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Carriage of micro-organisms by domestic cockroaches and implications on food safety

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Abstract. Domestic cockroaches *Blattella germanica* were trapped from various homes in Gaborone, Botswana using 'Dyroach' traps. Isolations of bacteria, yeasts and moulds were done on external body parts and on the faecal pellets using various selective media. Body parts of cockroaches were also fixed with OsO_4 vapour for 24 h, sputter coated with gold under special conditions and examined in a Phillips (1) XL30 ESEM in low vacuum mode. A wide spectrum of bacteria including common food spoilage and pathogenic organisms, such as *Bacillus* spp., *Staphylococcus* spp., *Escherichia coli*, *Pseudomonas* spp., *Enterobacter* spp., *Klebsiella* spp., *Erwinia* spp. *Salmonella* sp., *Shigella* sp. and *Serratia* spp. were isolated. Yeasts commonly associated with food spoilage, such as *Pichia* sp., *Candida* sp. and *Torulopsis* spp. were found on many cockroaches. In addition, various groups of moulds, some associated with food spoilage and others known to produce mycotoxins, such as *Aspergillus flavus*, *Aspergillus fumigatus* and *Aspergillus parasiticus* were isolated. Antimicrobial sensitivities of bacterial isolates revealed resistance patterns to various agents. Since cockroaches are prevalent in homes, particularly in food preparation areas and since their body parts and faecal pellets have been found in food storage areas, concern about their impact on food quality and safety is raised and possible control measures including education of communities on proper sanitation are suggested.

Key words: cockroaches, pathogenic micro-organisms, antibiotic resistance, bacteria, fungi

Résumé. Des blattes domestiques *Blattella germanica* ont été piégées dans plusieurs maisons à Gaborone, au Botswana à l'aide de pièges 'Dyroach'. On a réalisé des isolements de bactéries, de levures et de moisissures à partir de plusieurs morceaux d'exuvie et des fèces en utilisant différents milieux de culture sélectifs. Des morceaux d'exuvie ont également été fixés avec des vapeurs d'OsO_4 pendant 24 h, recouverts d'une couche d'or et examinés en microscopie électronique à balayage sous vide à l'aide d'un microscope Phillips (1) XL30 ESEM. On a réussi à isoler un vaste spectre de bactéries comprenant des organismes pathogènes et présents dans les déchets de nourriture tels que *Bacillus* spp., *Staphylococcus* spp., *Escherichia coli*, *Pseudomonas* spp., *Enterobacter* spp., *Klebsiella* spp., *Erwinia* spp., *Salmonella* sp., *Shigella* sp. et *Serratia* spp. Des levures fréquemment associées

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aux déchets de nourriture, telles que *Pichia* sp., *Candida* sp. et *Torulopsis* spp. ont été trouvées sur plusieurs blattes. De plus, plusieurs groupes de moisissures, certains associés aux déchets de nourriture, d'autres connus pour produire des mycotoxines tels qu'*Aspergillus flavus*, *Aspergillus fumigatus* et *Aspergillus parasiticus* ont été isolés. Des tests de sensibilité aux antibiotiques appliqués à plusieurs isolats bactériens ont permis la mise en évidence de forme de résistance à différents antibiotiques. Dans la mesure où les blattes sont très communes dans les habitations, en particulier sur les lieux de préparation des aliments et où leurs exuvies et leurs fèces ont été trouvés dans les lieux de stockage de la nourriture, on a pu montrer l'importance de leur impact sur la qualité et l'innocuité de la nourriture, imaginer des mesures de prévention et suggérer l'éducation des communautés sur des mesures sanitaires adaptées.

Mots clés: blattes, microorganismes pathogènes, résistance antibiotique

Introduction

Cockroaches are regarded as the most important household pests that are found in many places particularly in areas where food preparation, storage and sale take place (Rivault *et al.*, 1993a; Vythilingam *et al.*, 1997). Recently, with the increase in street food vending in Botswana, cockroaches have been reported to be the most common insects in streets where food is vended (Oteng, 2003). It is expected that more than 40% of cockroach populations will be found in urban areas because of inadequate solid waste disposal, accumulated waste, poor housing standards and inadequate water supplies (Gratz, 1999). The increase in cockroach infestation has been attributed specifically to mishandling of refuse, including the use of deformed, rusty, overfilled, uncovered and punctured bins, and to lack of timely collection of refuse (Boase, 1999).

The lifestyle of cockroaches makes them the perfect vector for food spoilage micro-organisms. Cockroaches are scavengers that survive on a wide variety of organic matter. The presence of cockroaches in large numbers in homes serves as a source of these insects in food vending sites, since they can be transported with food utensils (Mpuchane *et al.*, 2005). They excrete and regurgitate partially digested food onto the surfaces including food (De Jonge, 1993). Due to their rough body surfaces and their foraging habits, they collect dirt including micro-organisms as they move around. They carry bacteria on their cuticle (Rivault *et al.*, 1993b) and in their midgut area (Cloarec *et al.*, 1992; Paul *et al.*, 1992). In addition, they deposit their droppings (faecal pellets) and shed body parts including nymphal skins as they forage. They have also been reported to deposit various nitrogenous products, which have been shown to be allergenic. Their secretions are responsible for an objectionable cockroach-like smell of affected foods.

