

Research Note

Effects of Wearing Knitted or Rubber Gloves on the Transfer of *Escherichia coli* between Hands and Meat

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ABSTRACT

On eight occasions, five volunteers each handled five pieces of meat with bare hands or while wearing dry or wet knitted gloves or rubber gloves after hands had been inoculated with *Escherichia coli* or after handling a piece of meat inoculated with *E. coli*. On each occasion, after all meat was handled, each piece of meat, glove, and hand were sampled to recover *E. coli*. When hands were inoculated, *E. coli* was recovered from all meat handled with bare hands, in lesser numbers from some pieces handled with knitted gloves, and from only one piece handled with rubber gloves. When pieces of inoculated meat were handled, the numbers of *E. coli* transferred to uninoculated meat from bare hands or rubber gloves decreased substantially with each successive piece of uninoculated meat, but decreases were small with knitted gloves. The findings indicate that, compared with bare hands, the use of knitted gloves could reduce the transfer of bacteria from hands to meat but could increase the transfer of bacteria between meat pieces, whereas the use of rubber gloves could largely prevent the first and greatly reduce the second type of bacteria transfer.

Workers at meat packing plants commonly wear gloves made of cotton and/or synthetic fibers if they do not wear gloves made of steel mesh, damage-resistant plastic, or rubber (2, 7). Gloves of the former type are now usually made from knitted polyester or cotton (P/C) materials with an open mesh structure. The wearing of P/C gloves largely prevents direct contact between workers' hands and meat and enhances the comfort of workers. The P/C gloves help avoid hands slipping on wet meat and on greasy rails provided for support on stairs, platforms, and walkways and insulate hands from chilled meat that must be handled. Moreover, both the short-term discomfort from accumulation of sweat within impervious gloves (10) and the longer-term discomfort of dermatitis that can be induced by regular and prolonged wearing of such gloves (1) are avoided when P/C gloves are worn. However, the hygienic consequences of wearing P/C gloves are uncertain as, with few exceptions, published reports describe only the effects of wearing thin latex or vinyl gloves during medical procedures or when serving food (5). Therefore, a study was conducted to obtain an initial indication of how the wearing of P/C gloves might affect the transfer of bacteria between the hands of workers and meat and between pieces of meat.

MATERIALS AND METHODS

Preparation of inocula. A wild-type strain of *Escherichia coli* (11) was grown to the stationary phase in one-twentieth-strength brain heart infusion agar (Difco Laboratories, Detroit, Mich.) at 25°C to obtain a cell suspension with an optical density

of about 0.2 at 600 nm. A 10-fold dilution of the suspension in a 10% (wt/vol) solution of skimmed milk powder (Our Compliments, Sobey's Inc, Stellarton, Ontario, Canada) that had been heated at 104°C for 30 min, then cooled, was prepared. Two such skimmed milk preparations were prepared from fresh cultures on each of 8 days, with one culture being used for the inoculation of hands or meat. Dilutions of each skimmed milk preparation, to 10⁻⁵, were prepared, and two 10-ml portions of the highest dilution were each filtered through a hydrophobic grid membrane filter (QA Life Sciences, San Diego, Calif.), which was incubated on a plate of lactose monensin glucuronate agar (QA Life Sciences) for the enumeration of coliforms (4).

Transfer of *E. coli* from hands to meat. A 1-ml portion of a skimmed milk preparation was placed in the palm of one hand of each of five members of the laboratory staff. The participants each rubbed their hands together to distribute the preparation over all surfaces of both hands, which were allowed to dry for 10 min (12). Then, each participant handled five pieces of meat, which each measured about 5 by 5 by 15 cm, from a batch of 30 pieces cut aseptically from rump primal cuts. Each piece of meat was squeezed for 2 min. The order in which the pieces were handled was identified. Five pieces of meat were used for determination of the numbers of *E. coli* on meat that was not handled.

Each piece of meat was swabbed over its entire surface with a cellulose acetate sponge (speci sponge, VWR Canlab, Mississauga, Ontario, Canada) that had been moistened with about 9 ml of 0.1% (wt/vol) peptone water (6). Each sponge was stomached with a further 9 ml of peptone water. The stomacher fluid, undiluted or diluted as required, was filtered through hydrophobic grid membrane filters for the enumeration of coliforms as before. The experiment was repeated three more times, with the participants wearing dry P/C gloves, wet P/C gloves, or rubber gloves on the different occasions. The P/C gloves (Mr. Glove and Safety Ltd.,

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Edmonton, Alberta, Canada) were knitted from a 70% polyester and 30% cotton yarn. The flock-lined rubber gloves were about 0.5 mm (20 mils) thick (Ansell Canada Inc., Bromont, Quebec, Canada). Both types of gloves are commonly used at Canadian meat plants. When meat was handled with wet P/C gloves, 10 ml of sterile, distilled water was placed in the palm of each gloved hand, and each hand was closed and opened 10 times before meat was handled.

