RELATIVE CLEANABILITY OF VARIOUS FINISHES OF STAINLESS STEEL IN A FARM BULK TANK[1, 2]

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No significant difference was found in the relative cleanability of Nos. 2B, 3, 4, and 7 stainless steel finishes as measured by bacteriological tests. Therefore, it can be concluded that from a bacteriological cleanability standpoint, based on the conditions of this study, the selection of a stainless steel finish from among those used in these studies for a farm bulk tank or any comparable piece of equipment should be based on factors other than bacteriological cleanability.

The relative cleanability of the stainless steel used in sanitary equipment is of great importance to sanitarians, food processors and equipment manufacturers. Hays *et al.* (4) and Kaufmann *et al.* (5) studied the removal of air-dried films of milk inoculated with bacteria under laboratory conditions. Hays *et al.* (4) observed from 99.99 to 100% removal of *E. coli* from 18-8 stainless steel having 2B, 7 mill, 80, 100, and 120 grit surfaces after manual scrubbing for 15 seconds with an alkaline cleaner at room temperature. Kaufmann *et al.* (5) used the Direct Surface Agar Plate test (2) to detect spores of *B. globigii* which remained on the surface after washing; no significant difference in bacterial cleanability at the 5% level was noted after a minimum spray-washing for 2 seconds with an alkaline detergent at 161±3°F. The present study was undertaken under controlled field conditions of soiling and cleaning using a farm bulk tank fabricated from Type 302 stainless steel having Nos. 2B, 3, 4, and 7 finishes.

Materials and Methods

Description of Tank

A 200-gallon round-bottom farm bulk tank of standard basic design was constructed with a lining of Type 302 stainless steel having Nos. 2B (bright, cold-rolled), 3 (80-100 grit), 4 (120-150 grit), and 7 (325 grit plus buffing) finishes. The tank was constructed in such a manner that each side-wall contained a section of each finish 13.75 in. wide. End-walls were fabricated so that one contained a 2B and 3 finish and the other a 4 and 7 finish (Fig. 1). The welded areas joining the individual sections had a polish equivalent to a No. 4 finish.

Soiling and Cleaning

Soiling and cleaning conditions were designed to approximate those used in actual practice and controlled so the results could be interpreted statistically.

In the initial series of tests, plant water having a hardness of 200 p.p.m. was used for all cleaning procedures; in the second series a water with a synthetic hardness of 370 p.p.m. was employed (3). Attempts to increase the hardness beyond this level resulted in the precipitation of the salts from solution. A commercial chlorinated alkaline detergent was used at the recommended level in the initial series. In the second series of tests using a synthetic water of 370 p.p.m. hardness, the same cleaning compound was used at 1/3 the level. Reducing the detergent level might encourage relative differences in cleanability to appear.

The farm bulk tank was filled with cold, raw milk to within 1.5 in. of the top. After standing for 30-36 hours at 36°F. to simulate actual farm holding practices, the tank was emptied. Within 1/2 hour after draining the tank, all interior surfaces were rinsed with water at 125°F. A spray-arm consisting of a 12-inch section of 1.5-inch stainless steel tube with

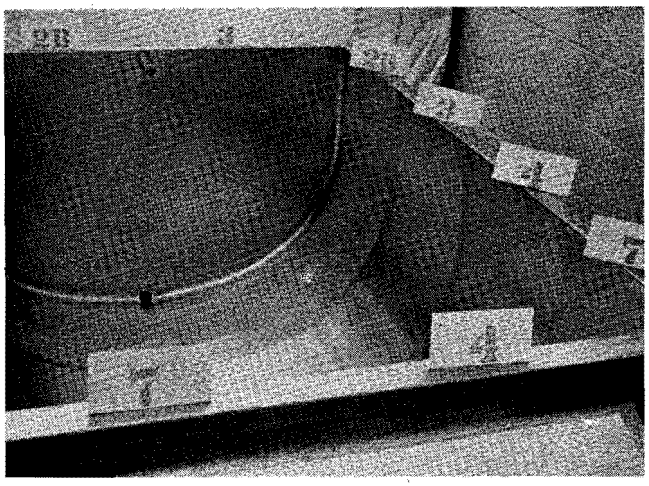

Figure 1. View of farm bulk tank showing finishes on side and end walls.

