Journal of Food Protection, Vol. 59, No. 7, 1996, Pages 751–756

Trimming and Washing of Beef Carcasses as a Method of Improving the Microbiological Quality of Meat

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(MS# 95-163: Received 7 July 1995/Accepted 20 December 1995)

ABSTRACT

A study to compare procedures and interventions for removing physical and bacterial contamination from beef carcasses was conducted in six carcass conversion operations that were representative of modern, high-volume plants and located in five different states. Treatment procedures included trimming, washing, and the current industry practice of trimming followed by washing. In addition, hot (74 to 87.8°C at the pipe) water washing and rinsing with ozone (0.3 to 2.3 ppm) or hydrogen peroxide (5%) were applied as intervention treatments. Beef carcasses were deliberately contaminated with bovine fecal material at >4.0 log colony-forming units (CFU)/cm^2 in order to be better able to observe the decontaminating effects of the treatments. Carcasses were visually scored by 2 to 3 trained personnel for the level of gross contamination before and after treatment. Samples (10 by 15 cm, 0.3 to 0.5 cm thick) for microbiological testing were excised as controls or after application of each procedure or intervention and analyzed for aerobic mesophilic plate counts, *Escherichia coli* Biotype I counts, and presence or absence of *Listeria* spp., *Salmonella* spp., and *Escherichia coli* O157:H7. Average reductions in aerobic plate counts were 1.85 and 2.00 log CFU/cm^2 for the treatments of trimming-washing and hot-water washing, respectively. Hydrogen peroxide and ozone reduced aerobic plate counts by 1.14 and 1.30 log CFU/cm^2, respectively. In general, trimming and washing of beef carcasses consistently resulted in low bacterial populations and scores for visible contamination. However, the data also indicated that hot- (74 to 87.8°C at the pipe) water washing was an effective intervention that reduced bacterial and fecal contamination in a consistent manner.

Key words: Beef carcass, contamination, decontamination, trimming-washing

The USDA regulation commonly referred to as "zero tolerance" requires that physical contamination on beef carcasses be trimmed off before carcass washing and chilling *(14, 25)*. It is assumed that trimming will completely remove the physical contamination as well as the microbiological contamination of the tissue, assuring that the product is safe and wholesome. However, under commercial beef slaughtering conditions, trimming may be a highly variable process, with its efficacy primarily related to the skill and/or diligence of the individual doing the trimming. In addition to variations in technique among individuals, the physical contact with the carcass may contribute to additional contamination if the equipment has not been properly sanitized. Furthermore, holding of carcasses for trimming at the warm slaughter room temperature before final washing and chilling may allow for better attachment of bacteria *(4)*. Previous studies have identified personal equipment, such as knives, mesh gloves, and aprons as reservoirs of bacteria in the abattoir *(22, 23)*. The actual efficacy of trimming as a method of reducing bacterial contamination on animal carcasses has not been evaluated in a controlled, scientific study, published in the scientific literature.

Washing and sanitizing procedures have generally proven effective for reducing overall bacterial populations as well as numbers of specific bacterial pathogens on meat. These procedures have involved the use of water rinsing *(1, 15)* as well as a variety of sanitizing agents *(6, 24)*. Organic acids have received the most attention among the sanitizers and many researchers have reported on the bactericidal effects of acetic, lactic, and citric acids (for a comprehensive review, see reference *[6]*). In addition, trisodium phosphate has been approved as a sanitizer for poultry *(10)*, and approval for red meat may be granted in the future. Several laboratory-scale studies have used fecal material as a contaminating agent in washing studies *(5, 7, 11, 12)*. However, there are apparently no in-plant studies to determine the efficacy of washing in removing ingesta and manure from carcasses. In addition, the possibility that carcass washing may potentially spread contamination from one area of a carcass to another must also be considered *(8)*, even though this latter issue may relate more to equipment design and efficacy of a specific washing process and not to

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the process in general. Gorman et al. *(11, 12)* reported increased removal of fecal material and reduced bacterial counts with increasing spray-washing pressures and temperatures in a pilot spray-washer and found no spreading of the contamination to areas adjacent to the inoculation site. Decontamination also increased with use of ozonated water and solutions of hydrogen peroxide and trisodium phosphate. Ozone and hydrogen peroxide can inactivate microorganisms by acting as oxidants. In general, under the conditions of those studies *(11, 12)*, these spray-washing treatments were as effective as trimming in removing physical and microbiological contaminants from beef brisket tissue.

