Microbial counts of food contact surfaces at schools depending on a feeding scheme

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The prominence of disease transmission between individuals in confined environments is a concern, particularly in the educational environment. With respect to school feeding schemes, food contact surfaces have been shown to be potential vehicles of foodborne pathogens. The aim of this study was to assess the cleanliness of the surfaces that come into contact with food that is provided to children through the National School Nutrition Programme in central South Africa. In each school under study, microbiological samples were collected from the preparation surface and the dominant hand and apron of the food handler. The samples were analysed for total viable counts, coliforms, *Escherichia coli*, *Staphylococcus aureus* and yeasts and moulds. The criteria specified in the British Columbia Guide for Environmental Health Officers were used to evaluate the results. Total viable counts were high for all surfaces, with the majority of colonies being too numerous to count (over 100 colonies per plate). Counts of organisms were relatively low, with 20% of the surfaces producing unsatisfactory enumeration of *S. aureus* and *E. coli* and 30% unsatisfactory for coliforms. Yeast and mould produced 50% and 60% unsatisfactory counts from preparation surfaces and aprons, respectively. Statistically significant differences could not be established amongst microbial counts of the surfaces, which suggests cross-contamination may have occurred. Contamination may be attributed to foodstuffs and animals in the vicinity of the preparation area rather than to the food handlers, because hands had the lowest counts of enumerated organisms amongst the analysed surfaces.

Introduction

The National School Nutrition Programme (NSNP) is a South African school feeding scheme aimed at alleviating poverty and improving learning capacity of children through school feeding.[1,2] The feeding scheme was introduced nationwide in 1994 and is funded through a provisional grant that is transferred to provinces according to the *Division of Revenue Act* as well as directives from the Department of Basic Education (DBE) and the National Treasury (Grant Framework 2010/11).[3,4] The DBE coordinates and oversees the programme, ensuring adherence to policies and relevant legislation through monitoring. The Provincial Education Departments are tasked with the procurement of goods and services for the NSNP while adhering to conditions stipulated by the Grant Framework.[3,4] Ntuli[5] explains that schools are funded according to a national system of ranking and funding of schools referred to as a quintile. The DBE ranks schools within quintiles according to this system, taking into account the socio-economic circumstances (such as inequality and poverty) of learners and schools. For example, schools rated at the lowest quintiles (1 and 2) receive more funding than schools ranked higher based on the Norms and Standards for Funding Schools.[5] The schools targeted for the NSNP are primary and secondary schools ranked in quintiles 1 to 3.[3]

Similarly to other confined environments, the school environment favours direct transmission of diseases among individuals; foodborne illnesses are therefore a concern in the administration of the NSNP in schools. School environments are particularly prone to epidemiological outbreaks as a result of the nature of inter-personal dynamics.[6] The risk is augmented by the introduction of an additional variable that supports microbial proliferation, such as food. Food, water and surfaces may be contaminated with considerable quantities of pathogenic microorganisms during food preparation and consumption, which may result in illnesses.[7] Young children are particularly vulnerable to pathogenic bacteria and are at risk of developing pathological conditions, including haemolytic uremic syndrome and osteomyelitis, when infected with pathogens such as *Escherichia coli*, *Staphylococcus aureus* and some opportunistic pathogens upon consumption of contaminated foods.[6,8] Possible outbreaks amongst school children are of concern as illnesses from pathogenic bacteria may last up to 3–5 days.[8,9]

The main factors that lead to foodborne illnesses are improper time or temperature control, poor personal hygiene of the food preparer and cross-contamination.[10,11] Blackburn[12] describes food contact surfaces and food handlers' hands as significant potential vehicles of pathogens. These surfaces have been found to have a significant contribution to cross-infection and pose a constant risk of microbial transfer.[13] The treatment of such surfaces through cleaning and sanitisation is important in reducing the number and type of potential pathogens.[14] Frequent sanitation (cleaning and disinfection) is the most effective control in ensuring the microbiological safety of foodstuffs.[12] It is also critical to ensure that cleaning is achieved to a degree that substantially reduces cross-contamination and ensures the integrity of the food.[15,16] Failure to effectively clean and disinfect these surfaces is a risk factor in the dispersal of foodborne pathogens.[17]

In addition to cleaning and sanitising, the application and evaluation of monitoring methods is necessary for ensuring the efficiency of sanitation procedures in the food-processing environment.[18] Furthermore, microbiological testing plays an important role in identifying potential threats and their sources as well as in evaluating the effects on the final product. Assessments may further assist in developing and implementing preventative measures[12] and may promote food safety in school feeding schemes such as the NSNP. The NSNP was introduced to serve food to pupils across the country, mainly among poverty-stricken communities. However, because the programme is rolled out at schools that are primarily deficient of proper catering facilities, the maintenance of hygiene may be questionable during the administration of the programme. It was envisaged that the current study would provide information, through the use of microbiological methods, on the general hygiene of surfaces in contact with

foodstuffs during the administration of the NSNP at participating schools in Bloemfontein, South Africa.

