BACTERICIDAL EFFECTIVENESS OF IODOPHOR DETERGENT-SANITIZERS[1]

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The bactericidal properties of an iodine liquid and an iodine powder detergent sanitizer were found to be practically equal. At 25 ppm. of available iodine both products compared favorably with 100 ppm. of available chlorine in killing E. coli, S. typhosa, M. pyogenes **var.** aureus **and** Ps. aeruginosa, **in the presence of hard water, whole milk, and dishwash soil. The iodine detergent-sanitizers can be recommended for sanitizing food utensils, if field tests substantiate results of the laboratory performance tests.**

The milk and food industry is showing considerable interest in the new iodine sanitizing agents. The germicidal property of elemental iodine has been known for a long time, but the combination of iodine and a surface active agent to form an iodophor is a rather recent development. Terry and Shelanski(4), Lazarus(2), and Johns (1) have reported favorably on the germicidal properties of the iodophors.

Since surface active agents differ in the degree of their re-activity with iodine, it is logical to expect varying degrees of efficiency from the iodophors or similar products now being marketed. This study deals with the bactericidal effectiveness of two new iodine detergent-sanitizers.[2] These products are designated throughout this report as iodine liquid and iodine powder. The iodine liquid contains elemental iodine in a loose complex with certain nonionic surfactants, particularly the ethylene oxide condensates, which also act as a solubilizing medium. The iodine liquid also contains an acid, generally phosphoric, which stabilizes the iodine and enhances its germicidal properties.

The iodide powder does not contain elemental iodine; it contains iodine-iodate salts in combination with certain acids that react when dissolved to release free iodine and also similar nonionic surfactants to act as a solubilizing medium or as a carrier for the iodine.

EXPERIMENTAL METHODS

This study was planned to test the bactericidal properties of iodine liquid and iodine powder and to determine the effectiveness of calcium hypochlorite as a control material against the following organisms: *Pseudomonas aeruginosa* (A.T.C.C. No 10197), *Micrococcus pyogenes* var. *aureus* (A.T.C.C. No. 6538; F.D.A. No. 209), *Escherichia coli* (resistance equal to U.S.P.H.S. No. 198 strain), *Salmonella typhosa* (Hopkins strain F.D.A. 26; A.T.C.C. No. 6539) and *Bacillus cereus*. The iodine detergent sanitizers were tested at 12.5 ppm. and 25 ppm. available iodine concentration, whereas calcium hypochlorite was tested at 100 ppm. of available chlorine. The effect of hard water, whole milk, and dishwash soil on bactericidal efficiency also was investigated.

Bactericidal test procedure. A modification of the Weber and Black(6) method was used. The chief modifications introduced into the Weber and Black method were (a) substitution of vials (16 mm. mouth dia.) for test tubes to hold the germicidal mixture, and (b) agitation of the germicidal mixture with a glass-covered metal rod (15 mm. x 1.5 mm.), rotated by a magnetic stirrer submerged in the constant temperature bath, in place of swirling the test tubes. Percentage kill was not determined beyond 99.9999 per cent.

Determining iodine in test solution. In this study, iodine solutions of 25 and 50 ppm. (representing double-strength solutions required before mixing with the bacterial suspension) were checked by a colorimetric method before and immediately after the actual bacteriological test. Iodine in solution at very low concentration may be completely extracted with chloroform to yield a pink solution. The intensity of the color varies directly with the iodine concentration, determined with a Beckman Model B spectrophotometer. Iodate—iodide solution of known value served as standards for comparison. Iodine concentrations as low as 5 ppm. could be determined by the colorimetric method with a high degree of accuracy.

Determining hydrogen-ion concentration. The pH value of the various bactericidal solutions was determined with the Beckman, laboratory model G, pH meter, using a glass electrode, at 25° C.

Preparation of hard water. A stock solution of hard water (2000 ppm. $CaCO_3$) was prepared according to United States Navy specification 51D10.

