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RELATIVE CLEANABILITY OF STAINLESS STEEL TUBING AND MILK DISPENSER CANS HAVING VARIOUS FINISHES[1]

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INTRODUCTION

THE CLEANABILITY OF STAINLESS STEEL surfaces in contact with milk during handling and processing is of importance to the dairy industry, public health officials, detergent manufacturers, and others. Until recently, the role of the finish, with respect to cleanability, has been studied almost entirely by observing the visual appearance of the surface.

This study is a continuation of an exhaustive investigation which was undertaken to determine the relative cleanability of various stainless steel finishes used in the fabrication of five representative types of milk processing equipment. Specifically, the purpose of this study was two-fold: (a) to ascertain the relative cleanability of stainless steel tubing finish that approximates No. 2 (bright annealed), 4 and 7 of sheet finishes used to handle hot and cold milk and (b) to make the same evaluation of a No. 2B, 3, 4 and 7 finish on stainless steel milk dispenser cans. The trials were conducted under carefully observed plant operating conditions using commercial equipment and recommended cleaning procedures.

Previous reports indicate there is no significant difference in relative bacterial cleanability of No. 2B, 3, 4 and 7 finishes in laboratory trials using 8 x 8-inch panels (2), high temperature short time pasteurization unit (HTST) and a pasteurizing vat (3), and farm bulk tank (4). Masurovsky and Jordan (5) have reported total average residual equivalent bacterial populations of 520, 510, 510 and 480 on No. 2B, 3, 4 and 7 finishes of stainless steel, respectively. On the basis

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of a Chi Square Test applied to these data no significant difference in cleanability is indicated.

EXPERIMENTAL

Description of Equipment

Cans. Six cans of each finish containing sidewalls having a No. 2B, 3, 4 and 7 finish were used in this study. The area tested comprised the sidewall since the bottom, shoulder and neck were drawn from the same finish but might not be equivalent to the test surfaces under the study. To minimize the variations contributed by the welded areas, seams were polished comparable to a No. 4 finish.

Pipelines. One and one-half inch stainless steel tubing with representative finish that approximates No. 2 (bright annealed), 4 and 7 of sheet finishes was used in these trials. For the cold milk tubing studies, two sections of each finish, 8 to 12 feet long, were placed in the regular lines between the storage vats (receiving) and the balance tank ahead of the HTST press. For hot milk lines the holding tube of a HTST system was used. Duplicate sections, 51 in. long of each finish were placed in this unit.

Soiling Procedures

Cans. The cans were soiled by filling with cold (40°F) pasteurized, homogenized milk that had been standardized to 3.5 percent milk fat. After standing for 2 minutes, the cans were emptied, inverted and drained for 10 minutes. To assure a high level of bacterial contamination, comparable to that which might occur under some commercial conditions, the cans were stored for 18-24 hours at 98°F.

Pipelines. The stainless steel tubing was substituted for sections of the regular sanitary pipeline in the M.S.U. Dairy Plant. The cold raw milk line was soiled by pumping whole milk or skim milk at 38-42°F through the system for 5 to 7 hours each day. The flow rate was approximately 7500 pounds per hour. The cold milk line was in use 4 months before testing was initiated. Hot milk soiling was accomplished by replacing six sections of the holding tube with the test tubing. The flow rate was 7500 pounds per hour for a period of 5 to 6 hours. The temperature of the milk in the holding tube was approximately 165°F. This unit was in operation for 2 months prior to beginning the bacteriological examination.

Cleaning Procedures

Cans. The water used in all studies was approximately 10 ppm in hardness. A straight-line can washer was used to clean the cans. The cleaning cycle consisted of several steps — prerinse, wash, flush, hot water rinse, steaming and hot air. The washer was fed at the rate of six cans per minute, the maximum rate recommended by the manufacturer.

In the first step the cans were prerinsed with a jet of water at 55°F. for 14 seconds at the rate of 155 g.p.h. This treatment seemed to remove loose soil effectively as indicated by the visual appearance of the rinse water at the end of the rinsing. In the second step the cans were washed with a chlorinated alkaline detergent solution (1 oz per 3 gal. water) at 160-165°F. for 11 seconds. In this treatment the flow rate was 1,440 g.p.h. Automatic feeder systems were used to maintain the alkalinity and chlorine levels at 2,500 and 240 ppm, respectively. Immediately after washing the detergent solution was flushed from the can using hot water at 170°-175°F. Flushing was carried out for 12 seconds at the rate of 1750 g.p.h. Another water rinse at 200°-205°F. was given for 12 seconds. The cleaning treatments described in the preceding steps constitute T-1. The final steps in the cleaning cycle consisted of steaming for 12 seconds and then blowing filtered air at 225°F. into the can for 12 seconds at the rate of 25 c.f.m. Cans receiving all the treatments are referred to as T-2.