The lack of scientific studies documenting the effectiveness of trimming in removing microbiological contamination under commercial conditions of beef slaughter, combined with the lack of in-plant evaluation of the effectiveness of carcass washing in removing physical contamination, makes a comparison of the efficacy of these two processes difficult. The objectives of this study were to evaluate beef decontamination under commercial conditions using the current practice of trimming and washing as well as other interventions, and to examine the issues of removal of both physical and microbiological contamination.

MATERIALS AND METHODS

Selection of beef carcasses

Six beef-slaughtering operations were selected as being representative of modern, high-volume plants. The plants were geographically dispersed, being located in five states, and were operated by four different companies. Four of the plants processed predominantly fed steers and heifers, while the other two processed mostly nonfed cows. The carcasses used for testing were randomly selected at 5- to 10-min intervals from the carcasses being processed (from 100 to 400 head per h, depending on the particular plant), and deliberately contaminated with fecal material obtained from the external surface of the hide of each carcass. The carcasses were contaminated by manual digitation on the inside round at the "high-rimmer" area of processing, immediately after the hide was opened, to create an area of contamination approximately 1.9 cm in diameter (ca. 2.84 cm^2). Testing was performed during the months of June and July, 1994, and it was spread over 3 days in each plant with 8 carcasses of each treatment tested on a given day.

Intervention treatments

Four primary treatments were evaluated in each of the six packing plants: inoculated, not treated control (CNT); trimmed only (T); washed only (W); and the combination of trimmed and washed (TW). The control (CNT) carcasses were neither trimmed nor washed in the area of contamination (before sampling), while the trimmed and washed (TW) carcasses were subjected to the current industry practice of trimming to remove all visible contamination and then washing using automated spray-washers before entrance of the carcasses into the chiller. Carcasses were identified with tags for specific treatments and the areas to be trimmed and sampled were circled with purple, edible ink. Carcasses were subjected to standard trimming practices, but were sampled prior to final washing. Knife-trimming (to remove visible contamination) was performed by plant personnel to meet USDA-FSIS zero-tolerance standards for removing fecal and other visible material *(14, 25)*. The plant personnel trimming carcasses were instructed to routinely immerse the knife (approximately 15 cm in length) and the hook in hot (82°C) water prior to touching a new carcass surface. Trimming varied among individuals, but generally involved placing the hook above the contaminated area and, in one motion downward, removing the contaminated portion.

The W carcasses were not trimmed in the marked area of contamination, but they were processed through the standard automated spray-washer before sampling. Two of the plants used Cary (Joplin, MO) and four used Chad (Lenexa, KS) spray washers. The approximate length of the cabinets was 4 and 11 m for the Chad and Cary cabinets, respectively, while the length of the spray was approximately 3 and 7 m, respectively. In all of the washers, the angle of spray was 25°, but three also had bars at 0°. The washer types were two USDA #7500, three USDA #BW-3000, and one USDA #4000C. All washers had four type #2510 nozzles, while three also had bar-type four-hole nozzles. The total water output ranged from a low of 605 to a high of 2,683 liters/min. The water temperatures during normal washing ranged between 28 and 42°C; the pressures between 410 and 2,758 kPa and the spray-washing times between 18 and 39 s.

The experimental intervention treatments of a hot- (74 to 87.8°C at the pipe) water final wash with no trimming (HW), no trimming but carcass rinsing with ozonated (0.3 to 2.3 ppm) (Marley M series model M30 ozonator and Air Sep AS-10 air generator; Marley Cooling Tower Company, Mission, KS) water (OZ) after final washing, and no trimming but carcass rinsing with hydrogen peroxide (5% solution) (Curtin Matheson Scientific, Aurora, CO) after final washing (PER) were evaluated at two of three plants (two fed steer and heifer plants and one nonfed cow plant). Because of differences in facilities and equipment between the three plants, there was some variation in the level and extent of application of these intervention treatments. The specific conditions—where available or accessible—for each intervention in each plant are given in Table 1.

Sampling

In practice, the CNT and T carcasses were sampled on the final trimming rail of the slaughtering chain before washing, while the W and TW carcasses were sampled immediately after washing.