Preparation of dishwash soil. The composition of the dishwash soil was as follows: butter 3 per cent,

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[2]"Idonyx" products supplied by the Onyx Oil and Chemical Co., Jersey City, N. J.

TABLE 1—AVERAGE CONCENTRATION OF IODINE AND CHLORINE IN GERMICIDAL TESTS

Product tested	Iodine powder (ppm. I)		Iodine liquid (ppm. I)		Ca hypochlorite (ppm. Cl)
Nominal concentration desired	12.5	25	12.5	25	100
Concentration as determined at beginning of test	12.6	25.1	12.5	25.1	100.1
Standard deviation	(±0.3)	(±0.7)	(±0.1)	(±0.2)	(±1.1)
Concentration as determined at end of test	12.5	24.9	12.3	24.9	99.7
Standard deviation	(±0.4)	(±0.6)	(±0.3)	(±0.4)	(±0.8)
Average	12.5	25.0	12.4	25.0	99.9

Note: Average time between beginning and end of germicidal test was 2 hrs. 20 min., with a maximum of 4 hrs, and a minimum of 1 hr. and 15 min.

lard 3 per cent, peanut butter 3 per cent, flour 3 per cent, dried egg yolk 3 per cent, evaporated milk 5 per cent, distilled water 80 per cent. The materials were blended in a Waring Blendor, homogenized (hand homogenizer), and then sterilized in an autoclave. The amount added to the test solutions was measured in percentage by volume.

Preparation of whole milk. One part of sterile evaporated whole milk was diluted with one part of sterile distilled water. The amount added to the test solutions was measured in percentage by volume.

PRESENTATION OF RESULTS

Although it was desirable to prepare the various bactericidal solutions at the exact strength selected, *e.g.* 12.5, 25.0, and 100 ppm., it was impractical to do so. Therefore, the values represent nominal concentrations. Table 1 gives the average concentration of iodine and chlorine at the beginning and end of the germicidal tests and also the standard deviation from the mean. The germicidal solutions were stored in glass-stoppered volumetric flasks while the bactericidal tests were made. It should be noted that the

TABLE 2—BACTERICIDAL EFFECTIVENESS OF IODINE DETERGENT SANITIZERS

Kind and concentration of product tested	Minimum time in seconds for 99.9999% kill					
	Dist. water	Hard water (500 ppm.)	1% Whole milk	1% Dishwash soil	1% Whole milk + hard water (500 ppm.)	1% Dishwash soil + hard water (500 ppm.)
	Ps. aeruginosa 103,000,000 per ml.					
12.5 ppm. Iodine powder	15	15	60	15	....	....
12.5 ppm. Iodine liquid	15	15	60	30	....	....
25 ppm. Iodine powder	15	15	15	15	15	15
25 ppm. Iodine liquid	15	15	15	15	15	15
100 ppm. Ca hypochlorite	15	15	15	15	....	....
	M. pyogenes var. *aureus* 104,000,000 per ml.					
12.5 ppm. Iodine powder	15	15	300	30	....	....
12.5 ppm. Iodine liquid	15	15	300	30	....	....
25 ppm. Iodine powder	15	15	30	15	30	15
25 ppm. Iodine liquid	15	15	30	15	30	15
100 ppm. Ca hypochlorite	15	15	30	15	....	....
	E. coli 118,000,000 per ml.					
12.5 ppm. Iodine powder	15	15	15	15	....	....
12.5 ppm. Iodine liquid	15	15	15	15	....	....
25 ppm. Iodine powder	15	15	15	15	15	15
25 ppm. Iodine liquid	15	15	15	15	15	15
100 ppm. Ca hypochlorite	15	15	15	15	....	....
	S. typhosa 99,000,000 per ml.					
12.5 ppm. Iodine powder	15	15	15	15	....	....
12.5 ppm. Iodine liquid	15	15	15	15	....	....
25 ppm. Iodine powder	15	15	15	15	15	15
25 ppm. Iodine liquid	15	15	15	15	15	15
100 ppm. Ca hypochlorite	15	15	15	15	....	....
	B. cereus 88,000,000 per ml.					
12.5 ppm. Iodine powder	>15 min.	>15 min.	>15 min.	>15 min.	.....	.....
12.5 ppm. Iodine liquid	>15 min.	>15 min.	>15 min.	>15 min.	.....	.....
25 ppm. Iodine powder	>15 min.	>15 min.	>15 min.	>15 min.	>15 min.	>15 min.
25 ppm. Iodine liquid	>15 min.	>15 min.	>15 min.	>15 min.	>15 min.	>15 min.
100 ppm. Ca hypochlorite	>15 min.	>15 min.	>15 min.	>15 min.	.....	.....

