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ORIGINAL ARTICLE

Cleaning and decontamination efficacy of wiping cloths and silver dihydrogen citrate on food contact surfaces

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Abstract

Aims: To test the efficacy of four wipe cloth types (cotton bar towel, nonwoven, microfibre and blended cellulose/cotton) with either quaternary ammonia cleaning solution or silver dihydrogen citrate (SDC) in cleaning food contact surfaces.

Methods: Swab samples collected from untreated, cloth-treated and cloth disinfectant-treated surfaces were subjected to hygiene monitoring using adenosine triphosphate (ATP) bioluminescence and aerobic total plate counting (TPC) assays.

Results: Adenosine triphosphate measurements taken after wiping the surfaces showed poor cleaning by nonwoven cloths (2·89 RLU 100 cm^{-2}) than the microfibre (2·30 RLU 100 cm^{-2}), cotton terry bar (2·26 RLU 100 cm^{-2}) and blended cellulose/cotton cloth types (2·20 RLU 100 cm^{-2}). The cellulose/cotton cloth showed highest log reduction in ATP-B RLU values (95%) and CFU values (98·03%) when used in combination with SDC disinfectant.

Conclusions: Cleaning effect of wiping cloths on food contact surfaces can be enhanced by dipping them in SDC disinfectant. ATP-B measurements can be used for real-time hygiene monitoring in public sector, and testing microbial contamination provides more reliable measure of cleanliness.

Significance and Impact of the Study: Contaminated food contact surfaces need regular hygiene monitoring. This study could help to estimate and establish contamination thresholds for surfaces at public sector facilities and to base the effectiveness of cleaning methods.

Introduction

Cross-contamination of food contact surfaces is a major safety concern for food-service facilities where any inefficient cleaning with reusable wiping cloths could spread harmful bacteria and viruses posing potential serious health hazards to consumers. Nearly 80% of the reported foodborne outbreaks can be traced back to food-service facilities with major contributing factors being time/temperature abuse of prepared foods, poor personal hygiene of the food preparer and cross-contamination in the food-service establishments (Collins 1997). Thus, microbiological quality evaluation of commercial food preparation and serving surfaces in food-service establishments is critical to public health. A significant reduction in bacterial load and improved hygiene conditions of such areas can be achieved by the use of efficient cleaning cloths and disinfectants. Regular monitoring for the effectiveness of cleaning practices could serve as a crucial preventative measure for potential foodborne outbreaks. From the point of food production and preparation to consumption, there could be several opportunities for food to become contaminated. Food contact surfaces have been predominantly incriminated in the contamination of food products in the food industry (Tebbutt 1984; Evans *et al.* 1998). Although cleaning is regularly practised in food-service establishments, there is great reliance upon visual assessment for hygiene monitoring, which is not reliable

in determining the potential risk constituted by the contaminated food contact surfaces (Tebbutt *et al.* 2007). Evidently, the data pertaining to the presence of foodborne pathogens on surfaces of food-service establishments and their potential to spread from surfaces to food are justification enough to ensure effective cleaning regimes. The microbiological assessment of food contact surfaces is therefore necessary to determine the effectiveness of cleaning methods on surfaces (Verran *et al.* 2002).