TABLE 1. *Description of hot-water and chemical-intervention treatments evaluated for decontamination of beef carcasses*

Treatment	Plant 1	Plant 2	Plant 3
Hot water (HW)			
Water temperature (°C) at pipe	NP[a]	74	87.8
Wash duration (s)[b]		18	11
Pressure (kPa)		2,413	1,310
Ozonated water (OZ)			
Concentration (ppm)	0.3–0.9	2.3	NP
Rinse duration (s)	3	13	NP
Pressure (kPa)	138	138	NP
Hydrogen peroxide (PER)			
Concentration (%, vol/vol)	5.0	5.0	NP
Rinse duration (s)	3	13	NP
Pressure (kPa)	138	138	NP

[a] Not performed.

[b] The wash cabinet in plant 3 provided a continuous wash of the entire carcass; the cabinet in plant 2 provided for a three-stage, sequential wash, beginning at the hind legs and moving down the carcass. The result of this design is that, although the total wash was 22 seconds, each portion of the carcass received a wash for a period equivalent to approximately 33% of that time.

Each sample, consisting of a 10 by 15 cm area (150 cm^2) and approximately 0.3 to 0.5 cm thick, was aseptically excised from the original contaminated area of the inside round using standardized sterile templates. The broad area of the inside round of carcasses to be used in the study was marked with purple edible ink. In addition, test carcasses were appropriately tagged. After excision, the samples were immediately chilled on ice, and shipped with "blue ice" packets in insulated containers by overnight air express to the analytical laboratory (Chicago, IL). The temperature of the samples was determined on arrival at the analytical laboratory, and samples were inspected for any obvious signs of temperature abuse. The samples were considered to have been properly maintained during shipment if they were received by the laboratory within 24 h, the sample temperature was below 5°C, and the "blue ice" packets were still frozen.

Visual scoring

The area of the inside round, where the contamination was placed, of each carcass was scored immediately after contamination and immediately prior to microbiological sampling for visual contamination using a 0 to 5 arbitrary scale (Table 2). Because this was a subjective score, the same 2 to 3 trained individuals scored all of the carcasses in all of the plants to assure that the carcass scores were assigned consistently. The study involved testing 24 carcasses (samples) per treatment (8 per day) in each of the plants.

Microbiological analyses

Samples were weighed and homogenized or stomached for 2 min in 200 ml of Butterfield's phosphate buffer *(20)*. A Waring blendor was used to homogenize samples from plant 1, while a Stomacher 400 (Tekmar Co., Cincinnati, OH) was used to homogenize samples from plants 2 through 6. Homogenates were analyzed for *Salmonella* spp., *Listeria* spp., *Escherichia coli* O157:H7, aerobic plate counts, and *E. coli* counts. Analysis for each of the three pathogens used portions of 25 ml from the stomached samples (20% of the blended samples) and determined presence or absence of the pathogen in a sample. The lactose preenrichment method *(2)* was used for *Salmonella* spp. A two-step broth enrichment procedure *(17)* was used for *Listeria* spp., with the second broth being incubated for 40 to 48 h and then streaked for isolation onto modified Oxford medium *(17)* and lithium chloride phenylethanol moxalactam agar (Difco Laboratories, Detroit, MI) for isolation of the organism *(9, 16)*. *Escherichia coli* O157:H7 was isolated and identified by the procedure of Okrend et al. *(18)*. Aerobic plate counts *(19)* and *E. coli* Biotype I most probable numbers *(13)* were determined according to standard procedures. Colony-forming units per gram were converted to colony-forming units per cm^2 by multiplying the count by the sample weight and dividing by the fascia surface area of the sample. The sensitivities of the pathogen detection methods were 0.05 and 0.03 organisms per cm^2 for stomached and blended samples, respectively.

