Dru Sahai,[1*] Emily Peterson,[1] and Ye Li,[1,2]

[1]Public Health Ontario, 480 University Ave, Suite 300, Toronto, ON, M5G 1V2, Canada
[2]Dalla Lana School of Public Health, University of Toronto, ON, M5T 3M7, Canada

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6200 Aurora Ave., Suite 200W, Des Moines, IA 50322-2864

Microbiological Assessment of Utensils Cleaned by Domestic Dishwashers in Ontario Small Establishments

ABSTRACT

The purpose of this study was to evaluate whether domestic dishwashers used in small establishments that generate a low volume of utensils per day are capable of staying within the prescribed limit of no more than 100 bacterial colonies per utensil (Ontario Regulation 562 – Food Premises). A questionnaire was used to capture the characteristics and operating parameters of 103 domestic dishwashers across Ontario. Two temperature data loggers were placed inside the dishwasher to monitor the temperature during the entire operation of the dishwasher, one on the top and one on the bottom rack. After completion of the whole cycle, utensils were swabbed and analyzed for bacteria using the heterotrophic plate count (HPC) method. This field study illustrated that 83% of the domestic dishwashers evaluated were able to stay within the prescribed limit. This is consistent with the results of a similar Ontario study involving commercial dishwashers. Dishwashers that used chlorinated detergents or those that contained utensils classified as somewhat soiled or very soiled before washing were significantly more likely to fail to stay with the prescribed limit ($P < 0.05$). With increasing maximum rinse temperature, dishwashers were found to be significantly less likely to fail ($P < 0.05$).

INTRODUCTION

In small establishments, such as family daycare services, group homes, and residential care homes in which relatively small numbers of utensils are washed, the installation of a commercial dishwasher may not be cost effective or practical because of plumbing and electrical requirements. As a result, some health units allow the use of domestic dishwashers by small establishments that serve food once or twice per day.

Under normal operating conditions, domestic dishwashers cannot achieve the high water temperature prescribed under Ontario's Food Premises Regulation to thermally sanitize utensils (82°C for a minimum of 10 s). Chemical sanitization at a lower temperature (24°C) is allowed under the regulation, provided a prescribed chemical sanitizer is used at the required concentration during the sanitizing rinse cycle. However, domestic dishwashers are not designed to automatically dispense the sanitizer at a set time and

Corresponding author: Phone: +1 647.260.7784; Fax: +1 647.260.7600; Email: dru.sahai@oahpp.ca

concentration. Although it is possible to add the sanitizer manually, adding and verifying the required concentration of the sanitizer is cumbersome and can be a potential safety concern. Additionally, most domestic dishwashers do not have external thermometers showing wash and rinse temperatures — a requirement under the Food Premises Regulation. For these reasons, the use of domestic dishwashers in commercial establishments is regarded as "non-compliant." However, the regulation does allow the use of other machines or devices, such as domestic dishwashers, provided it can be demonstrated to the Medical Officer of Health's satisfaction that they are able to effectively clean and sanitize utensils to within the prescribed limit of no more than 100 bacterial colonies per utensil (hereafter referred to as the prescribed limit) as determined by HPC (referred to as the standard plate test in Ontario's Food Premises Regulation) *(6)*.

A phone study conducted prior to our study revealed that just over half of the 36 health units in Ontario allow the use of domestic dishwashers, provided certain conditions are met. For example, some health units mandate the use of chlorinated detergents, while some permit only NSF- (National Sanitation Foundation) certified domestic dishwashers to be used, with mandatory use of the machine's sanitizing option. NSF International (NSF) has developed a standard (NSF/ANSI Standard 184) for residential dishwashers. Standard 184 requires the heating of utensils with fresh, hot water (62°C or greater during the sanitization rinse cycle) for specified time/temperature combinations in order to achieve a cumulative heat factor level necessary to thermally sanitize the utensils *(12)*. This time/temperature relationship is measured in Heat Unit Equivalents (HUEs). To conform to the sanitizing requirement, an HUE greater than 3600 during the rinse cycle must be achieved. An HUE value is determined by measuring the surface temperature of a utensil during each second of the rinse cycle, then combining those values across the complete duration of the cycle to obtain a total heat equivalence *(12)*. During this study, if the sanitation cycle was engaged, the rinse water temperature was used to determine if an HUE of at least 3600 was achieved. It was assumed that the temperature of the rinse water reflected the temperature at the utensil's surface *(2)*. Domestic dishwashers certified to NSF/ANSI Standard 184 have been verified under strictly controlled laboratory conditions (as opposed to field conditions) to achieve a 5-log (i.e., 99.999%) reduction in bacterial colonies when the sanitizing cycle is used *(12)*. This approach is the same sanitization criterion required under NSF/ANSI Standard 3, which deals with the certification of commercial dishwashers *(13)*. Thus, although a certified domestic dishwasher does not operate identically to a commercial unit, it could be just as effective at cleaning and sanitizing utensils. However, the cleaning and sanitizing efficiency of domestic dishwashers in the field is uncertain and is an ongoing issue for health units, for a number of reasons:

- Even if a health unit specifies that the sanitizing cycle (an option available on NSF-certified domestic dishwashers) be used, there is no assurance that under real-life field conditions, results will fall within the prescribed limit.