TABLE 3—HYDROGEN-ION CONCENTRATION OF IODINE DETERGENT SANITIZER SOLUTIONS.[a]
(pH at 25° C.)

Kind and concentration of product tested[b]	Distilled water	Hard water (500 ppm.)	Whole milk 1%	Dishwash soil 1%	1% Whole milk + hard water (500 ppm.)	1% Dishwash soil + hard water (500 ppm.)
12.5 ppm. Iodine powder	3.42	3.43	5.13	3.78	.....	.....
12.5 ppm. Iodine liquid	3.27	3.28	4.33	3.41	.....	.....
25 ppm. Iodine powder	3.23	3.22	3.75	3.33	3.70	3.52
25 ppm. Iodine liquid	3.00	3.00	3.51	3.02	3.32	3.05
100 ppm. Ca hypochlorite	8.95	8.79	8.18	7.52	.....	.....

[a]Average for the five organisms in the germicidal tests.
[b]Concentration means parts per million of available iodine and chlorine.

solutions were relatively stable under the conditions of the test.

Bactericidal effectiveness against non-sporeformers. Calcium hypochlorite solution (100 ppm. available chlorine) was used as a standard for comparison because 50 ppm. available chlorine as hypochlorite is the minimum concentration permitted under the *Ordinance and Code Regulating Eating and Drinking Establishments* as recommended by the United States Public Health Service(7). In actual practice, hypochlorite solutions are usually prepared at a strength of 100 ppm. available chlorine and replenished when reduced to 50 ppm. available chlorine. In the comparison of the iodine detergent-sanitizers with hypochlorite, 99.9999 per cent kill of the test organisms was taken as the end point(5).

The data obtained were too extensive to be presented in their entirety. Each product was tested once by the modified method of Mueller(3) in a preliminary survey and twice by the Weber and Black method(6). The results are summarized in Table 2, and their interpretation is based on the U. S. Public Health Service recommendation(6) that effective germicides, regardless of type, proposed for food utensil sanitizing, when tested in recommended "use" concentration should produce approximately 100 per cent kill in not more than about 30 seconds when diluted in the water actually employed in sanitizing food utensils. It will be noted from Table 2 that the iodine powder and liquid were practically equal in bactericidal effectiveness. Calcium hypochlorite (100 ppm. available chlorine) produced 99.9999 per cent kill in not more than 30 seconds for all four non-sporeforming organisms, under all conditions of the test. Both iodine detergent-sanitizers at a concentration of 25 ppm. available iodine equalled calcium hypochlorite in effectiveness as a germicide against all four non-sporeforming organisms. This was true even in the presence of hard water, whole milk, and dishwash soil. Both iodine detergent-sanitizers at a concentration of 12.5 ppm. available iodine equalled calcium hypochlorite in effectiveness against *E. coli* and *S. typhosa* under all conditions of the test. However, against *Ps. aeruginosa* and *M. pyogenes* var. *aureus*, the effectiveness of 12.5 ppm. of available iodine equalled that of calcium hypochlorite only in distilled water, and was not equal to that of chlorine in the presence of whole milk and dishwash soil. Of the four non-sporeforming organisms tested against iodine, *M. pyogenes* var. *aureus* had the greatest resistance, followed by *Ps. aeruginosa.*

Bactericidal effectiveness against a sporeformer. Table 2 indicates that calcium hypochlorite and the iodine detergent-sanitizers were not very effective against *B. cereus* two-year spores for the concentrations of bactericide and contact times employed.