TABLE 2. *Relationship between visual scores and level of contamination on the carcasses*

Numerical visual score	Visual score description
5	Very visible; 4.84 cm^2; green to black in color
4	Obviously visible; 3.23 cm^2; green to black in color
3	Plainly visible smear of fecal material, 4.84 cm^2; or mass of fecal material, 1.61 cm^2; yellow to black in color
2	Noticeable smear of fecal material, 3.23 cm^2; light in color
1	Not plainly visible smear of fecal material, 1.61 cm^2; very light in color
0	No fecal, or appearance of fecal, material present

Statistical analyses

A chi-square test was used to compare results of each test treatment to those of the control treatment for qualitative test results, with significance defined at the 95% level ($P \leq 0.05$). Analysis of variance and the least squares difference test for *post hoc* comparisons of means were used to evaluate treatments for plate count and most probable number results. These analyses were completed using STATISTICA™ for Windows rel. 4.5 (StatSoft™, Tulsa, OK). Scores evaluating visual appearance were analyzed using the same statistical procedures. A normal distribution was assumed for logarithmic transformations of the plate count and most probable number data. No statistical analyses were performed to compare plants because this was not an objective of the study.

RESULTS AND DISCUSSION

The current meat inspection system relies on visual examination to estimate the contamination status of meat animal carcasses during slaughtering and dressing. Although the scores used for evaluation of visual contamination in this experiment were subjective measurements based on an arbitrary scale (Table 2), they do provide a basis for comparison among treatments. The visual evaluation scores before application of treatments were not significantly ($P > 0.05$) different, indicating that carcasses used in the study were consistently contaminated across treatments (Table 3)—as would be expected, because they were deliberately soiled with fecal material. As expected also, the visual scores for the control samples did not change significantly ($P > 0.05$) after completion of the slaughtering and dressing procedure (before final carcass washing). Because the controls were designated as "no trim-no wash," any change in these scores would indicate some variability in the processing procedure which had not been taken into account.

The lowest numerical visual score (0.16) obtained after application of the decontamination treatments was that for the trimmed and washed (TW) samples (Table 3). This score was significantly ($P < 0.05$) lower than those obtained with any other treatment, indicating that the currently applied decontamination treatment resulted in carcasses with the least visible contamination. Trimmed (T), hot water (HW), ozone (OZ) and peroxide (PER) treatments resulted in visual scores which were higher than those for the TW treatment, but were lower ($P < 0.05$) than that achieved with washing (W) only. Conventional washing without trimming was the least effective treatment in removing visible contamination from the carcasses.

The mechanism of removing visible contamination by use of the TW treatment would appear to be a combination of physical removal by trimming, with additional removal of debris and foreign material by washing. Trimming, by itself, left some visible contamination, probably through accidental recontamination, as was indicated by the slightly higher

scores compared to TW samples (Table 3). The visual score (0.54) obtained with the HW treatment suggests that the warmer water was, in fact, more efficient than was washing with water at conventional temperature (scored at 1.14) in removing the contamination, possibly by liquefying the surface fat layer and allowing the contamination to be washed off more easily. Scores for visual contamination could, perhaps, be reduced even further with appropriate adjustments in spray-washing nozzles and pressures.

An approximate two-log-cycle reduction in aerobic bacteria was obtained by application of the TW and HW decontamination procedures, compared to the untreated (CNT) controls (Table 4). The mean microbiological populations after application of these two treatments were not significantly ($P > 0.05$) different, but were significantly ($P < 0.05$) lower than those obtained with any of the other decontamination treatments. Of particular interest was the smaller carcass-to-carcass variation, as noted by the lower standard deviation, which was obtained with the HW treatment. This observation may indicate that the HW intervention treatment is capable of providing a more uniform reduction in microflora of carcasses.

Trimming alone (Table 4), as done by industry personnel at normal slaughtering speeds (100 to 400 carcasses per hour, depending upon the particular plant) and operating practices, reduced contamination by approximately 1.3 log CFU/cm^2. The lower microbiological contamination detected on trimmed samples reported by Prasai et al. *(21)* was due to the fact that trimming in that study *(21)* was conducted on stationary carcasses under aseptic conditions with a sterile knife, and the trimmed area was sampled for microbiological analysis immediately after trimming. In the present study, carcasses were trimmed by regular plant personnel as they moved on the slaughterline at normal speeds, and the trimmed areas were not sampled for microbiological analysis until they reached the final trimming rail of the slaughtering process. Thus, we believe that these results, representing six plant operations, are indicative of current industry practices.