Pipelines. The cold raw milk pipelines were cleaned on a separate circuit by a cleaned in place (CIP) method. The line was prerinsed for 3 minutes with water at 115-125°F. Detergent washing was accomplished by recirculating a commercial alkaline cleaner (1 oz. per gal.) for 15 minutes at 160°F. After six soilings, an acid detergent (1 oz. per 2 gal.) was used in lieu of the alkaline solution. After washing, the detergent was drained and the tubing flushed for 3 minutes with water at 115-125°F. Bacteriological tests were undertaken immediately on the cold milk lines without sanitization.

The hot milk line was cleaned as part of a circuit that included the HTST press, flow diversion valve, steam infuser, vacuum chamber, homogenizer, and connecting pipeline. Upon completion of processing, the line was prerinsed for 10 minutes with water at 162°F. An acid detergent solution at 175°F (5 pints in 70 gal.) was recirculated for 30 minutes. Following this, a slurry of an alkaline detergent, in the proportion of 5 lbs. per 70 gal. of solution was added directly to the acid solution. Recirculation at 175°F. was continued for 30 minutes. The wash solution was flushed from the system with water at 162°F for 15 minutes. The surfaces were tested 16 to 18 hours after washing, but before sanitizing.

Testing Procedures

Cans. Modified rinse and swab techniques were used to evaluate the bacteriological cleanability of each can. In the rinse test (1), 500 ml of sterile phosphate buffer (pH 7.0) was added aseptically to each can. The area exposed in the rinse test was 600 square inches; this represents the entire surface of the sidewall. In testing, the can was placed horizontally on rollers and rotated at 35 r.p.m. for 4 minutes to provide complete coverage of the surface and some agitation. This speed was selected as it provided some turbulence and agitation of the rinse solution to aid in the removal of bacteria on the sidewall. At the end of the 4-minute period, the rinse solution was aseptically returned by a closed system to the original container and held at 39°F. until plated. Standard plate count agar containing 0.5 percent additional agar was used to prepare five plates, each containing 10 ml of rinse solution. Counts were made after incubation at 98°F. for 48 hours. A series of three cans of each finish was tested after treatments T-1 and T-2. The results in Table 1 are expressed as the total number of bacteria recovered per can (500 ml. of rinse solution).

A modified swab test using a large swab as described by Kaufmann *et al* (4) was also used to study the bacterial cleanability of the dis-

TABLE 1—Bacterial counts of can surface after various cleaning treatments—rinse test

(600 square inches)

Trial number	After washing (T-1) Finish of stainless steel				After steaming and hot air drying (T-2) Finish of stainless steel			
	2B	3	4	7	2B	3	4	7
1..........	(a)220	(a)300	(a)277	(a)227	(a)266	(a)313	(a)440	(a)147
2..........	147	310	183	123	70	310	73	157
3..........	423	563	140	523	83	47	70	143
4..........	160	223	137	140	53	93	73	50
5..........	110	143	130	160	53	170	50	60
6..........	123	63	73	133	36	93	67	87
7..........	127	193	113	190	30	60	70	160
8..........	77	110	113	357	23	40	60	60
9..........	73	137	87	347	33	50	40	43
Grand Average.	161	223	139	241	72	127	106	101

(a) These values represent the average of three replications.

penser can. A 5-inch strip around the circumference of the can was tested in this study; this represented 200 sq. in. The moistened swab was rubbed over the test area three times and placed in a 500 ml bottle containing 50 ml of sterile phosphate buffer. The bottle was shaken 25 times and duplicate 10 ml samples were plated using the same medium as above. Counts were made after incubation at 98°F. for 48 hours. The results shown in Table 2 are expressed as the number of organisms recovered from 200 sq. in.

TABLE 2—Bacterial counts of can surface after various cleaning treatments—swab test

(200 square inches)

Trial number	After washing (T-1) Finish of stainless steel				After steaming and hot air drying (T-2) Finish of stainless steel			
	2B	3	4	7	2B	3	4	7
1..........	(a)22	(a)32	(a)19	(a)13	(a)40	(a)19	(a)53	(a)51
2..........	97	146	132	75	70	143	98	70
3..........	150	183	75	228	57	55	75	115
4..........	29	47	29	37	46	58	49	31
5..........	21	33	46	44	30	44	67	13
6..........	29	13	19	41	15	16	17	22
7..........	40	31	37	45	22	84	75	24
8..........	12	25	15	17	7	13	21	17
9..........	25	47	36	21	40	29	25	52
Grand Average.	48	62	45	58	36	51	53	44

(a) These values represent the average of three replications.