Hydrogen-ion concentration. The pH values obtained on suspension of each of the five test organisms (double concentration of approximately 200 million organisms per milliliter) were as follows:

Ps. aeruginosa	7.61
M. pyogenes var. *aureus*	7.60
E. coli	7.54
S. typhosa	7.40
B. cereus	7.70

Since the pH values of the suspensions of the various test organisms did not differ greatly, the pH values of the various test solutions prepared can be reported as average values in terms of hydrogen-ion concentration for the five organisms tested (table 3).

CONCLUSIONS

Iodine liquid and iodine powder detergent-sanitizer products had equally effective bactericidal properties.

The iodine detergent-sanitizers at 25 ppm. of available iodine compared favorably with 100 ppm. of available chlorine in killing *E. coli*, *S. typhosa*, *M. pyogenes* var. *aureus*, *Ps. aeruginosa* in the presence of hard water (500 ppm. $CaCO_3$), one per cent whole milk, and one per cent dishwash soil.

At 12.5 ppm. of available iodine, the iodine detergent-sanitizers compared favorably with 100 ppm. of available chlorine in killing *E. coli* and *S. typhosa*, in the presence of hard water (500 ppm. $CaCO_3$), one per cent whole milk, and one per cent dishwash soil.

Available iodine at 12.5 ppm. compared favorably with 100 ppm. of available chlorine in killing *Ps. aeruginosa* and *M. pyogenes* var. *aureus* when tested in distilled water and in hard water. However, 12.5 ppm. of available iodine was not equal to 100 ppm. of available chlorine in killing *Ps. aeruginosa* and *M. pyogenes* var. *aureus* when tested in the presence of whole milk and dishwash soil.

According to these findings, the iodine detergent-sanitizers can be recommended for sanitizing food utensils, if field tests substantiate results of the laboratory performance tests.

REFERENCES

1. Johns, C. K. Iodophors as Sanitizing Agents. *Canad. J. of Technol.*, 32: 71-77. 1954.

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waste can below for disposal of unconsumed food waste.

b. Water Scrapping. This type of scrapping breaks down into various methods:

(1) Flush off by means of warm water streams, utilizing a special shower head and insulated, self-closing squeeze valve. For this method, the china is placed in the dish rack and the rack located over a large strainer-equipped sink.

(2) Flush off by means of warm water streams, utilizing a special shower head and insulated, self-closing squeeze valve in combination with a food waste disposer. For this method, the china is placed in dish racks and the rack located over a large recess in the soiled dish table, under which is located an electrically-driven, food-waste disposer.

(3) "Salvajor" Method. This is a trade-name of a device which combines water scrapping and soil collection. The dishes are held under a stream of water of sufficient force to flush off gross soil, with a minimum of splashing. The water is recirculated, with fresh water added constantly for dilution purposes. The large particles of food soil are trapped by screens, through which the return water passes. The "Salvajor" is an independent unit, which is placed in the soiled dish table ahead of the dishwashing machine.

(4) Mechanical Scrapping. This method is by means of a spray-type washing unit with a power-driven, recirculating pump. The water is recirculated in the same manner as the wash compartment of a spray-type dishwashing machine. This unit usually utilizes for its replenishing detergent water supply, the spill-over water from the wash tank of the accompanying dishwashing machine. The pre-wash device is usually a separate unit and is used in conjunction with the standard, *automatic dishwashing machine*. The racks are usually automatically conveyed through the water scrapping unit, thence through the dishwashing machine. This method is generally accepted today as the most modern and efficient method in better installations.