- In the absence of specific advice on the operating parameter to which domestic dishwashers should be set in order to achieve results within the prescribed limit, some health units hesitate to allow their use as an alternative to commercial dishwashers.

It is significant to note that in 1991, a review of the Food Premises Regulation by the Canadian Institute of Public Health Inspectors (Ontario Branch) recommended the Food Premises Regulation be updated to accommodate modern domestic dishwashers and that there be an evaluation of the use of domestic dishwashers in establishments with a small numbers of residents (i.e., a small establishment that generates a small number of dishes). However, these recommendations were never pursued *(14)*.

The purpose of this domestic dishwasher study was to assess the microbiological quality of utensils to determine whether domestic dishwashers, allowed by some health units in Ontario, are capable of yielding results within the prescribed limit. The specific objectives of this study were:

1. To estimate the percentage of domestic dishwashers used in small establishments that generate a low volume of utensils that are capable of staying within the prescribed limit.

2. To determine what dishwasher characteristics/operating parameters and utensil characteristics may contribute to success or failure in staying within the prescribed limit.

MATERIALS AND METHODS

Four health units in Ontario that have allowed the use of domestic dishwashers were invited to participate in the study. These health units were all within a short commuting distance of a Public Health Ontario Laboratory that performs HPC swab analysis. The study was conducted between September 2012 and May 2013. A list of establishments that allow domestic dishwashers was obtained, and telephone calls were made to these establishments by a public health inspector (PHI) to recruit them for the project. The PHI confirmed that a domestic dishwasher was being used in each establishment and explained the purpose of the study. All establishments contacted were willing to participate in the study, and a total of 103 domestic dishwashers were evaluated within the study period. The distribution of the number of

establishments participating by health unit was 35, 25, 23 and 20 for health units 1, 2, 3 and 4.

Bias in the selection of establishments for the study was likely not an issue, as all establishments that were allowed to use a domestic dishwasher were sampled in three of the four health units. In the fourth health unit, a few establishments could not be sampled prior to the sampling cut-off date of the study.

Site visit

A site visit to each participating establishment was made by a trained investigator or public health inspector familiar with swabbing techniques. Visits were made around the breakfast or lunch hour to ensure that a load of soiled utensils would be available for washing and subsequent swabbing. It should be noted that the bacterial load of the utensils before they were washed by the dishwasher was not established, and it should not be assumed that all dishwashers evaluated in this study were used to wash utensils that were equally contaminated. No effort was made to influence how the utensils were prepared before being loaded into the dishwasher or what type of detergent or dishwasher program (cycle/options) was used at each site.

At each site:

1. A domestic dishwasher questionnaire was filled out to capture the characteristics and operating parameters that can influence a domestic dishwasher's ability to clean and sanitize. These included age, presence of a turbidity sensor, NSF certification, whether or not the detergent used contained chlorine bleach, cycle/options used, incoming water temperature, wash and rinse temperature, percentage full, what was done to prepare the utensils for the dishwasher (i.e., rinsed or scraped) and the extent to which the utensils were soiled before being washed.

2. The label and MSDS of each detergent was checked for the presence of chlorine. In some cases the manufacturer of the detergent was contacted to confirm the presence or absence of chlorine.

3. The age of the dishwasher was estimated; if this was not known by the operator, the manufacturer was contacted to attempt to establish the age.

4. A check was made to verify if the dishwasher was NSF/ANSI Standard 184 certified and whether it had a turbidity sensor (the operating manual was consulted if necessary).

5. The maximum temperature of the hot water from the kitchen tap was taken, using a waterproof digital thermometer with maximum hold (Comark KM 14; Comark Instruments, Norwich, Norfolk, UK).

6. Two waterproof temperature data loggers (Tinytag® Splash 2, TG-4105; Gemini Data Loggers Ltd., Chichester, UK) were placed in the dishwasher to monitor the temperature during a complete operating cycle, one on the top rack and one on the bottom rack. The data loggers have a resolution of 0.01°C, a range between -30°C and 105°C and can store up to 32,000 temperature readings. Units were set to record the temperature every 2 s and are configured by the manufacturer to an accuracy of ±0.4°C at 0°C and ±0.5°C at 105°C.

7. The dishwasher operator was asked to operate the dishwasher as it would normally be operated. On domestic dishwashers, the sanitation cycle is an option. The operator is responsible for initiating the sanitizing cycle by pushing a button on the front panel of the unit.

8. After completion of the full wash cycle, utensils were randomly selected for swabbing, and the data from the temperature data loggers were downloaded.

9. Swabs were then packaged in ice, placed in an insulated laboratory container and transported to the laboratory for analysis.