Materials and methods

Sampling protocol

Ten schools were randomly selected from amongst beneficiaries of the NSNP in the Bloemfontein area. The sample represented schools in quintiles 1, 2 and 3, and included primary, intermediate, combined and special schools from the rural and urban regions. To maintain confidentiality, each school was assigned an alphabetical code. For each school, representative microbial samples were collected from three previously cleaned surfaces that had come into contact with foodstuffs, namely the preparation surface, and the hand (thumb, forefinger, middle finger and palm of dominant hand) and apron of the food handler. In total, 120 surface samples were collected. All samples were transported on ice to the laboratory where investigations were conducted without delay. All analyses were performed in triplicate.

Sampling procedure and microbial analysis

Microbial samples were collected and quantified using 65-mm Rodac plates (Lasec, Cape Town, South Africa). The media were prepared according to the manufacturers' instructions, followed by preparation of the contact plates according to the method proposed by Ness[19]. The selected agar media were used to investigate total viable counts (TVC), total coliforms, *E. coli*, *S. aureus* and yeasts and moulds on the dominant hand of each food preparer. Four contact plates (containing the respective agar media) were used for each of the three food contact surfaces – the preparation surface and the food handler's hand and apron.

Total viable counts

Plate count agar (Merck, Johannesburg, South Africa) was used for the enumeration and detection of TVC and plates were incubated at 36 °C for 24–48 h.[20]

Total coliforms and *Escherichia coli*

Total coliforms and presumptive *E. coli* were enumerated using Chromocult coliform agar (Merck) and incubated at 36 °C for 24–48 h. Typical coliforms were salmon pink to red in colour, whilst *E. coli* presented as typical dark blue to violet colonies.[21]

Staphylococcus aureus

Baird-Parker agar (Merck) supplemented with egg yolk telluride emulsion was used for the enumeration of presumptive *S. aureus* and plates were incubated at 36 °C for 24–48 h. Grey–black shiny colonies with white margins surrounded by clear zones were identified as *S. aureus* colonies.[22]

Yeasts and moulds

Potato dextrose agar (Merck) plates were incubated at 25 °C for 3–5 days for the enumeration of yeasts and moulds.[23] Typically, yeasts exhibited cream-coloured to white colonies and moulds appeared as filamentous colonies of various colours.

Analysis of data

Upon differentiation of microbial colonies on appearance and colour, the colonies were counted using a Symbiosis aCOLade colony counter (Vacutec, Johannesburg, South Africa) and expressed as colony-forming units (CFU)/cm^2. All results were evaluated using the British Columbia Centre for Disease Control (BCCDC) Guide for Environmental Health Officers and classified according to the following criteria: satisfactory (<5 CFU/cm^2); acceptable (5 CFU/cm^2 to 10 CFU/cm^2); and unsatisfactory (>10 CFU/cm^2).[24] The guideline provided by the BCCDC articulates well with the units and best described assumptions used in this study. In addition, the BCCDC guide was found to cover significantly more categories than the South African R.918 of 1999 which offers only the guideline of 100 CFU/cm^2 for surfaces.[25] For the purposes of this study, counts of over 100 colonies – as determined by the probable number of volumes which produced a matrix of growth rather than individual countable colonies – were labelled as 'too numerous to count' (TNTC). Significance was determined using an unpaired *t*-test and was defined at a *p*-value of 0.05.

Results and discussion

As shown in Table 1, in terms of TVC, 80% of all the surfaces sampled had counts that were TNTC. For total coliforms, 60% of the counts obtained from hands were satisfactory while 20% were acceptable and 20% were not detectable. For preparation surfaces, 40% of coliform counts were satisfactory and 20% were acceptable, whereas 30% were unsatisfactory and 10% were not detectable according to the BCCDC guide. Furthermore, 80% of the apron counts were satisfactory, 10% were acceptable and 10% were not detectable for total coliforms. For hands and aprons, 50% and 90%, respectively, of *E. coli* counts were satisfactory; the remaining counts of both surfaces were not detectable. Additionally, 60% of the *E. coli* counts for the preparation surfaces were satisfactory, 10% were acceptable, 20% were unsatisfactory and 10% were not detectable (Table 1). For hands, 80% of the *S. aureus* counts were satisfactory, 10% were acceptable and 10% were not detectable, whereas for preparation surfaces, 60% were satisfactory, 20% were acceptable and 20% were unsatisfactory, and all detectable counts (90%) were satisfactory for aprons. According to the BCCDC guidelines, for hands, 60% of the counts of yeasts and moulds were satisfactory, 20% were acceptable, 10% were unsatisfactory and 10% were not detectable. For the preparation surfaces, 40% of the counts were satisfactory, 50% were unsatisfactory and 10% were not detectable; and 40% of the counts were satisfactory and 60% were unsatisfactory for aprons (Table 1). Of the three surfaces analysed, preparation surfaces enumerated the highest counts of total coliforms, *E. coli* and *S. aureus*. Aprons yielded the highest counts of yeast and moulds while hands had the lowest counts of these organisms.

