer of bacteria and viruses from hands to kitchen surfaces, hands to food, and the survival of organisms on these surfaces *(3, 18, 24, 25)*.

The primary objective of this study was to determine four bacterial transfer rates: chicken to bare hands, chicken to hands through gloves, bare hands to lettuce, and hands to lettuce through gloves. A secondary objective was to fit the transfer data to statistical distributions so they could be incorporated in a quantitative risk assessment *(19)*.

MATERIALS AND METHODS

Bacterial strain and growth conditions. The methods were adapted from Chen et al. *(7)*. A nonpathogenic indicator microorganism, *Enterobacter aerogenes* B199A, with attachment characteristics similar to *Salmonella* on chicken *(27)*, was used for all experiments. The *E. aerogenes* strain was resistant to nalidixic acid that allowed it to be enumerated in both the presence of background microorganisms on the food and resident microflora on the hands of participants. Chicken breast meat and lettuce were obtained from a local supermarket. Control experiments showed that nalidixic acid-resistant *E. aerogenes* cells were not initially present on any of the test surfaces.

E. aerogenes cells were grown overnight at 37°C with shaking (150 rpm) in tryptic soy broth (Difco, Detroit, Mich.) containing 50 μg/ml nalidixic acid (Sigma Chemical Co., St. Louis, Mo.). Cells were harvested by centrifugation (Micro 7; Fisher Scientific, Pittsburgh, Pa.) at 5,000 × *g* for 3.5 min and washed three

* Author for correspondence. Tel: 732-932-9611, ext. 214; Fax: 732-932-6776; E-mail: schaffner@aesop.rutgers.edu.

† Present address: National Food Processors Association, 1350 I Street N.W., Suite 300, Washington, DC 20005, USA.

times in phosphate-buffered saline (0.1 M, pH 7.2) (Fisher Scientific). Cell pellets were resuspended in phosphate-buffered saline and adjusted by a spectrophotometer (model UV160; Shimadzu Scientific Instruments, Columbia, Md.) to an A_{660} of approximately 0.5, corresponding to $\sim 10^8$ CFU/ml. Appropriate 10-fold dilutions in phosphate-buffered saline were made to determine the cell density of the inoculum and enumerate samples collected from various surfaces. Next, 0.1 ml of the two lowest dilutions was plated in duplicate on MacConkey agar (Difco) containing 50-μg/ml nalidixic acid. Pour plating was done in duplicate by mixing 1 ml of a sample with 10 ml of warm agar for samples containing low levels of *E. aerogenes.* Agar plates were incubated at 37°C for 24 h prior to enumeration.

Study participants. Fifty-four university students and staff participated in the study to produce at least 30 different data points for each transfer rate evaluated. Eighteen males and 36 females participated. All participants appeared to have normal, healthy skin on the surface of their hands without any obvious cuts or abrasions. Both hands of each participant were sampled so that handedness would not be a factor. Each participant was informed as to the general nature of the experimental procedures and signed a consent form prior to taking part in the experiments.

Contamination of chicken and hands. The top surface of portions (150 g) of chicken was evenly inoculated with 1 ml *E. aerogenes* suspension and was then held for 15 min to facilitate attachment. Virgin polyethylene gloves (Fischer Scientific) were donned without the technician's assistance in order to better simulate a real world situation. Volunteers diced the chicken into 1-cm cubes on a sterile plastic cutting board (American Chef, Bentonville, Ark.) with either bare or gloved hands and then transferred chicken pieces from the cutting board to a container three times.

Contamination of lettuce. The same volunteers diced a 25-g portion of lettuce on a fresh cutting board and then placed the lettuce in a filter bag. Both hands were sampled using the glove juice technique *(7, 22)* after cutting the lettuce. Lettuce was homogenized in a stomacher (Cooke Laboratory Products, Alexandria, Va.) at 230 rpm for 2 min with 225 ml of tryptic soy broth. The solid lettuce pieces were discarded and samples were then centrifuged at 8 × *g* for 20 min. Supernatant was poured off and cells were enumerated by pour plating on MacConkey agar containing 50 μg/ml nalidixic acid.