Heat unit equivalents

Heat unit equivalents (HUEs) were computed from water temperatures recorded at 2 s intervals to examine whether the dishwashers tested met NSF sanitization criteria. While the NSF criterion specifies a 1 s interval for HUE calculations, a 2 s interval was used in this study because of capacity limitations of the data logging units used for temperature measurement. A Microsoft Excel formula was used to round down individual measured temperatures to the closest comparable temperature from NSF/ANSI Standard 184 and to convert the rounded temperature to a corresponding HUE. These calculated HUE values were then summed and multiplied by two to account for the difference in sampling interval. If this cumulative calculated value met or exceeded 3600 HUEs, the sample was determined to have met the NSF sanitization criteria *(12)*.

Training

To ensure accurate, precise, and consistent data, training sessions were held for all investigators involved in this study. Hands-on training was provided by a certified public health inspector on filling out the domestic dishwasher questionnaire, where and how to place the data loggers in the dishwashers, downloading of the data from the data logger, what utensils to swab, proper swabbing technique, proper storage and transport of the swabs to the laboratory and filling out the environmental bacteriology swab tests

form. For their reference, detailed written instructions were provided to each investigator *(Appendix)*.

Swabbing and transportation

Where possible, investigators swabbed four different types of kitchen utensils, such as bowls, forks, spoons, plates, cups or glasses. Four of each different utensil type were selected at random from the dishwasher after it had finished its full cycle. One swab was used for each group of four similar utensils, yielding four total swabs and 16 individual items swabbed per dishwasher. All surfaces were swabbed using Sanicult™ Transport Swabs (Remel, Thermo Fisher Scientific) containing a sterile buffer solution. To ensure consistency, swabbing procedures were developed based on the United States Public Health Service's (USPHS) "Procedure for the bacteriological examination of food utensils and/or food equipment surfaces" *(17)*. The USPHS procedure does not specify the area of plates or bowls to be swabbed *(17)*. For this study, it was decided to swab a 3 in. x 3 in. area of the inner surface. For spoons and forks, the full inner and outer surface of the "eating end" of the utensil was swabbed. After sampling, the swabs were placed in an insulated laboratory container with icepacks and transported to the laboratory. Samples were normally processed the same day, but on occasion, because of the time frame, swabs were refrigerated overnight at 4°C and processed the next day. In accordance with the laboratory's standard operating procedure for HPC analysis, all swabs were plated within 24 hours of collection.

As required by the Food Premises Regulation, HPC was used as an indication of microbial contamination of multiservice utensils. All analyses were performed based on the standard procedures outlined in the Standard Methods for the Examination of Dairy Products *(18)*. Each swab was vortexed, and 1 ml of the solution was plated on Standard Methods Agar. The plates were incubated at 32°C for 48 h. Upon completion of incubation, plates were counted using a colony counter (New Brunswick scientific colony counter, model c-110w; New Brunswick Scientific Co., New Brunswick, NJ). Swab results were reported as the number of residual bacterial colony counts per vial submitted.

Interpretation of results

The Food Premises Regulation states that HPC from a multi-service article shall not exceed 100 bacterial colonies per utensil. Consistent with common swabbing techniques used by health units in Ontario, one swab was used for four similar utensils, and the bacterial colony count for each swab was divided by four to get the average count per utensil. A dishwasher was classified as fail if the average count for any utensil that was washed in the dishwasher exceeded the prescribed limit of 100.

Statistical analysis

R version 3.1.0 was used for all analyses *(16)*. Descriptive statistics were performed by dishwasher and also separately by individual swab result.

Logistic regression was performed using the R package rms *(7)* to examine the association between dishwasher characteristics or operating parameters and the ability of a dishwasher to achieve the prescribed standard. The *a priori* characteristics included in the model were dishwasher age, wash cycle used (light/economy/quick wash, normal, heavy duty/pots and pans), heat drying, presence of a turbidity sensor (yes, no), presence of chlorine bleach in the detergent (yes, no), proportion full (full, <50%, ≥50%, overloaded), rinsed before placing in dishwasher (yes, no), use of sanitizing cycle (yes, no), HUE met (yes, no), maximum rinse temperature, and the degree of soil on the dishes prior to loading (very clean/somewhat clean, very dirty/somewhat dirty). The number of plastic items swabbed was also controlled for in the model, given that this could impact the results. A total of 103 dishwashers were used for this analysis.

Mixed effects logistic regression using R package lme4 *(1)* was used to examine the relationship between swab failure and item material (plastic, ceramic, glass, metal) and type (bowls, cups, glasses, mugs, plates, utensils, other) while taking into account that multiple items were swabbed per dishwasher. Each individual swab was categorized as pass or fail based on whether or not results fell within the prescribed limit. Both item material and item type were determined for each swab based on the description of the items swabbed by the investigator; a total of 406 swabs were categorized and used for this analysis. The reference category used for the analysis was ceramic bowls. This model included the fixed effects of the item material and type, and random intercepts for dishwashers.

RESULTS

Of the 103 domestic dishwashers evaluated, 85 (83%) yielded results that fell within the prescribed limit of no more than 100 bacterial colonies per utensil as determined by HPC. *Table 1* shows a breakdown of the dishwasher characteristics and operating parameters and the number and percentage of dishwashers that failed to meet the prescribed limit.