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two lines of staggered holes, 1/16 in. in diameter and 1/4 in. on center, was used to deliver an evenly dispersed, non-turbulent stream of water at a rate of 2 gal. per minute. Rinsing was carried out by holding the unit 2 in. from the wall of the tank at a point just above the cream line and allowing the water to flow over each section for 15 seconds. This rinse removed all of the visible milk soil except the cream line.

After rinsing, the tank was brushed with a nylon-bristle, can-washing brush. The handle of the brush was removed to enable the operator to grasp the brush with the palm of the hand and thereby exert a uniform pressure on the soiled surface of the tank. A cleaning pattern using one stroke (across and back) adjusted to include the width of two panels, constituted the brushing procedure. The brush was immersed in detergent at 125°F. after each stroke. A final flushing similar to the initial rinsing operation was used to remove residual detergent.

To encourage soil build-up the end-walls of the tank were rinsed and sanitized but not brushed with detergent after soiling. After 12 soilings, each end was examined using bacterial and visual techniques. The end-walls were then scrubbed with detergent to remove the nutrient broth which remained after bacteriological testing.

To equalize the exposure to the sanitizing agent, each test surface was fogged with 200 p.p.m. of chlorine solution; after one minute the residual chlorine was inactivated by a one-minute fog-rinse with sterile 10% sodium thiosulfate solution. The surface was bacteriologically tested immediately following this procedure.

Testing

A standard swab contact test (*1*) using a 40-square inch area and a large swab test based on a 120-square inch area were used to determine the residual bacteria. Tests were undertaken immediately after rinsing (T-1); rinsing, washing-flushing (T-2); and rinsing, washing-flushing, and sanitizing (T-3). After each treatment (T-1, T-2, T-3) the tank was completely covered with four individual sections of sterile cloth to eliminate air-borne contamination of the interior. All surfaces except the particular area under examination remained covered prior to testing. During the actual test period the immediate area was covered with a sterile rubber template to eliminate air-borne contamination and to clearly locate the specific area. After T-1, from 1 to 3 hours elapsed before bacteriological testing was undertaken. After T-2 and T-3, no time elapsed before testing.

The test pattern used on each finish is shown in Fig. 2. The standard swab test (SS) was made after rinsing (T-1) and after sanitizing (T-3) on the areas