Data analysis. Total CFU were determined for chicken, hands, and lettuce. The number of *E. aerogenes* on the hands before cutting the lettuce was calculated by adding the number of cells isolated on both hands (post lettuce cutting) to the number of cells isolated from the lettuce. Where no *Enterobacter* were detected, the level of detection was used for the number of cells present. The level of detection for the hand was 100 CFU. Detection limit for lettuce was dependent on the amount of concentrate remaining after centrifugation, on average around 30 CFU. A comparison was made between data sets where none-detected values were not included in data analysis and where none-detected values were replaced with the detection limit, and no appreciable differences in the distributions were noted. Transfer rates were calculated using the equation:

$$(\text{CFU on destination})/(\text{CFU on source}) \times 100 = \text{transfer rate } (\%)$$

Data were compiled and logarithmically transformed in Excel (Microsoft Corporation, Redmond, Wash.) spreadsheets. Transfer rates were fit to distributions using Bestfit (Palisade Corp., Newfield, N.Y.). The accuracy of fit of a distribution was determined using the Kolmogorov-Smirnov test *(2).*

TABLE 1. *Nalidixic acid-resistant* E. aerogenes *isolated from various surfaces when volunteers cut chicken with bare hands then cut lettuce with gloved hands*

Log$_{10}$ (CFU)/surface				Transfer rate (%)	
Chicken	Hand[a]	Lettuce	Hand[b]	Chicken to bare hand	Hand to lettuce through glove
8.23	6.94	2.19	6.94	5.16	0.0018
	6.98	2.35	6.98	5.68	0.0024
	6.36	3.10	6.36	1.38	0.0545
	6.48	1.88	6.48	1.80	0.0025
	6.01	1.46[c]	6.01	0.61	0.0028
	7.14	1.66	7.14	8.13	0.0003
	7.13	1.85	7.13	8.08	0.0005
	7.22	1.24	7.22	9.81	0.0001
	6.60	1.87	6.60	2.38	0.0019
	6.84	3.23	6.84	4.10	0.0246
8.14	6.95	2.30	6.95	6.51	0.0022
	6.77	2.02	6.77	4.22	0.0018
	6.79	1.55	6.79	4.44	0.0006
	6.66	2.45	6.66	3.28	0.0063
	6.33	2.01	6.33	1.54	0.0049
8.42	6.60	2.37	6.60	1.54	0.0058
	6.98	1.45	6.98	3.68	0.0003
	6.07	1.18[c]	6.07	0.45	0.0013
	6.51	1.86	6.51	1.23	0.0022
	6.30	2.14	6.30	0.77	0.0069
8.26	7.27	1.87	7.27	10.43	0.0004
	7.11	2.48	7.11	7.16	0.0024
	7.16	1.57	7.16	8.00	0.0003
	7.09	1.80	7.09	6.86	0.0005
	6.44	2.42	6.44	1.54	0.0096
8.23	6.40	1.72	6.40	1.49	0.0021
	7.01	2.79	7.01	6.00	0.0061
	6.66	1.35	6.66	2.69	0.0005
	6.62	1.34[c]	6.62	2.45	0.0005
	6.64	2.20	6.64	2.58	0.0036

[a] Estimated amount on hands before cutting lettuce calculated by: $10^{\log[\text{CFU on hands before}]} = 10^{\log[\text{CFU on lettuce}]} + 10^{\log[\text{CFU on hands after}]}$.

[b] Amount on hands after cutting lettuce.

[c] Zero value was replaced with detection limit.

RESULTS

Table 1 shows the results from the scenario where volunteers cut chicken with bare hands and then donned gloves before cutting the lettuce. The amount of *E. aerogenes* transferred from chicken to bare hands ranged from 6.01 to 7.27 log CFU. Chicken to bare hand transfer rate was between 0.61 and 10.43%. The amount of *E. aerogenes* transferred from hands to lettuce through a glove barrier ranged from below the limit of detection to 3.23 log CFU. The transfer rate from hand to lettuce through a glove barrier ranged from 0.0003 to 0.0545%.