Results from the logistic regression did not indicate any association between dishwasher failure and most of the characteristics or operating parameters of the dishwashers (age, wash cycle used, heat drying, presence of a turbidity sensor, chlorine presence in the detergent, proportion full, rinsing utensil before placing in the dishwasher, use of sanitizing cycle, and HUE met). However, dishwashers that contained utensils classified as somewhat soiled or very soiled before washing were more likely to fail ($P < 0.05$) than those that were classified as very clean or somewhat clean before washing, when all other characteristics and operating parameters and the number of plastic items were controlled

TABLE 1. Descriptive statistics of dishwasher characteristics/operating parameters and the number and percentage of dishwashers that failed to meet the prescribed limit of no more than 100 bacterial colonies per utensil

Dishwasher Characteristics/ operating parameters	Description	Number of dishwashers (% of total) or value	Number that failed to meet the prescribed limit[a] (% of total)
Overall results	Number of dishwashers evaluated	103 (100%)	18 (17%)
Brands	Number of brands evaluated	12	–
Age of dishwashers	Mean (years)	5 (SD = 4.0)	–
	<5 years	52 (50%)	9 (17%)
	5–10 years	43 (42%)	6 (14%)
	>10 years	8 (8%)	3 (38%)
Wash cycles as set by the operator	Light/Economy/Quick wash	10 (10%)	2 (20%)
	Normal	77 (75%)	14 (18%)
	Heavy Duty/Pots and pans	16 (15%)	2 (13%)
Dishwashers operated using sanitizing cycle option[c]	Units set on sanitizing cycle	22 (21%)	4 (18%)
	HUE[b] met for units set on sanitizing option	20 (91%)	4 (20%)
	HUE not met for units set on sanitizing cycle	2 (9%)	0 (0%)
	Units not having or set on sanitizing option	81 (79%)	14 (17%)
Dishwashers ran using heat drying option	Yes	62 (60%)	11 (18%)
	No	41 (40%)	7 (17%)
Dishwashers meeting NSF's Standard 184 HUE criteria[d]	Yes	24 (23%)	4 (17%)
	No	79 (77%)	14 (18%)
Dishwashers with a turbidity sensor	Yes	58 (56%)	9 (16%)
	No	45 (44%)	9 (20%)
Chlorine-based detergent used or bleach added by operator[e]	Yes	49 (48%)	11 (22%)
	No	54 (52%)	7 (13%)
Utensils preparation before loading	Rinsed (rinsed only or scraped and rinsed)	81 (79%)	12 (15%)
	Not rinsed (nothing or just scraped)	22 (21%)	6 (27%)
Degree of soiling[f]	Very clean or somewhat clean	89 (86%)	11 (12%)
	Somewhat soiled or very soiled	14 (14%)	7 (50%)
Dishwasher load[g]	≤50%	29 (28%)	5 (17%)
	>50%	41 (40%)	5 (12%)
	100%	29 (28%)	6 (21%)
	Overloaded	4 (4%)	2 (50%)

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TABLE 1. Descriptive statistics of dishwasher characteristics/operating parameters and the number and percentage of dishwashers that failed to meet the prescribed limit of no more than 100 bacterial colonies per utensil (cont.)

Dishwasher Characteristics/ operating parameters	Description	Number of dishwashers (% of total) or value	Number that failed to meet the prescribed limit[a] (% of total)
Overall maximum rinse temperature(°C)	Mean	61.0 (SD 7.0)	–
	<55	20 (19%)	8 (40%)
	55–59	22 (21%)	2 (9%)
	60–65	31 (30%)	4 (13%)
	>65	30 (29%)	4 (13%)

[a]No more than 100 bacterial colonies per utensil

[b]NSF/ANSI Standard 184 requires the heating of utensils for specified time and temperature combinations in order to achieve 3600 Heat Unit Equivalents (HUEs) at the surface of dishes to ensure adequate sanitization

[c]Fifty-four dishwashers in total had a NSF certified sanitizing cycle, but only 22 used this setting

[d]In addition to the 20 units that met the minimum HUE while on the sanitizing cycle, 4 other machines met the HUE while set on the high temperature wash cycle

[e]Three operators manually added bleach solution during rinse cycle

[f]Cleanliness of the utensils as judged by the investigator before the dishwasher was started

[g]Estimated percentage of a full load as judged by the investigator before the dishwasher was started

for. With increasing maximum rinse temperature, dishwashers were less likely to fail ($P < 0.05$) while the same characteristics were controlled for. Also, dishwashers were more likely to fail when chlorinated detergents were used ($P < 0.05$).

A summary of the overall maximum wash and rinse temperatures (average of top and bottom racks), as well as the incoming water temperatures, are presented in *Table 2*. It was observed that more than half of the domestic dishwashers had an incoming water temperature of less than 49°C, which is the minimum temperature generally recommended by dishwasher manufacturers for proper cleaning and sanitizing operations.