The presence of food residues on a food contact surface indicates that the surface has not been adequately cleaned, and the constituent food particles may provide nutrients for the consequent growth of micro-organisms (Leon and Albrecht 2007) that may also be potentially pathogenic. Some studies have recommended periodic microbiological assessment of high-risk food establishments to reduce the risk of foodborne disease outbreaks (Moore and Griffith 2002). However, microbiological methods such as the aerobic plate count take up to 48 h to give feedback on findings (Leon and Albrecht 2007). The efficacy of sampling methods and rapid assay methods for evaluating the cleanliness of food contact surfaces has been examined in several studies (Corbitt *et al.* 2000; Griffith *et al.* 2000; Larson *et al.* 2003; Matticka *et al.*2003; Chen and Godwin 2006; Hong and Brown 2009). Among several test methods, ATP bioluminescence (ATP-B) assay is one of the widely used methods for the detection of microbial contamination and food residues in the food industry (Corbitt *et al.* 2000; Lappalainen *et al.*2000; Larson *et al.* 2003; Chen and Godwin 2006; Powitz 2007). This method provides a real-time estimation of total surface cleanliness including the presence of organic debris and microbial contamination (Leon and Albrecht 2007). However, conflicting findings have been reported with regard to correlation between ATP bioluminescence and the number of bacteria in a sample tested using the total plate counting (TPC) method (Tebbutt *et al.* 2007; Whitehead *et al.* 2008). Hence, the ATP-B assay is used as an indicator of total cleanliness, and unlike the TPC method, it does not quantify the number of micro-organisms in a sample. Moreover, any trace of food residues may carry ATPs adding to the amount of microbial ATP. This should explain the reason why some studies have found poor correlation between ATP results and the number of bacteria in samples.

Selecting an effective combination of both cleaning materials and disinfectants is essential in ensuring the clean or hygienic food contact surfaces (Diab-Elschahawi *et al.* 2010). Even though the use of cleaning cloths and disinfectants is an important part of the cleaning process, reusable cleaning cloths usage is discouraged because of their ability to re-contaminate surfaces; however, food premises have continued to use them (Tebbutt 1991). Nonetheless, there is very little information on the effectiveness of commonly used cleaning materials in the deli environment. Studies have been conducted to determine the effectiveness of cleaning regimes (Tebbutt 1984, 1991; Griffith *et al.* 2000; Worsfold and Griffith 2001) but, with little focus on the efficacy of individual cleaning cloths. The use of cleaning cloths in combination with disinfectants has also been investigated (Tebbutt 1991; Tebbutt *et al.* 2007). Disinfectants are used to reduce the number of potential pathogens on food contact surfaces and are widely accepted to ensure food safety if properly used. Surfaces cleaned with a cloth soaked in a disinfectant are more likely to be successfully cleaned than those wiped with cloths that are not disinfected after use (Tebbutt 1991). To achieve maximum cleaning effect, cleaning cloths in most food-service establishments are usually soaked in dilute disinfectants whenever they are not in use. However, a majority of retail food-service establishments fail to prepare correct dilutions of disinfectants and do not change them until they are deactivated resulting to bacterial contamination of the cloths (Tebbutt 1988). Such contaminated cloths are difficult to adequately disinfect after each use (Tebbutt 1991). Silver dihydrogen citrate (SDC) spray is a ready to use disinfectant that has broad spectrum and residual disinfectant characteristics against bacteria, fungi and viruses. It contains silver ions stabilized in citric acid and is known to damage an organism's DNA and protein structure by lysing cell membrane, causing the cell death (Purebio 2012). We tested for the efficacy of four different wiping cloth types along with SDC or quaternary ammonia in cleaning food contact surfaces. The efficacy testing of SDC spray to reduce microbial counts on test surfaces was included in this study as the postwiping use of disinfectant sprays may contribute in the reduction in cross-contamination caused by inefficiently sanitized cleaning cloths. Thus, the study intends to assess the effectiveness of commonly used cleaning cloths in cleaning food contact surfaces, determine the effectiveness of cloth and disinfectant combinations in reducing food contact surface contamination to acceptable levels and correlate the detection capability of ATP-B and TPC testing methods.