Results from the scenario where volunteers cut chicken with gloves, changed gloves, then cut lettuce are shown in

TABLE 2. *Nalidixic acid-resistant* E. aerogenes *isolated from various surfaces when volunteers cut chicken with gloved hands and cut lettuce after donning clean gloves*

Log$_{10}$ (CFU)/surface				Transfer rate (%)	
Chicken	Hand[a]	Lettuce	Hand[b]	Chicken to hand through glove	Hand to lettuce through glove
8.79	4.33	1.44	4.33	0.0035	0.13
8.94	4.31	1.10	4.31	0.0023	0.06
	3.69	1.73	3.68	0.0006	1.10
8.29	4.20	0.85	4.20[d]	0.0082	0.04
8.75	4.28	2.21	4.27[d]	0.0034	0.86
	3.75	0.90[c]	3.75[d]	0.0010	0.14
	3.97	1.51	3.97[d]	0.0017	0.34
	2.35	1.37	2.30[c]	0.0000	10.59
8.20	3.70	2.65	3.66	0.0032	8.89
	5.09	3.00	5.09	0.0786	0.80
	3.18	1.40[c]	3.18[d]	0.0010	1.64
	3.76	1.82	3.76[d]	0.0036	1.13
	2.80	1.49	2.78[d]	0.0004	4.87
8.22	2.37	1.52[c]	2.30[c]	0.0001	14.16
	2.33	1.17	2.30[c]	0.0001	6.93
	2.35	1.36[c]	2.30[c]	0.0001	10.31
	2.35	1.42[c]	2.30[c]	0.0001	11.50
	4.75	1.60	4.75	0.0338	0.07
8.20	4.09	1.17	4.09	0.0078	0.12
	3.48	3.02	3.30[d]	0.0019	34.21
	3.14	1.91	3.11[d]	0.0009	5.84
	2.34	1.28[c]	2.30[c]	0.0001	8.68
7.67	2.33	1.08[c]	2.30[c]	0.0005	5.66
8.48	4.16	2.58	4.15	0.0048	2.61
	2.35	1.34[c]	2.30[c]	0.0001	9.91
	4.59	1.26	4.59	0.0129	0.05
	2.79	1.32	2.78[d]	0.0002	3.38
	3.79	1.15[c]	3.79	0.0020	0.23
8.66	5.45	3.74	5.44	0.0610	1.96
	2.36	1.43[c]	2.30[c]	0.0001	11.89
8.44	3.31	1.45[c]	3.30[d]	0.0007	1.38

[a] Estimated amount on hands cutting lettuce calculated by: $10^{\log[\text{CFU on hands before}]} = 10^{\log[\text{CFU on lettuce}]} + 10^{\log[\text{CFU on hands after}]}$.

[b] Amount on hands after cutting lettuce.

[c] Zero value was replaced with detection limit.

[d] Zero value replaced with detection limit for one hand.

TABLE 3. *Nalidixic acid-resistant* E. aerogenes *isolated from various surfaces when volunteers cut chicken with gloved hands then cut lettuce with bare hands*

Log$_{10}$ (CFU)/surface				Transfer rate (%)	
Chicken	Hand[a]	Lettuce	Hand[b]	Chicken to hand through glove	Bare hand to lettuce
8.789	4.36	1.73	4.36[d]	0.0037	0.23
8.94	4.33	3.45	4.26	0.0024	13.17
8.29	3.82	3.81	2.30[c]	0.0034	96.98
	2.35	1.33	2.30[c]	0.0001	9.71
8.39	3.02	2.16	2.95[d]	0.0004	13.96
	3.53	2.62	3.48	0.0014	12.28
	2.33	1.18	2.30[c]	0.0001	7.06
	3.28	2.49	3.20[d]	0.0008	16.32
	2.33	1.15[c]	2.30[c]	0.0001	6.54
8.27	2.36	1.49[c]	2.30[c]	0.0001	13.42
	2.50	2.06	2.30[c]	0.0002	36.71
	4.08	3.75	3.81	0.0065	46.89
	3.72	3.45	3.38[d]	0.0028	53.76
	2.58	1.92	2.48[d]	0.0002	21.83
8.06	3.36	2.71	3.26[d]	0.0020	22.21
	2.34	1.31	2.30[c]	0.0002	9.17
	3.57	1.72	3.57[d]	0.0032	1.41
	2.34	1.28[c]	2.30[c]	0.0002	8.68
	4.22	1.93	4.21	0.0142	0.51
7.67	4.81	3.47	4.79	0.1377	4.59
	3.21	2.85	2.95[d]	0.0035	44.00
	5.05	3.72	5.03	0.2418	4.67
8.27	2.35	1.36[c]	2.30[c]	0.0001	10.31
	2.37	1.52	2.30[c]	0.0001	14.13
	2.37	1.51[c]	2.30[c]	0.0001	13.79
	5.02	3.87	4.99	0.0559	7.07
	3.66	2.67	3.61[d]	0.0024	10.28
8.66	4.47	2.95	4.46	0.0065	3.01
	2.52	1.51[c]	2.48[d]	0.0001	9.64
	3.70	1.40[c]	3.70	0.0011	0.50