We also observed a high correlation between the maximum top and bottom wash temperatures ($r = 0.992$, $P < 0.001$) and maximum top and bottom rack rinse temperatures ($r = 0.997$, $P < 0.001$). An example of a typical temperature recording over the complete dishwasher cycle, shown in *Fig. 1*, illustrates the high degree of agreement between top and bottom temperatures.

Although 54 (52%) of the 103 domestic dishwashers evaluated were NSF/ANSI certified, only 22 (41%) were operated using the sanitizing cycle as an option during this study. Two (9%) of the 22 dishwashers that used the sanitizing cycle failed to meet the minimum HUE of 3600 required by the NSF for sanitizing purposes.

A breakdown of utensil material type along with the respective geometric mean bacterial colony count and percentage of swabs that failed to meet the prescribed limit is presented in *Fig. 2*. When the geometric mean bacterial colony count by material type was compared for individual swabs, it was observed that plastic items had significantly higher counts than ceramic items ($P < 0.001$). However after item type (bowl, cup, plate etc.) and the random effect of dishwashers were controlled for using mixed effects logistic regression, plastic items were no longer significantly different from ceramic items. In this mixed effects regression model, item type also did not contribute significantly to swab pass/fail when material type and the random effect of dishwashers were controlled for.

DISCUSSION

Some health units in Ontario allow the use of domestic dishwashers because they recognize it may not be cost effective or practical for some small establishments that generate only a low volume of soiled utensils per day to install a commercial dishwasher. However, the question of how effective domestic dishwashers are at staying within the prescribed limit of no more than 100 bacterial colonies per utensil is uncertain. This study helps to resolve this uncertainty.

To determine whether our pass rate of 83% is of public health significance, it is necessary to compare our results to results from comparable studies of commercial dishwashers. We found only one such study, a 1980 unpublished undergraduate thesis by Shimoda *(15)* that employed the same study, swabbing and culturing methodology as our study.

TABLE 2. Summary of the wash, rinse and incoming water temperatures measured across all dishwashers (n = 103)

Water temperatures	Mean temperature (°C) ± SD	Range of temperatures (°C)
Overall wash water temperature (average of top and bottom data loggers)	55.1 ± 7.7	31.3 – 72.3
Overall rinse water temperature (average of top and bottom data loggers)	61.0 ± 7.0	43.8 – 73.9
Incoming water temperature (as measured at the kitchen tap)[a]	50.2 ± 7.3	34.5 – 80.9