Materials and Methods

Wiping cloths and treatments

Four different wiping cloths selected in this study were blended cellulose/cotton cloth (70% cellulose and 30% cotton; supplied by Kalle, Gurnee, IL, USA), nonwoven wipes (50% viscose and 50% polyester; supplied by Ecolab, St. Paul, MN, USA), microfibre cloth (supplied by Super Detail, Inc. San Diego, CA, USA) and cotton terry

bar towels (100% cotton utility dishcloth supplied by Mainstays, Pakistan). Quaternary ammonia cleaning solution (Oasis 146 Multi-Quat sanitizer; Ecolab Inc., St Paul, MN, USA) and SDC disinfectant (Pure Bioscience, El Cajon, CA, USA) were also used. Formica dining tables under daily use at a local operating food-service facility were selected as the representative food contact surfaces of public sector. A no cloth positive control was included along with the cloth and cloth-disinfectant combination treatments.

Quaternary ammonia treatment of food contact surfaces and sampling procedure

In this part of our study, the cleaning crew members of the dining facility were given with the four cloth types mentioned earlier for cleaning the Formica dining tables. The cloth treatment involved use of cloths dipped in quaternary ammonia and squeezed thoroughly before wiping. The tables in the premises were cleaned by following the set procedure of the establishment that included placing the cloths into a quaternary ammonia solution while the cloths were not being used. We asked the cleaning personnel to use each type of cloth over a period of 1 week for wiping the table surfaces. A different test cloth was used for each of the following weeks, until all of the four cloth types were tested. For each cloth type, six tables were randomly selected and five replicate samples from each table were collected after wiping. This was repeated for 3 days to collect a total of 360 samples for all four cloths. Sampling was carried out on 4th, 5th and 6th days after the introduction of a cleaning cloth to provide sufficient time to avoid prior cloth's cleaning effect. Sample collection was performed by swabbing a 100 cm^2 area of table surfaces within an aluminium square template. The swabbing was performed using ATP swabs that come with the ATP bioluminescence assay kit and were subjected to hygiene monitoring as described later. Relative light units (RLU) were recorded for each test area.

SDC disinfectant treatment of food contact surfaces and sampling procedure

This second part of the study was carried out by using three types of cleaning cloths consisting of two cloth types (blended cellulose/cotton cloth and nonwoven wipe) that performed best and worst, respectively, in the first study and a third cloth type (cotton terry bar towel) that is commonly used in the commercial food-service environment. No wipe positive control samples were collected before cloth treatments. The treatments were carried out by dipping a cloth in sterile water (Cloth type) and squeezed thoroughly before wiping. The wiping treatments were carried out by a trained research staff, which were designated to wipe the table surfaces throughout the study to ensure consistency and uniformity in the wiping method. Six randomly selected tables were assigned for each cloth type, and a before wipe positive control, postwiping cloth and cloth-disinfectant samples were taken/table. Manufacturer's recommended instructions were followed in using the SDC disinfectant wherein it was sprayed on the table surfaces and gently wiped with clean terry cloth after 5 min to minimize dampness caused by the disinfectant, and the sampling was carried out using sterile cotton swabs. This treatment was considered as a cloth-disinfectant treatment because the final microbial counts reflected the combined effect of both the terry cloth wiping and the disinfectant effect. This was repeated for 3 days in a week/cloth using different tables each day.

ATP bioluminescence (ATP-B) Assay

ATP samples were collected and measured using a SystemSURE Plus™ ATP Hygiene Monitoring System (Hygiena USA, Camarillo, CA, USA) as per the manufacturer's instructions (Hygiena, 2012). The ATP-B samples were collected with the provided Ultrasnap ATP test swab within a 100-cm^2 sampling area by swabbing in a zigzag horizontal and vertical pattern for 10 times each way, while rotating the swab and applying slight pressure on the surface being sampled. The tip of the swab handle was broken to release the luciferase/luciferin reagent, returned to its container in the device that was shaken from side to side for about 5 s and allowed to stand upright for 15 s. Readings were taken and recorded in RLU. An ATP-B test scale guidelines provided by the manufacturer were used as RLU >30 = dirty, RLU between 11 and 29 = caution and RLU < 10 = clean, and this scale was used to measure the effectiveness of the cleaning cloth types in removing total surface contamination from study surfaces.