[a] Estimated amount on hands before cutting lettuce calculated by: $10^{\log[\text{CFU on hands before}]} = 10^{10[\text{CFU on lettuce}]} + 10^{\log[\text{CFU on hands after}]}$.

[b] Amount on hands after cutting lettuce.

[c] Zero value was replaced with detection limit.

[d] Zero value replaced with detection limit for one hand.

Table 2. The quantity of *E. aerogenes* transferred to hands through the glove barrier was drastically lower than when chicken was cut with bare hands (Table 1) and ranged from below the level of detection to 5.45 log CFU. Chicken to hand transfer through a glove barrier ranged from below 0.0001 to 0.079%. The amount of *E. aerogenes* isolated from lettuce ranged from below the limit of detection to 3.74 log CFU. The transfer rate from hand to lettuce through a glove barrier ranged from 0.044 to 14.16%. Hand to lettuce transfer rate through a glove barrier was greatly affected by the initial inoculum on hands. It is also possible that the *E. aerogenes* in chicken juice that come from touching the chicken directly behave differently than those that contaminate hands through the glove barrier.

Table 3 shows the results from the scenario where volunteers cut chicken with gloved hands and then removed gloves before cutting lettuce. The amount of *E. aerogenes* transferred to the hand through a glove barrier ranged from below the limit of detection to 5.05 log CFU. The chicken to hand through a glove barrier transfer rate was between 0.0001 and 0.24%. The amount of *E. aerogenes* transferred from bare hands to lettuce ranged from below the level of detection to 3.81 log CFU. The bare hand to lettuce transfer rate was between 0.23 and 97%.

Figure 1 shows the distribution of transfer rates from chicken to gloved and bare hands. A gamma distribution (5.91, 0.40, −5.00) was used to describe the transfer data (from 60 volunteers) from chicken to gloved hand. Chicken to bare hand transfer data (from 30 volunteers) was de-

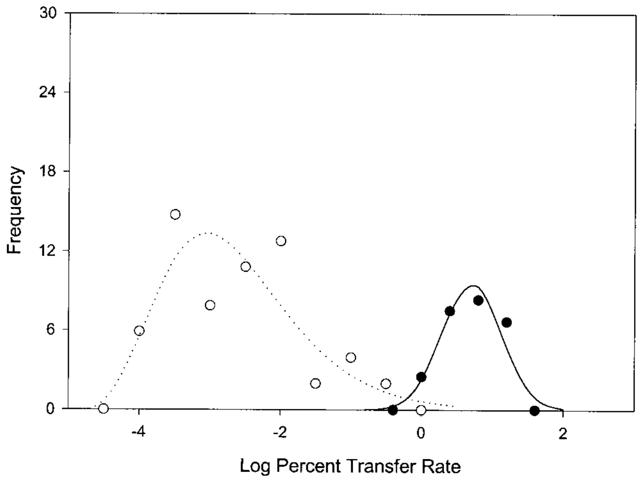

FIGURE 1. *Frequency distributions for percent transfer rates of nalidixic acid-resistant* E. aerogenes*: chicken to bare hand (●) and chicken to hand through glove (○); normal distribution (——) fit to bare hand data (mean 0.71, standard deviation 0.42) and gamma distribution (– – –) fit to gloved hand data (5.91, 0.40, −5.00).*