Pipelines. The number of bacteria remaining on the surface of the hot and cold lines were determined by a rinse test. In making this test the clamps at the unions were removed and the fittings swabbed with alcohol and flamed to reduce the possibility of contamination from these sources. Immediately after flaming, the ends of each tube were plugged with sterile rubber stoppers. One rubber stopper was fitted to permit 500 ml of sterile rinse solution to be added aseptically. To assist in removing organisms from the interior surface, the tubing was rotated and manipulated in such a manner that the solution flowed to each end 60 times in about 3 minutes. The pipe also was held horizontally and shaken 120 times through an arc of 8 inches in 1 minute.

Following this, the tube was again rotated and manipulated as described above. The rinse solution was drained into the original container under aseptic conditions. One hundred milliliters of the rinse solution was plated, using 10 ml. in each of 10 plates. Standard plate agar was used with an additional 0.5 percent agar. The incubation temperature was 90°F. The results shown in Table 3 are expressed as number of organisms per 40 sq. in. of tubing.

TABLE 3—Bacteria counts on cold milk lines with the rinse test(a)

(Based on a 40 sq. in. area(b))

Trial number	Finish of stainless steel		
	2	4	7
1	208	276	216
2	26	44	66
3	36	20	120
4	21	14	38
5	22	30	1
6	64	2	432
7	112	316	120
8	124	8	96
9	292	168	184
10	72	14	68
11	52	64	36
12	59	91	6
13	95	158	54
14	22	40	31
15	20	38	19
16	32	2	15
17	20	18	18
Average	75	76	89

(a) All counts made prior to sanitization.
(b) Suggested maximum standard is 500 per 40 square inches.

RESULTS AND DISCUSSION

Cans. The bacteriological results obtained with the rinse test and the large swab test are given in Tables 1 and 2, respectively. These data represent the average value based on the results obtained from three different cans of each finish. An analysis of variance was used to test the relative bacterial cleanability of the various finishes after comparable conditions of soiling and cleaning. On the basis of the rinse test, an analysis of variance of the individual replications indicated no significant difference at the 5 percent level in the cleanability of a No. 2B, 3, 4 and 7 finish after cleaning treatments T-1 or T-2. Similar findings were observed with the swab test. It is im-

TABLE 4—Bacteria counts on tubing soiled by hot milk(a)

(Based on a 40 sq. in. area(b))

Trial number	Finish of stainless steel		
	2	4	7
1	7(c)	14(c)	12(c)
2	5	12	18
3	5	9	14
4	16	25	73
5	50	45	55
6	19	21	19
7	14	23	23
8	9	22	18
9	25	34	41
10	14	25	23
Average	16	22	29

(a) All counts made prior to sanitization.
(b) The maximum recommended standard is 500 per 40 square inches.
(c) These values represent the average of two replications.

portant to note that in the rinse test the entire 600 sq. in. comprising the sidewall are examined, whereas, with the swab test only 200 sq. in. of surface are evaluated.

On the basis of the rinse test, the grand average bacterial counts on the No. 2B, 3, 4 and 7 finish were 161, 223, 139 and 241 per sidewall, respectively, after washing (T-1). After treatment with steam and drying (T-2), the grand average counts on the above finishes were 72, 127, 106 and 101, respectively. With the swab test, the grand average counts on these finishes after treatments T-1 and T-2 were 48, 62, 45 and 58, and 36, 51, 53 and 44, respectively. The counts obtained after swabbing represent the bacteria actually removed due to the scrubbing action of the swab procedure as well as the microorganisms present in the residual film of rinse solution which remained after draining. The organisms contributed to the swab test from the residual rinse were calculated to be in the order of 10 per test area. This represents from 15-20 percent of the value given in Table 2. The additional number recovered by the swab test is important and for these trials indicates the possible superiority of the swab test over the rinse procedure.

If one assumes homogeneous distribution of soil, it is possible to convert the data obtained with the swab test on 200 sq. in. to include the entire sidewall (600 sq. in.). On the basis of the counts given in Table 2, these calculated average values are 142, 186, 136 and 174 after T-1 and 109, 165, 160 and 132 after T-2. Coincidently, the values obtained with the swab test calculated to 600 sq. in. of surface compare favorably with those obtained with the rinse test.

In actuality, however, the swab test was undertaken on a portion of same surface after the rinse test had been completed. Since the swab test represents an additional test done on a portion of the same surface, it follows that the results of the two tests are cumulative. This final total represents the total calculated number of bacteria recovered from the sidewall. After washing, the calculated total average counts on No. 2B, 3, 4 and 7 finish were 305, 409, 274 and 415, respectively. After steaming and drying these values were 180, 280, 265 and 233, respectively. Compliance with the maximum recommended standard (1) was observed on each finish incorporated in the sidewall.