Aerobic total plate count (TPC) Assay

Sterile calcium alginate swabs (Puritan Medical Products Company LLC, Guilford, Maine, USA) were used to collect aerobic plate count samples from 100-cm^2 sampling areas adjacent to the area that was swabbed for ATP-B. The sampling procedure was similar to that for ATP-B, but after sampling, the swabs were placed in sterile tubes containing 2 ml of 0·1% buffered peptone water (BPW) that was held cold on ice. The BPW tubes were taken to the laboratory within 2 h of the sample collection exercise and thoroughly mixed to prepare serial dilutions of the samples. One millitre of the diluted samples was plated onto 3M aerobic count petrifilms (3M Co., St. Paul, MN,

USA) and incubated for 24 h at 37°C. Recovered colonies were then visually enumerated and expressed as CFU cm^{-2} as indicated later.

Data analysis

Both TPC and the ATP-B data were manually recorded in an Excel spreadsheet (Microsoft Corp., Redmond, WA) and were converted to CFU cm^{-2} and RLU cm^{-2}, respectively, using the following formulae;

$$\mathrm{CFU/cm^2} = \frac{(\text{Average CFU per table}) \times (\text{Volume of original suspension})}{(\text{Total surface area} \times \text{number of swabs}) \times (\text{Dilution factor})} \quad (1)$$

$$\mathrm{RLU/cm^2} = \frac{\text{Average RLU per table}}{\text{Total surface area}} \quad (2)$$

The mean log CFU 100 cm^{-2} and mean log RLU 100 cm^{-2} recovered after cleaning and disinfecting surfaces with each cloth and cloth-disinfectant combinations were analysed by analysis of variance using PROC ANOVA analysis in SAS 9·2 (SAS Institutes, Cary, NC, USA). Means separations were compared by least significant differences where means with the same letter were not considered significantly different ($P < 0{\cdot}05$).

Results

Cloth + quaternary ammonia treatments

Results of using quaternary ammonia-dipped cloth types for wiping the table surfaces are shown in Table 1. The RLU values depict the amount of light produced depending on the level of contamination from the sample (higher the ATP numbers or higher luminescence means high level of contamination). We noticed some negative RLU values because of variability in contamination of certain sampling areas, and those data points were not taken into consideration for calculations. The observed RLU values were log transformed for comparison and as shown in Table 1, the nonwoven wipe was the most poorly performing cleaning cloth type with the highest average mean log RLU (2·89 RLU 100 cm^{-2}). Significant mean differences ($P < 0{\cdot}05$) were noted between the mean RLU values of nonwoven cloth and all the other three cloth types. The RLU values of blended cellulose/cotton cloth and microfibre cloths also differed significantly. There were no significant mean differences between the cleaning effect of cotton terry bar and microfibre cloth types, and the cotton terry bar RLU values were on par with the blended cellulose/cotton cloth. However, the lowest RLU values of both the cotton terry bar and the cellulose/cotton cloth types suggested that their cleaning effect was superior in performance with other two cloth types. No plate counts were measured from this part of the study.

Table 1 Least significant differences values showing differences in mean log RLU 100 cm^{-2} for each cloth type in the first study*

		ATP-B test
Cloth types	*N*†	Mean log RLU 100 cm^{-2}
Nonwoven	59‡	$2{\cdot}89 \pm 0{\cdot}30^{A}$
Microfibre	90	$2{\cdot}30 \pm 0{\cdot}30^{B}$
Cotton terry	88‡	$2{\cdot}26 \pm 0{\cdot}25^{CB}$
Cellulose/cotton	90	$2{\cdot}20 \pm 0{\cdot}28^{C}$

*Means with the same letter notation are not significantly different.
†Number of samples collected per treatment.
‡*N* differs for some cloth types because negative values were removed (Negative values because of variability in contamination of sampling area were not included).