The objective of the TVC measure is to provide a general indication of the number of organisms present in the sample, thereby indicating the general hygiene status of the sample[26], whereas the presence of coliforms indicates a risk of occurrence of pathogens and is therefore a measure of the effectiveness of sanitation programmes[27,28]. In addition, coliforms, including *E. coli*, form part of the natural microbiota in the intestinal tracts of warm-blooded humans and other animals. Their presence generally indicates faecal contamination.[20,29,30] Pathogens may be present in faeces in concentrations of between 10^4 and 10^{11} per gram, indicating that even a tenth of a milligram of faeces on the skin may contain up to a million infectious bacterial cells.[8] A higher contamination of food by hands than that by surfaces was observed during a study by Taulo et al.[7] in which they found that the transfer of *S. aureus* was significantly higher than that of *E. coli*. The authors postulated that although the traditional cooking of thick porridge inactivated *S. aureus* and *E. coli*, the porridge could have been contaminated with the bacteria by hands and wooden ladles during serving. During the present study, however, the hands of food handlers yielded lower counts of all enumerated organisms (total coliforms, *E. coli*, *S. aureus* and yeasts and moulds) than did the preparation surfaces. This finding suggests that the sources of contamination are more likely the foodstuffs and animals (particularly rodents in rural areas) in the vicinity of the preparation area rather than the food handlers.

Although some visual differences were observed among the contamination levels of hands, preparation surfaces and aprons, there was no statistically significant difference in microbial counts among these food contact surfaces ($p \geq 0.05$). Thus, it appears that considerable cross-contamination occurred among the surfaces with no evident differences in, for example, cleaning regimes. Additionally, this observation points to the absence of a practice that isolates these surfaces from one another so as to prevent or hinder cross-contamination. Other factors which may lead to the contamination of surfaces include the use of contaminated water and shortcomings in surface sanitation methods, such as an incorrect detergent to water dilution ratio or an inadequate contact time

Table 1: Counts of various organisms from food contact surfaces of schools in Bloemfontein participating in the National School Nutrition Programme

School	Surface	Bacterial counts (CFU/cm²)				
		Total viable counts	Total coliforms	*E. coli*	*S. aureus*	Yeasts and moulds
A	Hands	TNTC	2.50	0.50	0.50	1.33
	Table	TNTC	9.88	4.13	1.47	3.31
	Apron	12.50	3.17	1.00	1.57	2.73
B	Hands	TNTC	0.40	ND	4.00	0.50
	Tray	TNTC	ND	ND	1.00	1.00
	Apron	TNTC	1.44	0.88	0.70	TNTC
C	Hands	TNTC	1.00	0.50	0.40	TNTC
	Sink	TNTC	1.17	1.25	0.60	TNTC
	Apron	TNTC	1.44	0.60	ND	TNTC
D	Hands	TNTC	1.00	0.50	3.67	7.00
	Table	TNTC	TNTC	7.00	12.19	TNTC
	Apron	TNTC	9.19	2.44	2.60	TNTC
E	Hands	TNTC	7.93	2.62	4.80	2.25
	Tray	TNTC	4.75	4.56	5.88	3.94
	Apron	TNTC	1.42	0.29	2.38	TNTC
F	Hands	TNTC	4.00	2.63	1.25	2.33
	Table	TNTC	13.75	11.88	4.31	TNTC
	Apron	TNTC	2.00	1.00	1.33	0.78
G	Hands	TNTC	1.50	ND	2.20	3.71
	Tray	TNTC	TNTC	TNTC	TNTC	TNTC
	Apron	4.06	1.70	1.40	2.77	TNTC
H	Hands	0.83	ND	ND	1.00	0.50
	Table	TNTC	2.75	1.00	1.20	ND
	Apron	TNTC	1.10	1.00	3.57	1.80
I	Hands	0.17	ND	ND	ND	ND
	Table	TNTC	6.13	1.00	1.13	17.19
	Apron	1.00	ND	ND	0.86	0.88
J	Hands	3.80	5.17	ND	5.57	5.75
	Table	TNTC	2.69	1.25	5.14	5.75
	Apron	TNTC	2.00	1.43	4.17	TNTC

TNTC, too numerous to count (>100 colonies); ND, not detectable using the current method.

for disinfectants.[7,31] A study by Mosupye and Von Holy[32], in which they assessed the facilities of street food vendors in Johannesburg, South Africa, indicated high aerobic plate and coliform counts from surface samples collected from a vendor who did not clean the food preparation surface during preparation whereas fewer counts were observed from a vendor who constantly cleaned the surface using a dishcloth. The main source of contamination by yeasts and moulds is the environment, particularly the air.[33] Preparation areas of the majority of the schools

were predisposed to becoming dusty because of a lack of proper kitchen facilities and ventilation which may contribute to contamination of surfaces and foodstuffs.