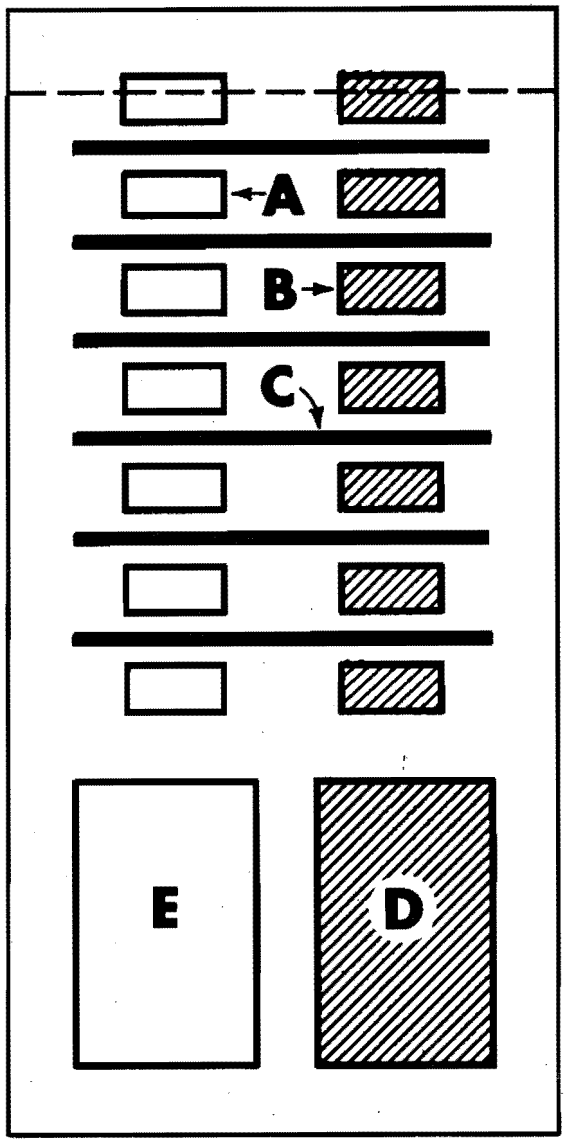

Figure 2. Schematic diagram showing the layout of the test areas examined on each sidewall section. (A) SS after rinsing, (B) SS after sanitizing, (C) SS after washing, (D) LS after sanitizing (E) LS after rinsing. Dotted line represents cream line.

indicated by the small rectangular outlines. Seven of the small rectangular areas provided 40 sq. in. A sterile removable flap covered each individual rectangular area while it was not actually being examined. After detergent washing (T-2), the standard swab test was made on another 40-square inch area as outlined by the long, thin rectangles in Fig. 2. To study a greater area, the large swab test (LS), utilizing 120 sq. in., was made after T-1 and T-3. The arrangement of the test areas was designed to insure that each area was swabbed only once in any single trial.

The large swab was rolled on a 6-inch, round applicator stick. The swab, *per se*, was 140 mm. long and

TABLE 1 — BACTERIA COUNTS PER 40 SQUARE INCHES OF SURFACE AFTER VARIOUS CLEANING TREATMENTS USING THE STANDARD SWAB TEST

Trial No.	SPC[a] (per ml. x 100)	After rinsing[b] (T-1) Finish No.				After washing (T-2) Finish No.				After sanitizing (T-3) Finish No.			
		2B	3	4	7	2B	3	4	7	2B	3	4	7
1	100	42[c]	9	14	13	14	20	73	1	0	3	5	0
2	23,000	78	79	65	232	8	16	28	19	2	6	3	3
3	11,000	84	2678	146	170	19	7	78	41	2	22	6	1
4	590	30	22	22	22	16	6	12	19	6	106	4	6
5	5500	60	70	251	138	11	35	26	6	10	2	7	4
6	260	59	82	71	201	80	26	12	26	3	4	2	1
7	140	954	165	57	45	102	28	9	1	0	1	0	16
8	5700	31	22	19	171	15	44	4	16	0	2	1	0
9	31	181	156	256	95	28	65	149	133	1	3	2	4
10	—	166	29	13	109	58	12	16	37	2	3	3	1
11	54	34	91	32	130	344	418	305	186	10	0	15	233
12	—	55	38	52	271	18	10	3	8	1	0	0	0
Av.	—	148	287	83	129	59	57	68	41	3	17	4	22

[a]SPC of milk in the tank just prior to draining.

[b]The hardness of the water was approximately 370 p.p.m. in all treatments.

[c]Average of two replications.

approximately 21 mm. in diameter. Sterilization was accomplished by autoclaving in a 6-inch test tube containing 10 ml. of distilled water to moisten the cotton for proper swabbing. The swab stick was removed from the tube and grasped along the entire length of the swab with large sterile flat-faced forceps; by grasping in this manner it was possible to exert a uniform pressure over the entire length of the swab while testing the area. The portion of the stick handled in transfer was removed with sterile clippers. The swab was drawn over the test area three times and placed in a 500 ml. prescription bottle containing 50 ml. of nutrient broth. The bottles were shaken 20 times, and 10-, 5-, and 1-ml. volumes were plated in duplicate using standard plate count agar. All counts were made after incubation at 95°F. for 48 hours. The data were tested using an analysis of variance.