At the end of each session of meat handling, each hand of each participant was sampled by rinsing for 2 min with 100 ml of 0.1% (wt/vol) peptone water in a stomacher bag (3). When P/C gloves were worn, each glove was placed in a bag and was stomached for 2 min with 100 ml of 0.1% (wt/vol) peptone water. When rubber gloves were worn, each glove was filled with 100 ml of 0.1% peptone water. The solution was agitated within the glove by squeezing it back and forth for 2 min. The glove and contents were then placed in a stomacher bag and were stomached for 2 min. Both 10- and 0.1-ml portions of fluids used for rinsing hands or gloves were filtered as before for the enumeration of coliforms. All coliforms recovered from meat, hands, or gloves were assumed to be *E. coli*.

Transfer of *E. coli* from meat to hands and between pieces of meat. Six pieces of meat were each placed in a separate stomacher bag with 1 ml of a skimmed milk preparation, and each piece of meat was massaged within the bag. The inoculated pieces of meat were placed on a sterile tray and allowed to dry for 10 min. Then, each participant squeezed one inoculated piece of meat for 2 min before handling five uninoculated pieces of meat as before. The experiment was repeated as before with the participants wearing dry P/C gloves, wet P/C gloves, or rubber gloves when handling both the inoculated and uninoculated meat pieces. Each inoculated and uninoculated piece of meat, each hand, and each glove was sampled as before for the enumeration of coliforms.

Analysis of data. Counts of *E. coli* per ml of inoculum or per piece of meat, glove, or hand were transformed to \log_{10} values. Values for handled pieces of meat were grouped in sets of five by the order in which the pieces of meat were handled in each experiment. Values for hands or gloves were grouped in sets of 10 for the hands or gloves used in each experiment. When 80% or more of the samples in a group yielded a count, values for the mean log (\bar{x}) and SD were calculated for the set of counts, with a log value of 0.5 per piece of meat, glove, or hand being assigned for samples from which no *E. coli* was recovered. Mean log values were separated by the multiple comparison Ryan-Einot-Gabriel-Welsch multiple range test option of the general linear model procedure in SAS, version 8 (SAS Institute Inc., Cary, N.C.). In addition, for each set of counts, a value for the log of the total number of *E. coli* recovered was calculated by summing the counts in each set and obtaining the log of the sum.

RESULTS

The log numbers of *E. coli* recovered from 16 skimmed milk preparations ranged from 6.95 to 7.30 log CFU/ml, with $\bar{x} = 7.11$ and $SD = 0.09$. Only one coliform was recovered from 40 uninoculated pieces of meat that were not handled. When uninoculated meat was handled after hands were inoculated, *E. coli* was recovered from all pieces of meat handled with bare hands, but the numbers recovered from successive groups of meat pieces tended to decrease (Table 1). When inoculated hands were covered by dry P/C gloves, *E. coli* was recovered in small numbers

TABLE 1. Statistics for the numbers of *E. coli* (CFU/piece) recovered from groups of five meat pieces when groups were handled consecutively by people with hands inoculated with *E. coli* and not wearing gloves or wearing dry or wet P/C or rubber gloves^a

Hand covering	Group of pieces	Statistics			
		\bar{x}	SD	No.	n
None	1	2.58 A ^b	0.50	0	3.48
	2	1.91 AB	0.61	0	2.87
	3	1.99 AB	0.50	0	2.91
	4	1.52 BC	0.52	0	2.48
	5	1.46 BCD	0.99	0	2.49
Dry P/C gloves	1	—	—	4	0.30
	2	—	—	4	0.30
	3	—	—	2	1.00
	4	—	—	3	1.15
	5	0.36 E	0.35	1	1.15
Wet P/C gloves	1	0.51 DE	0.49	1	1.38
	2	—	—	2	1.76
	3	—	—	2	1.25
	4	0.58 DE	0.32	0	1.38
	5	0.50 DE	0.63	1	1.60
Rubber gloves	1	—	—	5	ND
	2	—	—	5	ND
	3	—	—	5	ND
	4	—	—	5	ND
	5	—	—	4	0.90

^a \bar{x} , mean of \log_{10} counts; SD, standard deviation of \log_{10} counts; No., number of pieces from which *E. coli* was not recovered; n, \log_{10} of the total number recovered from five pieces of meat; —, insufficient data for calculation of the statistic; ND, none detected.