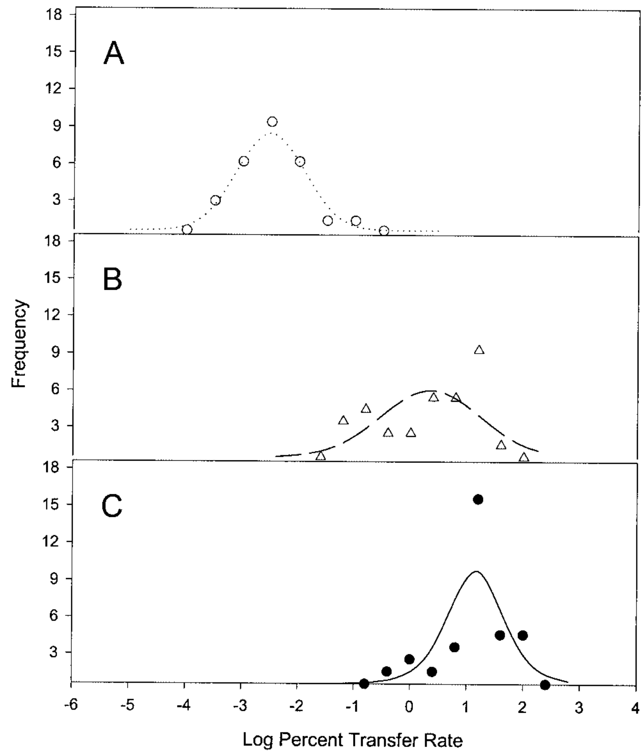

FIGURE 2. *Frequency distributions for percent transfer rates of nalidixic acid-resistant* E. aerogenes*: (A) Hands to lettuce through glove with higher (~6.5 log CFU) inoculum (○), normal distribution (···) fit to data (mean −2.52, standard deviation 0.61); (B) hands to lettuce through glove with lower (~4 log CFU) inoculum (△), normal distribution (– – –) fit to data (mean 0.35, standard deviation 0.88); (C) bare hands to lettuce (●) and logistic distribution (——) fit to data (1.16, 0.33).*

scribed by a normal distribution (0.71, 0.42). There was greater variability associated with the chicken to gloved hand transfer (possibly because the transfer rate was greatly effected by the condition and fit of the glove). Figure 2 shows hand to lettuce through a glove barrier transfer rate distributions. There was a significant difference between scenarios, the scenario where chicken had been cut with bare hands (Fig. 2A) and where chicken had been cut with gloved hands (Fig. 2B). Both data sets were fit to normal distributions. In the lower inoculum size scenario (~4 log CFU on hand—where chicken was cut with gloved hands) the transfer rate distribution had a mean of −2.52 and standard deviation of 0.61. In the high inoculum size scenario (~6.5 log CFU on hand—where chicken was cut with bare hands) the transfer rate distribution had a mean of 0.35 and a standard deviation of 0.88. The bare hands to lettuce transfer rate data (Fig. 2C) were fit to a logistic distribution (1.16, 0.33). The gloved hand to lettuce distributions had greater variability than the bare hand to lettuce distribution. All distributions selected were among the three best-fitting distributions ranked by Bestfit using the Kolmogorov-Smirnov test.

DISCUSSION

Contaminated hands are a major source of cross-contamination in the foodservice kitchen *(4)*. Our research demonstrates that bacteria can pass from food through gloves to the hand and from the hand through gloves to food. This is in agreement with others' findings that indicate that the glove barrier is not impervious to microorganisms. Doebbeling et al. *(10)* inoculated the outside of gloves with ~7 log CFU of *Staphylococcus aureus, Pseudomonas aeruginosa, Serratia marcescens,* or *Candida albicans* and found they transferred to hands in 5 to 50% of trials. The incidence of permeability in this study is lower than what was observed in our study. This could be attributed to better quality gloves or inactivity of volunteers. Korniewicz et al. *(16)* inoculated hands of volunteers with *S. marcescens* to test surgical vinyl and latex gloves that passed the watertight test. Thirty-four percent of the vinyl gloves and 20% of the latex gloves allowed penetration of *S. marcesens.*