[a]n = 102

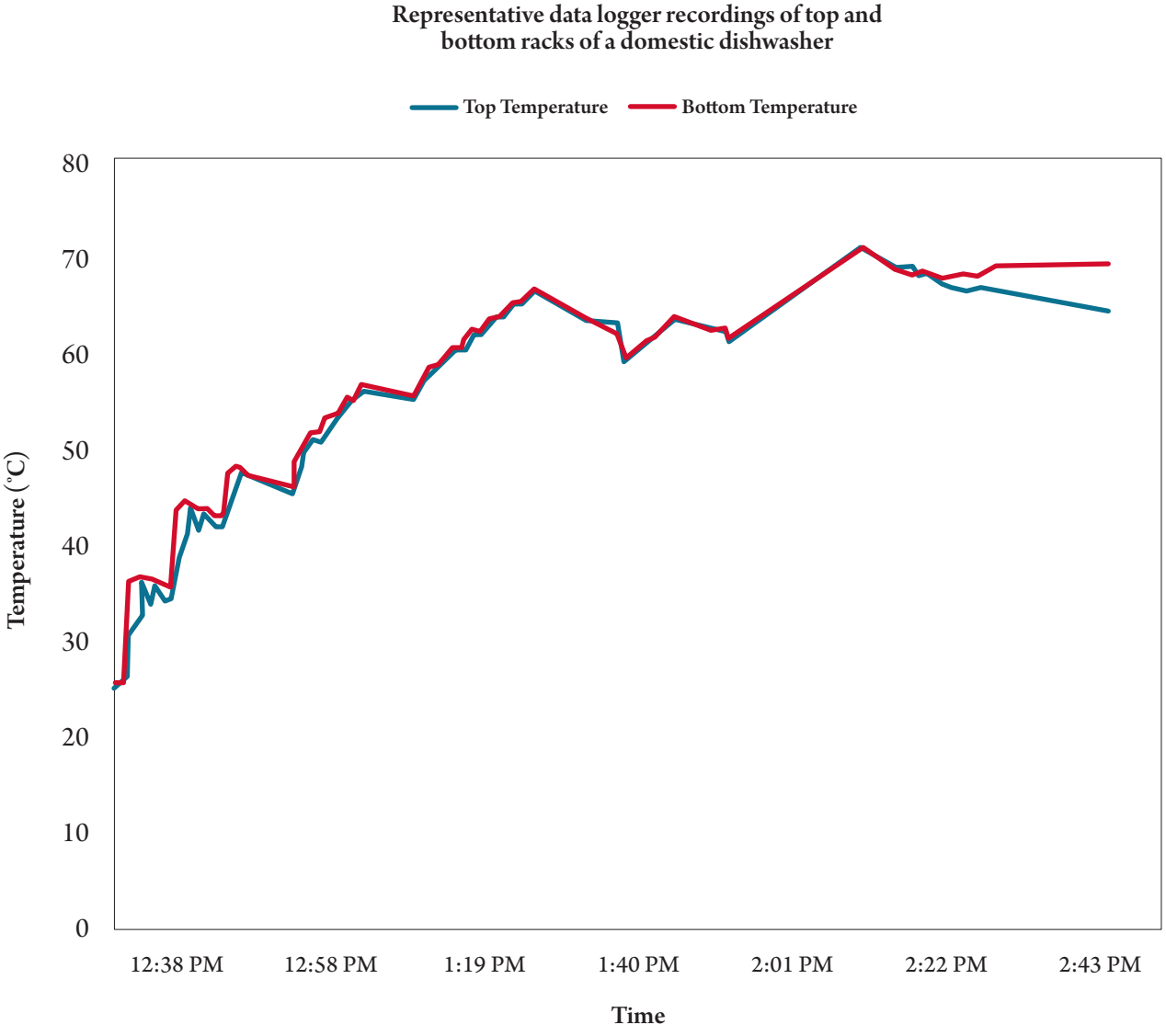

Figure 1. Data logger recordings of top and bottom racks temperatures (°C/min) of one representative domestic dishwasher evaluated in this study

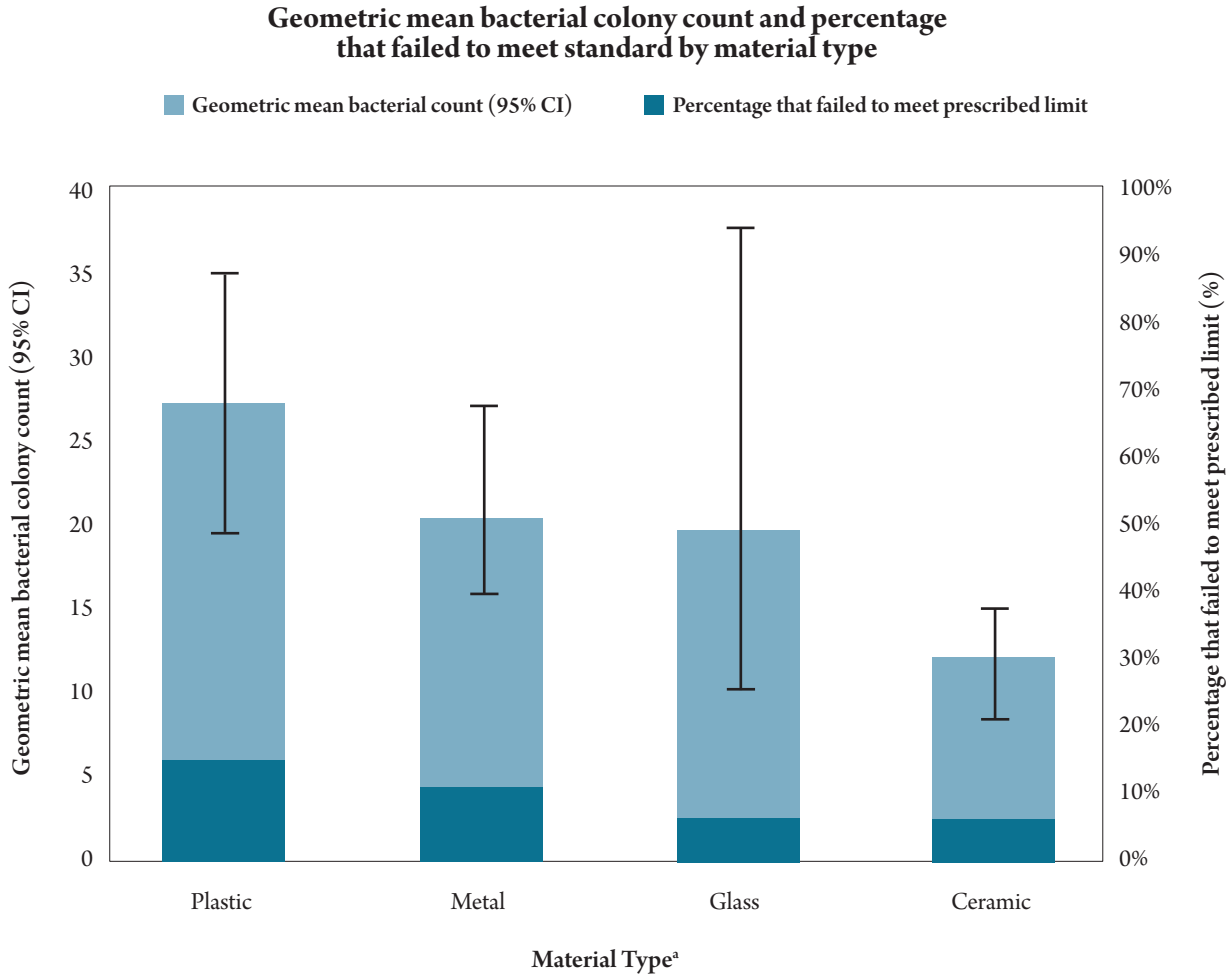

Figure 2. The geometric mean bacterial colony count by utensil material for individual swabs and percentage of swabs that failed to meet the prescribed limit of no more than 100 bacterial colonies per utensil

Shimoda *(15)* took swabs of utensils from 200 commercial dishwashing units in Ontario to determine if they met the standard of no more than 100 bacterial colonies per utensil. The author found that of the 200 commercial dishwashers, 159 (80%) met the bacterial colony count requirement, while 41 (20%) did not. Since our domestic dishwasher pass results are both high and consistent with those of Shimoda's, our findings support the effectiveness of the use of domestic dishwashers in small-scale establishments.