^b Mean logs with the same letter are not significantly different ($P > 0.05$).

from only some pieces of meat, but the numbers recovered from successive groups tended to increase. When inoculated hands were covered by wet P/C gloves, *E. coli* was recovered from most pieces in small numbers. When inoculated hands were covered by rubber gloves, *E. coli* was recovered from only one piece of meat.

E. coli was recovered from all inoculated hands after meat was handled (Table 2). Comparable numbers were recovered from hands that had been bare or covered by wet P/C or rubber gloves, but larger numbers were recovered from hands that had been covered by dry P/C gloves. The numbers from wet P/C gloves were more than and the numbers from dry P/C and rubber gloves were less than the numbers recovered from the hands on which the gloves had been worn.

E. coli was recovered from all inoculated pieces of meat, but numbers from pieces that had been handled were less than from pieces that were not handled (Table 3). For handled pieces, the most *E. coli* was recovered from pieces handled with rubber gloves and the least from pieces handled with dry P/C gloves.

When inoculated pieces of meat were handled before handling uninoculated pieces, *E. coli* was recovered from all uninoculated pieces handled with bare hands, and the

TABLE 2. Statistics for the numbers of *E. coli* recovered from hands of, and gloves worn by, five people with hands inoculated with *E. coli* after each person handled meat while not wearing gloves or while wearing dry or wet P/C or rubber gloves^a

Hand covering	Hands or gloves	Statistics			
		\bar{x}	SD	No.	n
None	Hands	3.60 AB ^b	0.56	0	4.87
Dry P/C gloves	Hands	4.36 A	0.57	0	5.59
	Gloves	3.02 BC	0.35	0	4.14
Wet P/C gloves	Hands	2.87 C	0.81	0	4.41
	Gloves	3.78 AB	1.66	0	5.08
Rubber gloves	Hands	2.52 C	1.30	2	4.64
	Gloves	—	—	6	2.08

^a \bar{x} , mean of log₁₀ counts; SD, standard deviation of log₁₀ counts; No., number of pieces from which *E. coli* was not recovered; n, log₁₀ of the total number recovered from five pieces of meat; —, insufficient data for calculation of the statistic; ND, none detected.

^b Mean logs with the same letter are not significantly different (*P* > 0.05).

numbers recovered from successive groups of uninoculated pieces tended to decrease (Table 4). The findings were comparable when rubber gloves were worn, but with little *E. coli* being recovered from only three of the pieces in the last group of uninoculated pieces. When dry or wet P/C gloves were worn, *E. coli* was recovered from all the uninoculated meat pieces, and the numbers recovered from each group of uninoculated pieces were similar.

After the handling of inoculated and then uninoculated meat, *E. coli* was recovered, in similar numbers, from all hands that had been bare or on which dry or wet P/C gloves had been worn (Table 5). The numbers recovered from dry and wet P/C gloves were similar and more than the numbers recovered from the corresponding hands. No *E. coli* was recovered from hands that had been covered by rubber gloves, and the numbers recovered from rubber gloves were less than the numbers recovered from hands that had been bare.

TABLE 3. Statistics for the numbers of *E. coli* (CFU/piece) recovered from groups of five pieces of meat which were inoculated with *E. coli* when the meat was not handled or was handled by people with bare hands or wearing dry or wet P/C or rubber gloves^a

Handling	Hand covering	Statistics		
		\bar{x}	SD	n
Not handled		5.42 A	0.28	6.19
Handled	None	4.16 C	0.20	4.89
Handled	Dry P/C gloves	3.01 E	0.34	3.81
Handled	Wet P/C gloves	3.60 D	0.29	4.38
Handled	Rubber gloves	4.69 B	0.20	5.43

^a \bar{x} , mean of log₁₀ counts; SD, standard deviation of log₁₀ counts; n, log₁₀ of the total number recovered from five pieces of meat.

^b Mean logs with the same letter are not significantly different (*P* > 0.05).

TABLE 4. Statistics for the numbers of *E. coli* (CFU/piece) recovered from groups of five meat pieces when groups were handled consecutively by people with bare hands or wearing dry or wet P/C or rubber gloves who had each handled a piece of meat inoculated with *E. coli* before handling the uninoculated meat^a

Hand covering	Group of pieces	Statistics			
		\bar{x}	SD	No.	n
None	1	3.23 A	0.20	0	3.97
	2	2.70 AB	0.24	0	3.46
	3	1.96 CDE	0.14	0	2.68
	4	1.90 DE	0.27	0	2.67
	5	1.61 E	0.23	0	2.36
Dry P/C gloves	1	2.44 BCD	0.21	0	3.18
	2	2.35 BCD	0.44	0	3.23
	3	2.39 BCD	0.34	0	3.21
	4	2.20 CDE	0.23	0	2.94
	5	2.19 CDE	0.24	0	2.94
Wet P/C gloves	1	2.84 AB	0.41	0	3.69
	2	2.59 BC	0.54	0	3.54
	3	2.50 BCD	0.23	0	3.25
	4	2.71 AB	0.31	0	3.51
	5	2.28 BCD	0.24	0	3.03
Rubber gloves	1	3.30 A	0.24	0	4.05
	2	2.24 BCD	0.18	0	2.97
	3	1.61 E	0.25	0	2.38
	4	0.99 F	0.42	0	1.84
	5	—	—	2	0.90