Our research indicates that glove use can decrease the transfer rate from a contaminant to hands. In a study from the healthcare literature, hands and gloves of nurses were sampled for gram-negative rods and enterococci after performing dental, respiratory, or rectal procedures *(21)*. There were 2 to 4 log CFU fewer organisms isolated on hands than on the outer portion of gloves. Although vinyl gloves were more likely to leak, a correlation was not observed between glove leaks and microbial contamination of hands. These findings may indicate that the physical quality differences between hospital gloves and foodservice gloves do not affect their permeability. These results are consistent with the findings of Fendler et al. *(12)*. Volunteers handled ground beef naturally and artificially contaminated with 5 log CFU *E. coli.* After 3 h, 2.88 log CFU (−0.85 log percent transfer rate) transferred to hands through gloves that were changed hourly and 2.18 log CFU (−1.55 log percent transfer rate) when gloves were not changed. Our studies found lower transfer rates for a single task, which may indicate that there is an increase in transfer through gloves over time.

Pether and Gilbert determined that *Salmonella* Anatum can transfer from finger tips to corned beef or cooked ham during a 5-s exposure *(24)*. Previous studies by our laboratory *(7)* produced similar results: volunteers cut chicken inoculated with *E. aerogenes,* washed hands, then cut lettuce. *E. aerogenes* was transferred from hands to lettuce in most trials. Chen et al. *(7)* also determined that handwashing produced approximately a 2-log decrease on hands. The amount transferred to lettuce from washed hands as determined by Chen et al. *(7)* is comparable to the amount transferred by gloved hands (when hands had not been washed) in this study. Neither glove use nor handwashing eliminates the risk of cross-contamination completely. Use of a multiple-intervention technique (e.g., combining handwashing and glove use) may have an additive effect and further reduce risk of cross-contamination from hands to food. Preliminary data from our laboratory (not shown) indicate that a combination of hand rinsing and glove use is more effective than gloves alone. In practice, gloves that are misused often become contaminated *(14)*. Therefore, it is important that hands be washed properly and gloves changed frequently.

The distributions obtained from our research could be incorporated in a quantitative risk assessment on handwashing *(19)* to predict the efficacy of a combined handwashing and glove use protocol.

CONCLUSIONS

In this study, we quantified bacterial transfer rates from food to hands and from hands to food with and without a glove barrier. The variability associated with these transfer rates was determined. Our findings indicate that a glove barrier can decrease the transfer of microorganisms from food to hands. However, our findings also show that the majority of gloves are permeable to bacteria in a setting simulating actual use. Transfer rate through the glove barrier may be affected by inoculum size. Future research to quantify how the permeability of the glove barrier changes over time is also needed to better determine how gloves would be best utilized in a foodservice kitchen.

ACKNOWLEDGMENTS

We thank the New Jersey Agricultural Experiment Station for providing partial funding for this project and the Food Risk Analysis Initiative.