Cloth treatments

The ATP-B levels measured as RLU values 100 cm^{-2} after wiping the table surfaces with each of the blended cellulose/cotton, cotton terry bar and nonwoven viscose/polyester cloth types (dipped in water and squeezed) were 169, 226 and 227 RLU 100 cm^{-2}, respectively. When compared with the control (dirty) surfaces, the blended cellulose/cotton, cotton terry bar and nonwoven viscose/polyester cloth types could bring down the mean log reductions in RLU values by 28·05, 25·10 and 18·09%, respectively. Further, there was no significant difference ($P > 0{\cdot}05$) in cleaning effect among the three cloth types (Fig. 1). Although the RLU log reductions after wiping with each cloth differed significantly ($P < 0{\cdot}05$) from the respective controls, the surfaces remained dirty with respective to the Hygiena ATP-B scale as these levels exceeded the acceptable RLU levels (Hygiena 2012).

The results of total plate counts (TPC) obtained from the samples collected after wiping the table surfaces with each of the three cloth types are presented in Fig. 2. For the positive controls, the TPC values measured before wiping the table surfaces with cotton terry, nonwoven viscose/polyester and blended cellulose/cotton cloths were 104·9, 125·4 and 50·1 CFU 100 cm^{-2} and were reduced by 67·08, 68·20 and 76·74% in the mean log CFU 100 cm^{-2}, respectively, after wiping. However, there was no significant difference in the log CFU 100 cm^{-2} values or the cleaning effect on table surfaces among the three cloth types (Fig. 2).

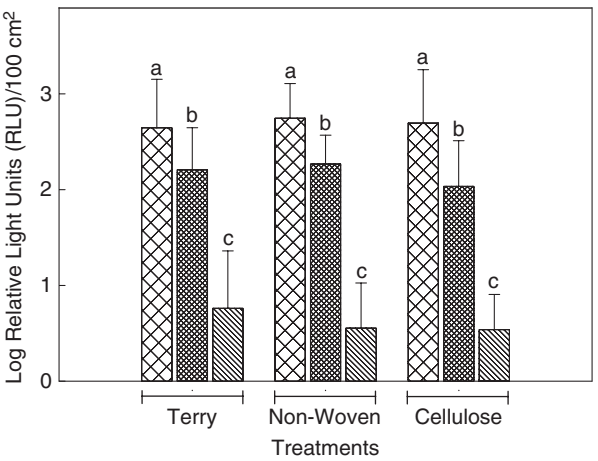

Figure 1 ATP-B results in relative log units (RLU) 100 cm^{-2}, indicating the efficacy of cleaning cloth types and cloth-disinfectant combinations in reducing total surface contamination. The RLU values for no wipe control (⊠), cloth alone (▨) and the cloth-silver dihydrogen citrate disinfectant combinations (▧) are shown. The ATP measurements are expressed in mean log RLU, and the same letter on the bar graphs indicates no significant statistical difference in the RLU values. Error bars represent the standard deviation of ATP-B measurement conducted in triplicate for each table surface sampled.