The reason dishwashers that contained utensils classified as "somewhat soiled" or "very soiled" were significantly more likely to fail in our study could be that some establishments used just the 'Light' or 'Normal' cycle for a heavily soiled load. Domestic dishwasher manufacturers recommend the use of the 'Heavy Duty/Pots & Pans' cycle, in addition to the high temperature option, when utensils are heavily soiled or have dried or baked-on food residue on them. With use of just the 'Light' or 'Normal' cycle, the water temperature and the volume of water impacting the food contact surface may have been insufficient to adequately remove food residue and bacteria *(10, 11)*.

It also was observed that as the maximum rinse temperature increased, dishwashers were significantly less likely to fail. This finding is expected, as thermal inactivation of microorganisms is well known to be a function of temperature and time *(5, 10, 12)*.

An interesting finding was that establishments using chlorine-based detergents were significantly more likely to fail than establishments that used non-chlorine-based detergents. Although chlorine is a well-established sanitizer,

we would not expect its presence in a detergent to improve the chances of a dishwasher meeting the prescribed limit. To be an effective sanitizer, chlorine must be added, in the right concentration, during the rinse cycle, after all food residues have been removed from the utensils during the wash (cleaning) cycle *(11)*. The presence of food residue on utensils protects microorganisms from direct contact with the sanitizer *(10)*. Based on this finding, health units that mandate the use of chlorinated detergents as a prerequisite for allowing domestic dishwashers may consider revising their policy. There is no obvious reason to explain the significant association between the use of chlorinated detergents and an increased failure rate, but it may be due to chance. Future research may want to investigate this association to confirm this finding.

The literature suggests that the number of passes could be improved if operators adhered to the dishwasher manufacturers' instructions *(4)*. We observed numerous deviations from these instructions, which the manufacturers state must be followed in order to achieve proper cleaning and sanitizing. Deviations from recommended operating procedures included inappropriate cycle selection, machine overloading, improper loading procedures resulting in "nesting" of utensils, and low incoming water temperature.

Soiled food contact surfaces must be exposed to the appropriate pressure and volume of water jets (determined by cycle selection) to achieve effective mechanical removal of dirt and bacteria during cleaning and rinsing *(11)*. Overloading a dishwasher can prevent the water jets from hitting the soiled areas. Utensils should be loaded with the handle down. Loading utensils with the handles up is more likely to cause "nesting," in which one utensil sits inside another, not allowing the soiled parts to be contacted by the pressurized water jets *(8, 12)*. The ability of some domestic dishwashers to achieve the water temperature necessary for sanitizing utensils is primarily a function of the incoming water temperature *(2)*. This may explain why domestic dishwasher manufacturers generally recommend that to effectively sanitize utensils, the incoming water temperature should be between 49°C and 66°C. It is suspected that one of the two units that were set on the sanitizing cycle failed to meet the required HUE because the incoming water temperature was too low (39°C) and could not heat the sanitizing rinse water high enough to achieve the temperature/time combination necessary for thermal sanitization.

It was consistently observed by the investigators in our study that plastic utensils (cups, plates and forks) used in daycare centers had deep scratches on them. The scientific literature suggests that scratched or scarred plastic utensils can harbor bacteria and may be difficult to clean, if not properly washed or sanitized *(3, 9)*. Our study was not specifically designed to look at this question, but our results suggested that plastic items may or may not yield different results than ceramic items; thus further research is needed to examine this association. Future research should examine the ability of both domestic and commercial dishwashers to clean plastic items versus other material types in public settings, such as daycare centers.

The primary limitation of this study was that the low failure percentage and small sample size could limit the ability to identify associations between dishwasher characteristics or operating parameters and failure to yield results within the prescribed limit.

Another limitation was that the temperature was recorded by measuring the water temperature next to the utensils rather than on the surface of the utensil. The effect of heat on microorganism inactivation on the food contact surfaces depends mainly on the surface temperature of the utensil and on the length of time during which the surface is exposed to heat *(11)*. However, Bryan and DeHart *(2)* noted that the temperature on utensils and the temperature of water next to the utensils were, for all intents and purposes, the same.

Establishments were informed of the study prior to our visit, which may have influenced the dishwashing practices used during the visit. This information may have increased compliance with manufacturer`s recommended operating procedures and influenced the measured pass rate.