Illness-causing bacteria may survive on various surfaces around the kitchen, including hands, utensils and cutting boards. The US Centers for Disease Control and Prevention[34] recommend that hands be washed for 20 s with soap and running water, followed by scrubbing at the back, between fingers and under the nails. Furthermore, for utensils and cutting boards to be sufficiently sanitised, hot water with detergent and a sanitising (bleach) solution should be used. Although not sufficient, handwashing alone significantly reduces levels of bacteria load. As a result of a lack of resources and infrastructure limitations, the majority of the schools participating in the NSNP did not have handwashing facilities within the food preparation areas, nor did they have readily available hot water. The water taps, particularly at schools located in rural areas, were located outside and were not in the vicinity of the food preparation areas. Snyder[35] found that rinsing hands in a bucket of acetic acid solution prepared with tap water (at room temperature) and distilled vinegar (5% acetic acid) significantly reduced *E. coli*. The solution proved to maintain effectiveness after several hand rinses (less than 1 CFU/10 mL was observed in the solution after 24 h).

In addition to cleaning practices, the nature of the contact surfaces may have an impact on contamination levels of foods with microorganisms. According to the South African Health Regulations (R.918 of 1999), the surface which comes into direct contact with food should be made of smooth, rust-proof, non-toxic and non-absorbent material that is free of open joints, chips or cracks.[25] Generally, smooth surfaces are easier to clean than irregular surfaces. Surfaces which may crack, splinter, scratch and distort provide harbourage for microorganisms and prevent proper cleaning and sanitising.[14] Additionally, organic material from food residues may reduce the effectiveness of disinfectant by either reacting chemically with the disinfectant or inhibiting the physical access of the disinfectant to the targeted microbiota.[36,37] The high levels of organic material likely to be present on food contact surfaces increase the hydrophilicity of the surfaces; bacteria attach more readily to hydrophilic surfaces, but struggle to remain attached to hydrophobic surfaces.[38-40] The majority (60%) of the schools sampled during the current study prepared food on wooden table tops while the other 40% used plastic surfaces (data not shown). According to Abban et al.[40], stainless steel is the material of choice in the food-processing environment. However, plastic cutting boards may also contribute greatly to cleanliness and minimise cross-contamination.[14] According to Entis[36], the cutting board is the most susceptible of all the kitchen utensils to contamination and the porous nature of wood leads to concerns regarding the potential for cross-contamination. The wooden food preparation surfaces employed by schools in this study were irregular and hydrophilic with distinct flaws, thus creating a favourable habitat for microorganisms to attach and grow. Conversely, it is noteworthy that the preparation surface (which was made of plastic) used by school G had counts that were TNTC for all enumerated organisms (Table1), which indicates that the method of sanitation may have a greater impact on the hygiene of surfaces than the nature of the material from which the surface is made.

Conclusions

Generally, in the present study, we found that preparation surfaces had the highest counts of the detected pathogens, whereas hands had the lowest counts of microorganisms. However, a significant difference in the microbial loads amongst the food contact surfaces could not be established. These findings suggest that although the surfaces may not have been sources of contamination, opportunity for cross-contamination among surfaces may exist because of a lack of surface isolation and shortcomings in cleaning regimes. To prevent cross-contamination, all equipment and working surfaces must be thoroughly washed with hot water and detergent after being used to prepare raw foods. In this regard, sanitation programmes have proved to be cost effective and simple to implement and to significantly reduce microbial contamination.[12,41] According to DeVere and Purchase[17], the traditional two-step detergent and rinse cleaning method has been substituted with various antibacterial products that have been developed to provide fast and effective cleaning to food preparation areas. Household bleach (sodium hypochlorite) is an inexpensive and readily available agent for sanitising preparation surfaces.[36] Individuals may carry thousands of bacteria (such as *S. aureus* and *Salmonella* bacteria) on the surface of their skin and are usually not aware that they may be carriers of food pathogens.[41] The importance of washing hands, particularly after using the toilet, should not be overlooked. With the various opportunities for food to become contaminated during production and preparation, monitoring procedures, which include microbial analyses, may contribute to ensuring the safety of foodstuffs.

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Authors' contributions

W.H.G. was the project leader and made conceptual contributions. R.J.F.L. made conceptual contributions and was responsible for the experimental and project design. N.N. performed all of the experiments and wrote the manuscript.

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