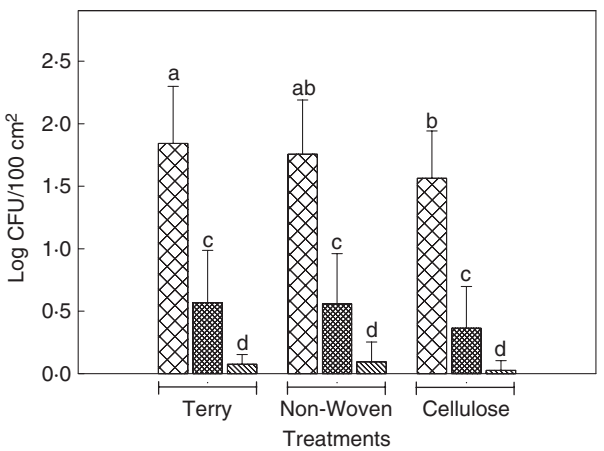

Figure 2 Total plate counting results in CFU 100 cm^{-2}, indicating the efficacy of cleaning cloth types and cloth-disinfectant combinations in reducing microbial counts from food contact surfaces. The results for no wipe control (⊠, cloth alone (▨) and the cloth-silver dihydrogen citrate disinfectant combinations (▧) are shown. The CFU measurements are expressed as mean log CFU 100 cm^{-2} where same letter on the bar graphs indicates no significant statistical difference in the CFU values. Error bars represent the standard deviation of ATP-B measurement conducted in triplicate for each table surface sampled.

Cloth + SDC disinfectant treatments

Wiping the table surfaces with the cloth types dipped and squeezed in SDC disinfectant showed significant reductions in the ATP-B values and the total plate counts compared with above-mentioned treatments. The ATP-B levels measured after the cloth-SDC treatments were near or within the acceptable levels of <10 RLU based on the ATP-B scale at 12, 5 and 6 RLU for cotton terry bar, blended cellulose/cotton and nonwoven viscose/polyester cloth-disinfectant combinations, respectively, and the corresponding mean log reductions were above 95% for all cloth types with no significant differences. However, the cleaning effect was significantly ($P < 0{\cdot}05$) improved with the use of disinfectant SDC with any cloth type when compared with the cloth alone treatments. This further suggested the cleaning efficiency of the tested cloth types can be enhanced when combined with the disinfectant spray as shown by the significant reductions in log RLU 100 cm^{-2} values (Fig. 1). Similar observations were noted with regard to the total plate counts wherein bacterial contamination was reduced to 0·7, 0·6 and 0·3 CFU 100 cm^{-2} for cotton terry, nonwoven viscose/polyester and blended cellulose/cotton cloth-disinfectant combinations, respectively, representing a corresponding reduction of 1·77 (95·70%), 1·66 (94·51%) and 1·54 (98·03%) log CFU 100 cm^{-2} (Fig. 2). Although the per cent log reduction for blended cellulose/cotton cloth-disinfectant combination was superior among all the cloth-disinfectant combinations, the mean differences of CFU 100 cm^{-2} were not significantly different ($P < 0{\cdot}05$).

Discussion

As several types of wiping cloths and disinfectants exist in the market for cleaning food contact surfaces, it is essential for food-service establishments to choose the best cleaning supplies that will not only clean the food contact surfaces but also reduce surface microbial loads to acceptable limits. This study assessed the effectiveness of selected cleaning cloth types and cloth-disinfectant combinations used in food-service establishments to clean the food contact surfaces. The ATP-B measurements indicated that none of the tested cloth types when used alone could bring the cleanliness to acceptable levels (RLU < 10). Further, the commonly followed cleaning practice in restaurants involving soaking of wiping cloths in quaternary ammonia for cleaning table surfaces also proved to be less effective in reducing contamination levels as seen by the RLU values. However, when the SDC disinfectant was used in the second study to sanitize the Formica surfaces, the contamination was reduced to acceptable levels for nonwoven and cellulose/cotton cloth types as per the ATP-B scale. Although the TPC for the dirty surfaces (positive controls) were <2·5 log CFU cm^{-2}, it is worth noting that low microbial levels on surfaces