Since dishwashing efficiency can be affected by the initial bacteriological load and the nature of the organic material on the utensil, it would have been interesting to assess utensils that were uniformly soiled and inoculated with a known bacteriological load before washing procedures were instituted *(10)*. This approach would have controlled for the nature of the organic material on the utensils and the degree of contamination. However, because this project was a field study, control over the degree of soiling and the initial bacterial contamination would have been logistically difficult and would not reflect the variability seen in the field. This observation is an important limitation, since not all food residue would be equally contaminated by bacteria, and in some instances a large proportion of the utensils placed in a dishwasher may have few bacteria adhering to them. Under such circumstances, even an ineffective dishwasher may achieve compliant results.

Also, in this study, we did not measure water pressure or volume, both of which can influence the rate of mechanical removal of food residue and bacteria during cleaning and rinsing *(11)* and could affect whether a domestic dishwasher achieves results within the prescribed limit.

The potential for human variation during the swabbing and analysis must also be considered. Swabbing results can vary depending on the angle and pressure applied to the swab, failure to swab the required area, incomplete release of bacteria during shaking of the swab, improper storage of the swabs, and laboratory errors. We tried to

minimize sampling variation by conducting training, providing written instructions, and ensuring use of standard laboratory protocols.

The key finding of this field study was that a high percentage (83%) of domestic dishwashers used in place of commercial units in small establishments, are able to stay within Ontario's prescribed limit of no more than 100 bacterial colonies per utensil when assessed by HPC. Dishwashers that used chlorine-based detergents or those that contained utensils classified as "somewhat soiled" or "very soiled" before washing were significantly more likely to fail. Dishwashers were significantly less likely to fail with increasing maximum rinse temperature. The performance of domestic dishwashers in our study was comparable to that of commercial dishwashers in a similar Ontario study *(15)* (83% vs. 80%) in terms of staying within the prescribed limit. Health authorities and regulators may find the results of this study useful when making decisions or formulating policy regarding the use of domestic dishwashers in small establishments that generate a low volume of utensils.

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Appendix

Instructions for Environmental Bacterial Swabs and Data Logging

1. Check for the following:
    a. Four swab kit
    b. Environmental Swab Test Form
    c. Domestic Dishwasher Evaluation Questionnaire
    d. Two temperature data loggers

2. Fill out the Domestic Dishwasher Evaluation Questionnaire.

3. For proper interpretation and evaluation of the study results it is extremely important that this questionnaire be filled out accurately and completely.

4. Launch the temperature data loggers name the file "name of the establishment - Top or Bottom" e.g., ("name of establishment" - Bottom).

5. Place one data logger in the middle of the top rack and one in the middle of the bottom rack. Make sure they are secure.

6. Instruct the dishwasher operator to operate the dishwasher as it would be normally be used.

7. After the dishwasher has gone through all its cycles, remove and stop the data loggers and then download the data.

8. Take swabs using the swab kits.

9. Utensil to be swabbed could include a plate, a bowl, a glass or cup, a spoon or fork.

10. Use one swab for each group of 4 similar multi-service utensils (spoons, forks, plates, bowls, knives, glasses or cups).

11. Open the sterile swab container; grasp the handle (cap) end of the swab being careful not to touch any portion that might be inserted into the vial. Care must be taken not to touch or contaminate the swab after it is removed from the vial.

12. Press out the excess solution against the interior wall of the vial with a rotating motion and remove the swab aseptically.

13. After swabbing each utensil, return the swab to the vial of buffer solution, agitate the swab in the solution and the swab next of the 4 utensils.

14. For the plate, rub the swab head slowly and thoroughly over an 8 cm (3 in) x 8 cm (3 in) area of the inner surface three times, reversing direction between strokes. Rotate the swab as the area is being sampled.

15. For the bowls, swab 3 times, reversing the direction of each stroke around the inner surface at the level at which the swab will hug the surface of the bowl about halfway between the bottom of the bowl and the rim. For large bowls, swab a 8 cm (3 in) x 8 cm (3 in) area of the inner surface three times.

16. For the glasses or cups, swab the upper 2 cm (½ in) of the entire inner and outer rim.

17. For spoons and forks swab the full inner and outer surface of the "eating end" of the utensil.

18. After sampling, place the swab in the vial containing the neutralizing medium and tighten the screw cap so as to prevent leakage.

19. Swabs must be properly labeled with the number and type of utensils swabbed and the material it is made of, e.g., 4 metal forks, 4 plastic bowls, 4 ceramic plates and 4 plastic cups.

20. Fill out all sections of the Environmental Bacteriology Swab Tests Form with the required information.

21. It is imperative that the time and date of the sample be placed on the Environmental Bacteriology Swab Tests Form.

22. Swabs should be labeled prior to sampling or immediately afterwards to prevent any mix up between samples.

23. Place the swabs in the Ziploc® specimen bag and the Environmental Bacteriology Swab Tests Form in the Ziploc® specimen bag pouch.

24. Packaged in ice and placed in the insulated laboratory container and transported to the Ontario Public Health Laboratory for analysis at 2° – 6°C. Aim to have the sample at the laboratory by 3:30 p.m. the same day.