TABLE 3. *Visual scores for cleaniness of intentionally contaminated carcasses before and after application of decontamination treatments*

Treatment[a]	Mean visual score[b]	No. carcasses treated	SD of mean
Before treatment			
Control (CNT)	3.51A	144	0.65
Trimmed (T)	3.47A	144	0.50
Washed (W)	3.39A	144	0.50
Trimmed and washed (TW)	3.42A	144	0.49
Hot-water washed (HW)	3.33A	48	0.52
Hydrogen peroxide (PER)	3.47A	47	0.50
Ozone (OZ)	3.52A	48	0.55
After treatment			
Control (CNT)	3.44A	144	0.70
Trimmed (T)	0.47D	144	0.88
Washed (W)	1.14B	144	0.78
Trimmed and washed (TW)	0.16E	144	0.35
Hot-water washed (HW)	0.54D	48	0.46
Hydrogen peroxide (PER)	0.85C	47	0.68
Ozone (OZ)	0.66CD	48	0.55

[a] See text and Table 1 for a description of treatments.
[b] Means within a scoring time followed by different letters are different ($P < 0.05$).

TABLE 4. *Populations of aerobic bacteria and* Escherichia coli *Biotype I on beef carcasses which were intentionally contaminated and then decontaminated with specific intervention treatments*

Bacteria counted (treatment[a])	Mean counts[b]	No. carcasses treated	SD of mean
Aerobic plate count			
(Control, CNT)	4.20A	142	1.32
(Trimmed, T)	2.88C	142	1.10
(Washed, W)	3.24B	144	1.15
(Trimmed and washed, TW)	2.35D	144	0.99
(Hot-water washed, HW)	2.20D	46	0.69
(Hydrogen peroxide, PER)	3.06BC	48	1.09
(Ozone, OZ)	2.90BC	48	1.04
E. coli Biotype I			
(Control, CNT)	2.23A	142	1.22
(Trimmed, T)	0.62C	142	0.69
(Washed, W)	1.19B	144	0.99
(Trimmed and washed, TW)	0.56C	144	0.59
(Hot-water washed, HW)	0.41C	48	0.28
(Hydrogen peroxide, PER)	1.25B	47	0.80
(Ozone, OZ)	1.09B	48	0.90

[a] See text and Table 1 for a description of treatments.
[b] Aerobic plate counts, CFU/cm^2; *E. coli,* MPN/cm^2. Means followed by different letters are statistically different ($P < 0.05$).

The mechanism of removal of contamination by the TW treatment is clear, because trimming physically removed most of the visually apparent contamination, while washing removed some of the residual microorganisms present. The identification of the mechanism by which other intervention systems reduced bacterial populations may be somewhat tenuous, because of the technical differences in application of the treatments at individual plants. Nevertheless, the mean bacterial populations obtained after hot-water washing were significantly ($P < 0.05$) lower than those obtained after conventional washing, indicating that there was a beneficial effect of the use of hot water. The hot water could be more efficient in physically removing contamination, as was suggested above, or there could be some heat injury or death of the bacteria because of the higher water temperature. Preliminary data have suggested that hot-water washing can be effective in reducing bacterial populations on beef carcasses *(3),* although the technical aspects (time, pressure, etc.) of washing with hot water had a substantial impact on the magnitude of the reduction. Widespread application of hot-water spray-washing in commercial establishments will require consideration of factors such as temperature-pressure-time interactions; spray-nozzle types, sizes, and configurations; potential condensate formation problems; and amount of water and heat energy needed.

Washing only, or application of ozone (OZ) and hydrogen peroxide (PER) rinses, resulted in average reductions in bacterial populations of approximately 1 log unit (Table 4). Although the application of the two chemical interventions,

OZ and PER, resulted in lower ($P < 0.05$) average microbiological populations than the control samples, the means were not significantly ($P > 0.05$) different from those achieved with conventional washing or trimming. It was interesting to note the relatively large populations of bacteria remaining on the surface after the treatments, even though the scores for visible contamination on carcasses treated by several of these interventions were quite low. The bacterial populations on the treated carcasses in the present study were in the range of those reported in the USDA-FSIS steer and heifer microbiological survey *(26),* even though the carcasses in the present study were deliberately contaminated as required by the experimental protocol.