Pipelines. The bacteriological data on the cold milk lines are given in Table 3. When the recommended cleaning cycle, as described above, was used, an analysis of variance indicates no significant difference in the bacteriological cleanability among the No. 2 (bright annealed), 4 or 7 finishes. The average values calculated on the basis of 40 sq. in. of surface are 75, 76 and 89 on the 2, 4 and 7 finishes, respectively, and compliance with the maximum recommended standard of 500 per 40 sq. in. was observed with all finishes.

The cold milk lines were also tested after a minimal cleaning cycle. Notwithstanding the improper cleaning treatment, an analysis of variance indicates no significant difference in relative bacterial cleanability when the No. 2, 4 or 7 finishes are compared. The grand average values, based on 22 replications, obtained on the No. 2, 4 and 7 finishes are 1197, 4394 and 3096 per 40 sq. in., respectively. Compliance with the maximum recommended standard of 500 per 40 sq. in. was observed 50, 36 and 64 percent of the time with the No. 2, 4 and 7 finishes, respectively. In studies on pipelines, Masurovsky and Jordan (5) using a limited ultrasonic cleaning technique, reported total average residual equivalent bacterial populations of 33, 37 and 30 ($X10^{-3}$) on standard surface Pyrex pipe, 120, and 180 grit stainless steel tubing, respectively. The close agreement shown in these figures may be interpreted to indicate no difference in cleanability under the conditions utilized in this experimental design.

The bacteriological results on the hot milk lines are given in

Table 4. An analysis of variance on the individual replicates indicates a significant difference at the 5 percent level in the bacteriological cleanability of the three finishes. The Multiple Range Test of Duncan indicates that the No. 7 finish is significantly different from the No. 2 and 4 finishes. The grand average bacterial counts per 40 sq. in. of surface on the No. 2, 4 and 7 finishes are 16, 22 and 29, respectively. Compliance with the maximum recommended standards was also observed 100 percent of the time.

The results obtained on the hot milk lines differ from those reported on a HTST unit and a vat pasteurizer which showed no significant difference (3). Since the HTST unit and the hot milk lines were soiled and cleaned simultaneously under the same conditions, one might expect similar results. Two factors, however, may be responsible for the difference observed: (a) a slight change in actual finish brought about in the rolling of tubing or (b) application of a different test procedure. The inefficiency of the rinse test in removing bacteria on a surface has been indicated in the can studies; the extent to which this may influence the findings requires further investigation. The difference in the results obtained in the pasteurizing vat as compared with the hot milk lines might be explained by the fact that soil deposition was variable in the former (3). This uneven deposition of soil made a comparison of surfaces difficult. In the previous studies (3), the wash procedure was sufficient to clean the most soiled surface; this may have resulted in the application of an excessive cleaning procedure on the surfaces containing less soil.

SUMMARY AND CONCLUSIONS

In testing the sidewalls of dispenser cans fabricated from stainless steel having No. 2B, 3, 4 and 7 finishes, no significant difference in bacteriological cleanability was noted.

When soiled by cold raw milk there was no significant difference in the bacteriological cleanability of stainless steel tubing finished comparable to No. 2 (bright annealed) 4 or 7 finish of stainless steel.

The results of standard plate counts on rinse tests of the same finishes when cleaned after soiling with milk at 165°F. showed no significant difference between No. 2 (bright annealed) and 4 finishes; but 7 was significantly different.

The results of this study on relative cleanability of milk tubing and dispenser cans, except for hot milk lines, confirm the results on

HTST plates and pasteurizing vat (3) and farm bulk tank (4). In all cases the influence of other factors on cleanability of stainless steel is much more important than the effect of finish.

LITERATURE CITED

1. American Public Health Association, Inc., *Standard Methods for the Examination of Dairy Products*, 10th Edition, 1790 Broadway, New York 19, N. Y. 345 pp.
2. Kaufmann, O. W., T. I. Hedrick, I. J. Pflug, C. G. Pheil and R. A. Keppeler (1960). Relative cleanability of various stainless steel finishes after soiling with inoculated milk solids. Jour. Dairy Sci. 43:28.
3. ———, (1960). The relative cleanability of dairy processing equipment having various finishes. Mich. Agr. Expt. Sta. Quart. Bul. 43:122.
4. Kaufmann, O. W., T. I. Hedrick, I. J. Pflug, and C. G. Pheil (1960). Relative cleanability of various finishes of stainless steel in a farm bulk tank. Jour. Milk & Food Tech. 23:377.
5. Masurovsky, E. B. and W. K. Jordan (1960). Removal of organisms from surfaces by ultrasonic methods. Jour. Dairy Sci. 43:1545.

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