^a \bar{x} , mean of log₁₀ counts; SD, standard deviation of log₁₀ counts; No., number of pieces from which *E. coli* was not recovered; n, log₁₀ of the total number recovered from five pieces of meat; —, insufficient data for calculation of the statistic.

^b Mean logs with the same letter are not significantly different (*P* > 0.05).

TABLE 5. Statistics for the numbers of *E. coli* (CFU/item) recovered from hands of, and gloves worn by, five people who handled meat inoculated with *E. coli* and the uninoculated meat while not wearing gloves or while wearing dry or wet P/C or rubber gloves

Hand covering	Hands or gloves	Statistics			
		\bar{x}	SD	No.	n
None	Hands	3.74 B	0.27	0	4.21
Dry P/C gloves	Hands	3.31 C	0.25	0	4.38
	Gloves	5.85 A	0.18	0	6.89
Wet P/C gloves	Hands	3.43 C	0.56	0	4.60
	Gloves	5.70 A	0.22	0	6.75
Rubber gloves	Hands	—	—	10	ND
	Gloves	—	—	7	2.53

^a \bar{x} , mean of log₁₀ counts; SD, standard deviation of log₁₀ counts; No., number of pieces from which *E. coli* was not recovered; n, log₁₀ of the total number recovered from 10 hands or gloves; —, insufficient data for calculation of the statistic; ND, none detected.

^b Mean logs with the same letter are not significantly different (*P* > 0.05).

DISCUSSION

When meat was handled with bare hands contaminated with *E. coli*, the numbers recovered from the uninoculated meat declined for pieces handled successively, from about 10 to about 1% of the numbers recovered from hands. Transfer of about 10% of inoculated bacteria from meat to bare hands and from hands to other food has been previously reported (9). However, it appears that the fractions of transient bacteria transferred from hands to sequentially handled items rapidly decline, but whether to a more or less constant fraction for an extended period or directly to sporadic contamination of items with one or a few CFUs is not known.

When meat was handled with contaminated hands covered by P/C gloves, the numbers of *E. coli* recovered were mostly between 1 and 10% of the numbers recovered from meat handled with contaminated bare hands. The data for wet P/C gloves suggest that most of the *E. coli* on hands was transferred to the gloves, but that a relatively small, approximately constant number was then transferred from the gloves to the meat. The data for dry P/C gloves indicate that the transfer of *E. coli* from hands to gloves was delayed compared with the transfer to wet gloves but that the numbers deposited on meat from initially dry or wet P/C gloves would finally be similar after the former gloves had absorbed meat juices.

When contaminated meat was handled while wearing P/C gloves, the number of *E. coli* transferred to the gloves was evidently much larger than the number transferred to bare hands. Despite that, the numbers subsequently transferred to uninoculated meat by bare hands or gloves were similar. However, unlike with bare hands, the numbers transferred from gloves to sequentially handled pieces of meat remained approximately constant. Thus, larger numbers of contaminants might be transferred to more uncontaminated items by P/C gloves than by bare hands after the handling of contaminated product.

Wearing of thick rubber gloves obviously prevented the transfer of *E. coli* from contaminated hands to meat. When rubber gloves were contaminated by handling of inoculated pieces of meat, the numbers of *E. coli* transferred to uninoculated meat were at first similar to the numbers transferred from similarly contaminated bare hands, as has been previously reported (8). However, the numbers of *E. coli* transferred from rubber gloves to subsequently handled pieces of meat reduced much more rapidly than the numbers transferred from hands. Those data indicate that the fraction of bacteria transferred from contaminated meat to rubber gloves would be less than the fraction transferred to

bare hands and much less than the fraction that would be transferred to P/C gloves. Moreover, subsequent handling of other meat would rapidly remove most bacteria from rubber gloves so that few of the subsequently handled pieces of meat would be contaminated, unlike when meat is handled with bare hands or while wearing P/C gloves. Thus, the findings of the study indicate that, compared with bare hands, P/C gloves could reduce the transfer of bacteria from hands to meat but could increase the transfer of bacteria between meat pieces, whereas rubber gloves could largely prevent the first and greatly reduce the second type of transfer.

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