REFERENCES

1. Adler, K. 1999. Recommendation on bare-hand contact with ready-to-eat foods finalized by micro committee. Food Chem. News 41:9.
2. Anonymous. 1996. BestFit user's guide. Palisade Corporation, Newfield, N.Y.
3. Bardell, D. 1995. Herpes simplex virus type 1 applied experimentally to gloves used for food preparation. J. Food Prot. 58:1150–1152.
4. Bean, N. H., J. S. Goulding, M. T. Daniels, and F. J. Angulo. 1997. Surveillance for foodborne disease outbreaks—United States, 1988–1992. Morbid. Mortal. Weekly Rep. 45:1–67.
5. Brooks, S. 1995. To fight hepatitis, put on the gloves: in parts of Idaho and Colorado, it's mandatory. Rest. Bus. 94:18.
6. Brough, S. J., T. M. Hunt, and W. W. Barrie. 1988. Surgical glove perforations. Br. J. Surg. 75:317
7. Chen, Y., K. M. Jackson, F. P. Chea, and D. W. Schaffner. 2001. Quantification and variability analysis of bacterial cross contamination rates in common foodservice tasks. J. Food Prot., in press.
8. DeGroot-Kosolcharien, J. 1991. Pandemonium of gloves: use and abuse. Am. J. Infect. Control 19:225–227.
9. DeGroot-Kosolcharien, J., and J. M. Jones. 1989. Permeability of latex and vinyl gloves to water and blood. Am. J. Infect. Control 17:196–201.
10. Doebbeling, B. N., M. A. Pfaller, A. K. Houston, and R. P. Wenzel. 1988. Removal of nosocomial pathogens from the contaminated glove: implications for glove reuse and hand washing. Ann. Int. Med. 109:394–398.
11. Fendler, E. J., M. J. Dolan, and R. A. Williams. 1998. Handwashing and gloving for food protection. Part I. Examination of the evidence. Dairy Food Environ. Sanit. 18:814–823.
12. Fendler, E. J., M. J. Dolan, R. A. Williams, and D. S. Paulson. 1998. Handwashing and gloving for food protection. Part II. Effectiveness. Dairy Food Environ. Sanit. 18:824–829.
13. Guzewich, J. J., and M. P. Ross. 1999. White paper, section one: a literature review pertaining to foodborne disease outbreaks caused by food workers, 1975–1998. [Internet, WWW], address: http://vm.cfsan.fda.gov/~ear/rterisk.html.
14. Kaneko, K., H. Hayashidani, K. Takahashi, Y. Shiraki, S. Limawongpranee, and M. Ogawa. 1999. Bacterial contamination in the environment of food factories processing ready-to-eat fresh vegetables. J. Food Prot. 62:800–804.
15. Katz, N., J. P. Gobetti, and C. Shipman. 1989. Fluorescein dye evaluation of glove integrity. J. Am. Dent. Assoc. 118:327–331.
16. Korniewicz, D. M., B. E. Laughon, A. Butz, and E. Larson. 1989. Integrity of vinyl and latex procedure gloves. Nurs. Res. 38:144–146.
17. Kotilaninen, H. R., J. P. Brinker, J. L. Avato, and N. M. Grantz. 1989. Latex and vinyl examination gloves. Arch. Intern. Med. 149:2749–2753.
18. Mbithi, J. N., S. Springthorpe, J. R. Boulet, and S. Sattar. 1999. Survival of hepatitis A virus on human hands and its transfer on contact with animate and inanimate surfaces. J. Clin. Microbiol. 30:757–763.
19. Montville, R., and D. W. Schaffner. 1999. A quantitative risk assessment for determining the efficacy of various hand washing practices. International Association of Milk Food and Environmental Sanitarians annual meeting program and abstract book. Abstr. T30. 1 August 1999 to 4 August 1999. Dearborn, Mich.
20. Murphy, J. 1999. Bare-hand contact ban for ready-to-eat foods debated my micro committee. Food Chem. News 41:17–18.
21. Olsen, R. J., P. Lynch, M. B. Coyle, J. Cummings, T. Bokete, and W. E. Stamm. 1993. Examination gloves as barriers to hand contamination in clinical practice. JAMA 270:350–353.
22. Paulson, D. S. 1993. Evaluation of three microorganism recovery procedures used to determine handwash efficacy. Dairy Food Environ. Sanit. 13:520–523.
23. Paulson, D. S. 1996. To glove or to wash: a current controversy. Food Qual. 2:60–64.
24. Pether, J. V. S., and R. J. Gilbert. 1971. The survival of salmonellas on finger-tips and transfer of the organisms to food. J. Hyg. 69:673–681.
25. Scott, E., and S. Bloomfield. 1990. The survival and transfer of microbial contamination via cloths, hand and utensils. J. Appl. Bacteriol. 68:271–277.
26. Yangco, B. G., and N. F. Yangco. 1989. What is leaky can be risky: a study of the integrity of hospital gloves. Infect. Control Hosp. Epidemiol. 10:553–556.
27. Zhao, P., T. Zhao, M. P. Doyle, J. R. Rubino, and J. Meng. 1998. Development of a model for evaluation of microbial cross-contamination in the kitchen. J. Food Prot. 61:960–963.