The mean populations of *E. coli* Biotype I followed the same general trend as did the populations of aerobic bacteria (Table 4), with the lowest populations obtained with the TW, HW, and T treatments. As with the aerobic plate counts, the HW treatment resulted in the least carcass-to-carcass variation, as was indicated by the lower standard deviation. Although the trimming-only (T) treatment resulted in statistically ($P < 0.05$) lower populations of aerobic bacteria than the W treatment and higher than the TW treatment, T was not significantly ($P > 0.05$) different from TW for *E. coli* counts. Use of these treatments (T, TW, HW) resulted in an average reduction in populations of approximately 1.7 log units when compared to the control. As was the case with the aerobic bacteria, the W, OZ, and PER treatments resulted in significant ($P < 0.05$) reductions in *E. coli* counts compared to the control.

All of the processing treatments—trimming, washing, and trimming and washing—significantly ($P < 0.05$) reduced the incidence of *Listeria* spp. and *Salmonella* spp. on the carcasses (Table 5). Trimming and washing resulted in the lowest incidence of these two bacteria of potential public health significance, although the individual treatments could not be statistically differentiated. The current industry practice of trimming and washing reduced the incidence of *Listeria* spp. from 43.7% to 12.6%, and reduced the incidence of *Salmonella* spp. from 30.3% to 1.4%. Although the initial incidence levels of these two bacteria seem high, these carcasses were deliberately contaminated to obtain sufficiently high counts for statistical analysis and are not typical of the average cattle being processed *(26).* Hot-water washing also significantly ($P < 0.05$) reduced the incidence of *Salmonella* spp. when compared to that of the control, but the reduction of *Listeria* spp. incidence was not significant ($P > 0.05$). PER and OZ treatments also reduced the incidence of pathogens and their effect should have included any residual activity, since sample analysis was conducted on the day after treatment. The total number of samples that were positive for *E. coli* O157:H7 was insufficient to compare treatments and/or to differentiate for their ability to reduce the level of *E. coli* O157:H7 contamination. However, the data suggested that none of the treatments could be relied upon to completely eliminate that pathogen (*E. coli* O157:H7) from the carcasses.

TABLE 5. *Incidence of bacteria of public health significance on samples from beef carcasses which had been intentionally contaminated and then decontaminated with specific intervention treatments*

Treatment[b]	No. samples (positive/total)[a]		
	Listeria spp.	*Salmonella* spp.	*E. coli* O157:H7[c]
Control (CNT)	62/142	43/142	1/142
Trimmed (T)	35/140*	11/142*	3/142
Washed (W)	39/143*	13/144*	1/144
Trimmed and washed (TW)	18/143*	2/144*	2/144
Hot-water washed (HW)	15/45	1/46*	0/46
Hydrogen peroxide (PER)	16/47	15/47	0/47
Ozone (OZ)	11/48*	19/48	0/48

[a] Treatment values within a genus marked with asterisks (*) are significantly ($P < 0.05$) different from the control treatment value.

[b] See text and Table 1 for a description of treatments.

[c] *E. coli* O157:H7: insufficient number of positive samples to determine treatment differences.

Conclusions

The current industry practice of trimming and washing of beef carcasses consistently resulted, in this study, in low bacterial populations and visual scores for fecal contamination. The data also demonstrated that hot-water washing may be an effective intervention strategy in reducing bacteria on beef carcasses, especially in producing more consistently low bacterial populations among carcasses by reducing the carcass-to-carcass variation. Ozone and hydrogen peroxide treatments, as applied in this study, had only minor effects and were approximately equivalent to conventional washing in reducing bacterial populations on beef.

ACKNOWLEDGMENTS

The authors would like to acknowledge the financial support of the Beef Industry Council and the Cattlemen's Beef Research and Promotion Board. The authors would also like to thank the following individuals for their contributions to this project: B. Gorman, G. Hilton, C. Kukay, and L. Cabedo, Colorado State University; C. Collins, S. Neibhur, and R. Tarte, Iowa State University; Dr. E. A. Boyle, V. McCart, Dr. R. K. Phebus, Dr. R. K. Prasai, C. Garcia, L. Bohra, and X. Liu, Kansas State University; Dr. J. Wellbourn and Dr. M. Curiale, Silliker Laboratories Group, Inc.; L. M. Lucia, J. C. Cunningham, S. D. Harris, and M. D. Hardin, Texas A&M University; Dr. S. Ingham, A. Patterson, S. Rasch, and J. Schoonmaker, University of Wisconsin.

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