reduce the accuracy and reproducibility of all sampling methods (Tebbutt 1991). Moreover, the low bacterial counts can also be attributed to the fact that the tested table surfaces were subjected to daily cleaning with quaternary ammonia prior to the initiation of the study. This cannot be said same for the higher ATP-B measurements because the test detects adenosine triphosphates from both eukaryotic and prokaryotic cells. It should also be noted that the chemical components of a disinfectant may also interfere with the ATP-B fluorescence as revealed by some studies on the possibility of disinfectants reducing the activity of the luciferase enzyme and also acting as ATP-releasing agents, thereby contributing to potential false positive results (Lappalainen *et al.* 2000; Powitz 2007). Hence, the ATP-B measurements should not be considered as alternative for the total plate count results but should be confirmed by estimating the TPC counts as demonstrated in this study. For these reasons, the table surfaces in this study would be considered 'clean' with regards to the presence of microbial cells based on the TPC assay, but 'dirty' based on the ATP-B test. In case of cloth treatments, although the tested cloth types in this study did not differ significantly in their cleaning effects, the blended cellulose/cloth type yielded higher per cent log reduction than others when used alone or in combination with the disinfectant or disinfectant. The log reduction levels in both RLU and CFU values were highest when the cloths were used with SDC disinfectant. In a different study where we compared cleaning fabrics for bacterial removal from food contact surfaces, we revealed that the blended cellulose/cotton cloth had the highest cleaning ability because its pores and thickness made it possible to trap bacteria (Koo *et al.* 2011). The cellulose/cotton cloth is a sponge-like cloth made of a blend of cellulose (70%) and cotton (30%) fibres. Glauber's salt (sodium sulphate) crystals are added in the fibres to enhance their absorption properties (Evans *et al.* 1998). These properties may have contributed towards the effectiveness of the cloth in this study.

During the study period, we noticed wide variation in the results for positive control from some of the table surfaces indicating the uneven contamination levels of the surfaces, and hence, certain steps in sample collection protocol such as the pressure applied when cleaning food contact surfaces, swabbing method, the effectiveness of the swab in picking up microbial contamination and consequently dislodging into the BPW could limit the sensitivity of the swabbing method (Tebbutt 1991). Finally, the efficacy of the testing methods could also be another confounding factor. Thus, there is a need to establish contamination thresholds for food contact surfaces on which to base the effectiveness of cleaning methods. It would be expedient to have microbial criteria for testing cleanliness of food contact surfaces. The European Commission (2001) has recommended a guideline of <10 CFU cm^{-2} for cleaned and disinfected surfaces in meat establishments. Other studies are recommending microbial levels less that 2·5 CFU cm^{-2} for clean and sanitized surfaces (Worsfold and Griffith 2001; Tebbutt *et al.* 2007). As the criteria used to determine the scales that come with the ATP-B test kits is not verified in this study, we followed the suggestion of Worsfold and Griffith (2001), who have stated that an ATP value of 500 RLU being would be equivalent to $<2{\cdot}5$ CFU cm^{-2} for a surface to be considered clean. Thus, based on the results of this work and the findings of other studies as discussed earlier, the standard criteria for acceptable microbial levels on food contact surfaces may range between $<2{\cdot}5$ and 10 CFU cm^{-2} depending on the usage of the surfaces being evaluated. Although it may not be easy to tell the level of contamination that may constitute a health risk (Tebbutt *et al.* 2007) unless specific pathogen tests are carried out, the microbial thresholds for clean surfaces would help food-service establishments to determine the efficacy of their cleaning regimes as well as to reduce the potential risk of spreading foodborne diseases.

In conclusion, we demonstrated that it is crucial for food-service establishments to make appropriate choices of cleaning and hygiene monitoring. The cleaning cloths should be used in combination with an effective disinfectant when cleaning food contact surfaces. Our results are in agreement with the findings made by Tebbutt (1988) who revealed that the combination of a disinfectant and physical removal of microbes with cleaning cloths is essential. TPC and ATP-B data displayed comparable trends of contamination levels suggesting that either method could be used to determine the effectiveness of cleaning methods on food contact surfaces. The ability of the ATP-B test producing real-time results could play a significant role in providing quick verifications for total surface cleanliness estimates including the presence of organic fragments and microbial contamination. After potential contamination has been detected, corrective measures could then be implemented in time before food is served or distributed. The use of ATP-B should not, however, replace the TPC method but should be used as a complementary method to provide quick confirmation of bacterial contamination on food contact surfaces.

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