RESULTS AND DISCUSSION

The bacteriological results obtained with the standard swab contact test and the large swab test are given in Tables 1 and 2, respectively. The analysis of variance of these data indicates no significant difference at the 5% level in bacteriological cleanability of the 2B, 3, 4, and 7 finishes after rinsing, regardless of the hardness of the water, the level of detergent or the test employed.

Analysis of variance of the bacteriological results after rinsing, washing-flushing of the 2B, 3, 4, and 7 finishes indicated no significant difference at the 5% level in bacterial cleanability among these surfaces.

After rinsing, washing-flushing, and sanitizing, no significant difference in bacterial cleanability was noted at the 5% level among 2B, 3, 4, and 7 finishes with the standard or large swab test. The sanitizing process reduced the number of residual bacteria to approximately the same level on all finishes within any one testing procedure.

The standard swab contact test was compared with the large swab test, corrected to a 40-square inch basis, using an analysis of variance. No significant difference between these two test procedures was observed based on the data obtained after rinsing. After sanitizing, a significant difference was observed when these two testing procedures were compared. The lack of correlation between these procedures under the conditions prevailing after sanitizing is due to the fact that more bacteria are present after rinsing than after sanitizing. With the former treatment each 40-square inch area is representative of the total contamination; swabbing a large area, therefore, does

not alter the results. Under the latter treatment, the bacterial level is greatly reduced, and each 40-square inch area is not representative of the overall surface contamination. In this instance the larger area covered by the large swab test provided a more satisfactory indication of the actual surface contamination. The total area examined by both tests comprised 70% of the total soiled area available (standard swab 23%, large swab 47%).

The bacteriological findings were compared with the recommended maximum standard as described in *Standard Methods for the Examination of Dairy Products* (*1*). After rinsing, results obtained with the standard swab test compiled 96, 96, 100 and 96% of the time with the 2B, 3, 4, and 7 finishes, respectively. In the previous laboratory study (5), compliance was observed 56, 63, 53, and 38% of the time with the four finishes. The deliberate attempt to minimize the removal of bacteria under laboratory conditions is undoubtedly responsible for the difference. After T-2, in the bulk tank study, compliance was obtained 96, 96, 96, and 100% of the time with the 2B, 3, 4, and 7 surfaces, respectively. Compliance under the conditions of the laboratory trials (5) was observed 100% of the time. Compliance was also obtained 100% of the time following a complete cleaning cycle of rinsing, washing-flushing and sanitizing. Similar findings were noted in the laboratory study.

A decrease in bacteria count was observed in all cases as the cleaning cycle progressed from treatments T-1 to T-3. Based on grand average values, detergent washing decreased the bacteria count from that obtained after rinsing by 65%. Sanitization reduced the count obtained after washing by 80%. These data indicate the desirability and need for adherence to the complete cleaning cycle to achieve maximum bacterial destruction.

From the results of the bacteriological studies, it is apparent that the Nos. 2B, 3, 4, and 7 finishes can be cleaned equally well with respect to bacterial removal. These findings are in agreement with earlier studies (5) carried out using a laboratory spray-washing device.