3. *The Dishwashing Machine* — It is imperative that the establishment be carefully studied and the dishwashing machine adequately sized for the operation. Since the various types of dishwashing machines have been previously discussed, no further comment is necessary at this point; however, the necessity of ample hot water facilities should be considered.

The machine itself is provided with adequate heating means for the wash tank, or, in the case of multiple-tank machines, for all tanks employed. The fresh, hot water supply for the final rinse for the various types of dishwashing machines is always a problem and, too many times, is not given enough serious consideration. Since this hot water supply must come fom the regular building supply, and since this supply is normally maintained at a temperature lower than lethal temperatures, a booster heater or booster recovery system is usually required. Booster heaters or booster recovery systems now are available for gas, steam, or electric heat. It is important in any installation planning that the heating and plumbing engineers carefully size these booster heaters or booster recovery systems for the particular size of machine being installed. All major dishwashing machine manufacturers provide data concerning rinse water consumption by their respective models.

4. *Clean Dish Tables* — Clean dish tables of sufficient size should be provided, allowing ample space for air drying of the china prior to unloading. When dishes are washed and rinsed at lethal temperatures, air drying in well-ventilated dish pantries can be accomplished in 30 to 45 seconds. With this time as a known factor, the clean dish table can be sized accordingly to suit the particular machine.

5. *Miscellaneous Factors* — There are several other general factors which make for a good installation.

To prevent breakage and abuse, and to permit more rapid handling, rack returns of the sliding or roller type should be employed wherever practicable. Proper storage for the racks should also be provided during the down-time of the dishwashing operation. All dish pantries should be well ventilated, ceilings sound-proofed, if possible, and well lighted. To reduce the noise level of the dish tables, there is available an inexpensive paint-on type sound deadener available.

It is recommended by all dish machine manufacturers that a well designed detergent dispenser be installed on the recirculated, pumped-wash unit. There are several dispensers available from the detergent manufacturers which will closely control the detergent feed.

Since all dishwashing machines are marketed through kitchen equipment houses, the fabrication of soil and clean dish tables and other appurtenances, as well as installation, is, therefore, a part of the kitchen equipment house's function. All well-established, kitchen equipment houses employ capable kitchen engineers who specialize in planning good dish pantry layouts and operations. Specialty men work extremely close with these kitchen engineers.

As in all other food service units, it is realized that improvements must constantly be made in food machine products. No industry can stand still—one either goes forward or soon falls by the wayside. In recent years, too much stress has been placed on streamlining in some types of products. It certainly is not necessary to make a food machine appear as though it is going 60 miles per hour in a given direction. Rather than stress streamlining in our food machine design, the motto "MAKE IT EASY TO CLEAN AND EASY TO KEEP CLEAN" should be uppermost in the minds of our design engineers.

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2. Lazarus, N. E. New Development in Detergent-Sanitizers. Milk Dealer, **42**: (1) 45, 68-71. 1952.

3. Mueller, W. S. A Micro Method for Evaluating Germicides Determining 100 per cent Kill. Modern Sanitation, **2**: (6) 45-46. 1950.

4. Terry, D. H. and Shelanski, H. Iodine as a Germicide—Part One. Modern Sanitation, **4**: (1) 61-65. 1952.

5. Weber, G. R. Effect of Concentration and Reaction (pH) on the Germicidal Activity of Chloramine—T. Public Health Rpts., **65**: 503-512. 1950.

6. Weber, G. R., and Black, L. A. Laboratory Procedure for Evaluating Practical Performance of Quaternary Ammonium and Other Germicides Proposed for Sanitizing Food Utensils. Am. J. Public Health, **38**: (10) 1405-1417. 1948.

7. United States Public Health Service. Ordinance and Code Regulating Eating and Drinking Establishments. Public Health Bull. No. 280, Government Printing Office, Washington, D. C. 1943, reprinted 1948.