The experimental design which permitted improper cleaning (never brushed with detergent) of the end-walls of the tank made visual observation of build-up possible. To demonstrate the presence of the film on the unwashed end-walls, a strip on each end panel was treated with a slurry of a chlorinated alkaline cleaner; the contrast between the area where the film was removed and the uncleaned surface is shown in Figure 3. This film, produced after only rinsing and sanitizing twelve times in a period of 24 days, was not readily detected prior to cleaning the

TABLE 2 — BACTERIAL COUNTS PER 120 SQUARE INCHES OF SURFACE AFTER VARIOUS CLEANING TREATMENTS USING THE LARGE SWAB TEST

Trial No.	SPC[a] of milk (per ml. x 100)	After rinsing[b] (T-1) Finish No.				After sanitizing (T-3) Finish No.			
		2B	3	4	7	2B	3	4	7
1	100	1508[c]	653	95	113	227	8	19	17
2	23,000	933	315	565	2035	11	21	77	56
3	11,000	900	783	923	1265	35	12	27	105
4	590	185	255	318	413	97	76	18	266
5	5500	783	645	328	228	847	334	8	37
6	260	1200	150	633	1573	80	340	42	33
7	140	351	111	267	602	449	85	0	64
8	5700	1188	1170	230	493	47	17	158	474
9	31	428	838	1520	665	50	38	22	22
10	—	105	578	135	370	215	94	50	213
11	54	830	203	303	320	43	253	638	1474
12	—	225	948	353	505	83	49	31	489
Av.	—	837	563	472	715	182	110	92	270

[a]SPC of milk in the tank just prior to draining.

[b]The hardness of the water was approximately 370 p.p.m. in all treatments.

[c]These values are the average of two replications.

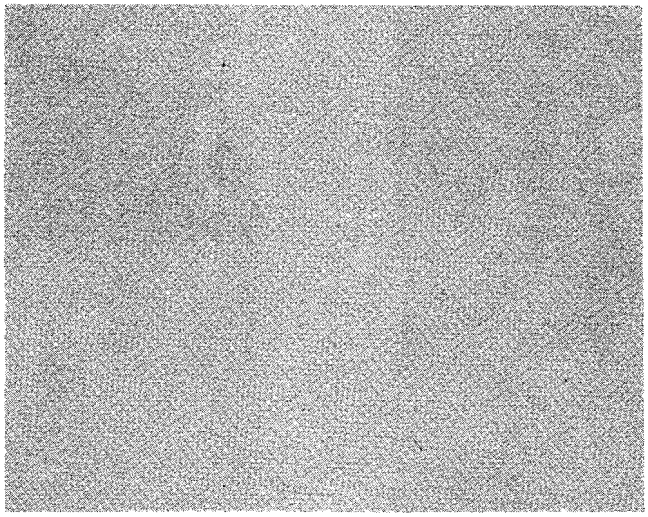

Figure 3. The film of soil shown on this finish is typical of that observed on all finishes after only rinsing and sanitizing for 12 trials. The film of soil is clearly visible in contrast with the cleaned strip in the center.

strip with detergent. It is significant that all finishes of the improperly cleaned end panels showed visual soil when cleaning was limited entirely to rinsing and sanitizing, whereas no build-up was observed on the various surfaces which were brushed with a detergent solution. The film, which showed slight fluorescence when examined with ultraviolet light, may be the start of milkstone formation (*6*). In these studies as in previous work (*6*), an organic acid cleaner failed to remove the film from the finishes after it had formed.

There was no significant difference in the bacterial count on the finishes incorporated in the end-walls even though there was soil build-up. In considering the relative cleanability of stainless steel finishes, the authors theorize that once the stainless steel surface has been covered with a layer of soil, the original surface can no longer affect the rate of build-up which, under identical conditions, should be equal for all dirty surfaces.

A quantitative comparison of the amount of film on each finish was not possible as suitable instruments are not available for objectively measuring the thickness of these films. Visual subjective measurements require careful interpretation because of the difference in the basic reflectance of the various finishes and because soil changes the relative reflectance of the finishes. Preliminary studies on the visual estimation of soil indicate that stainless steel with 2B, 3, 4, and 7 finishes with equal amounts of soil will not appear to be equally soiled when subjectively evaluated. Consequently, the authors believe that the evaluation of the sanitary condition of food handling equipment on the basis of visual appearance is subject to question, especially when the film of soil is very thin and uniformly deposited.

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