Several studies have demonstrated the involvement of cockroaches as vectors of pathogenic organisms in various environments (Fotedar and Banerjee, 1992; Bennet, 1993; Kim Kitae *et al.*, 1995). They have been implicated as reservoirs for *Salmonella* in livestock premises and in poultry-processing environments (Devi and Murray, 1991; Kopanic *et al.*, 1994; Marty, 1998). They have also been associated with nosocomial infections in hospitals (Sramova *et al.*, 1992; Cotton *et al.*, 2000; Prado *et al.*, 2002; Gliniewicz *et al.*, 2003). Food spoilage micro-organisms have also been isolated from the surfaces of cockroaches (Fotedar and Banerjee, 1992).

The occurrence of cockroaches in food preparation areas, the diversity of micro-organisms that they harbour and the fact that some of these demonstrate resistance to various antimicrobials have been of concern lately in Botswana, especially with the mushrooming of street food vendors. The impact cockroaches may have on the health of individuals has not been determined. In addition, no information on the carriage of food spoilage or food-borne micro-organisms in Botswana exists. With that in mind, research on carriage of micro-organisms on cockroaches was conducted in homes of three communities in Gaberone. In this paper, we report on the micro-organisms isolated from cockroaches trapped from kitchens and their antibiotic resistance patterns, and we highlight associated safety concerns.

Materials and methods

Cockroaches were collected over a 9-month period in 2000 and 2001 from kitchens in three locations (University Community, Old Naledi and Tlokweng) in Gaborone, Botswana using Dyroach traps (Robertsons Pty Ltd, South Africa), which contain cyclotene as an active ingredient. Four hundred and thirty-two traps with a tablet of attractant in the centre of a sticky surface were used. The attractant

caused movement of cockroaches towards the centre of the trap where they became immobilized by the sticky surface. Traps were then stored at 4°C in cold rooms for up to a week until analysed.

The University of Botswana (UB) community consists of by and large a high-income bracket group. Tlokweng community is predominantly middle income, while Old Naledi residents are a low-income group who still use pit latrines that are detached from the main residence.

Chemicals were purchased from Sigma, USA; media from Oxoid, Basingstoke, UK and the API20E strips from bioMeriux, France. Biolog microbiological identification system (Biolog Inc., USA) was used to identify the most predominant bacteria.

Isolation and enumeration of micro-organisms

Ten to thirty of the immobilized cockroaches from each trap were carefully removed with the aid of sterile forceps and suspended in a known volume of sterile peptone water. This was further diluted with the same diluent as deemed necessary. From each dilution, triplicate 0.1 ml aliquots were seeded into plate count agar for total aerobic mesophilic count. For total spore counts, a 1:10 dilution was heat treated for 8 min at 80°C, before plating duplicate 0.1–1 ml aliquots on plate count agar. Incubation was carried out at 30°C for 24–48 h.

Duplicate aliquots of 1, 0.1 and 0.01 ml from the different dilutions, were transferred into lauryl tryptose broth (10 ml/tube) tubes and incubated at 35 and 44.5°C to determine the most probable number (MPN) for total and thermostable coliforms, respectively. The presence and MPN of *Escherichia coli* was further determined by subjecting positive tubes at 44.5°C to a series of tests, including the following: indole production in tryptose broth at 44.5°C, gas production in lactose broth at 37°C, characteristic growth on eosin methylene blue agar and endo agar at 37°C, Gram-staining characteristics and reactions on API20E strips.

Faecal pellets were suspended in sterile peptone water, mixed thoroughly, and diluted as deemed necessary. Appropriate aliquots were applied on plate count agar and spread plated. Incubation was carried out for 24 h at 35°C.

Staphylococci were enriched in nutrient broth supplemented with 7% sodium chloride. After 24-h growth, a loopful of the sample was streaked on Baird-Parker medium and incubated at 35°C for 24 h. Black colonies with a raised centre and whitish margin were suspected to be staphylococci. These were further purified and subjected to various confirmatory tests, including growth characteristics in broth culture, Gram stains, catalase test, ability to withstand high salt concentration, oxidation/fermentation test, coagulase test and further characterized using API-Staph.

Samples were enriched for salmonellae in lactose broth followed by tetrathionate broth at 37°C for 16–24 h. Loopfuls of sample were then streaked into brilliant green agar (BGA). Characteristic colonies, which appear as smooth pink 1–2 mm colonies, were picked and streaked for pure culture isolation in fresh BGA and *Salmonella-Shigella* (SS) agar. Enrichment procedures for the isolation of *Shigella* species were essentially the same as for salmonellae. However, growth on solid medium was on SS agar.

Saccharolytic activity

Starch agar was used to detect saccharolytic bacteria after growth at 30°C for 48 h. Detection was by simple flooding of the plates with Gram's iodine solution.

Proteolytic activity

Nutrient agar supplemented with 2% casein and 20% gelatin was used to detect proteolytic bacteria after growth at 30°C for 48 h. Detection was by flooding with a solution of $HgCl_2$–HCl.

Antibiotic sensitivities

The Bauer *et al.* (1966) procedure was performed on the identified isolates using the following antibiotic discs: for Gram-positives—25 μg chloramphenicol, 5 μg erythromycin, 10 μg fusidic acid, 10 μg methicillin, 5 μg novobiocin, 1 unit penicillin G, 10 μg streptomycin, 10 μg tetracycline, 30 μg vancomycin, 30 μg cefepime and 30 μg cefprozil and for Gram-negatives—10 μg ampicillin, 5 μg cephalothin, 25 μg colistin sulphate, 10 μg gentamicin, 10 μg streptomycin, 25 μg tetracycline, 200 μg sulphatriad, 30 μg cefepime, 30 μg cefprozil and 25 μg cotrimoxazole. Inhibition diameters were measured and interpreted according to the manufacturers' recommendations (Mast Diagnostics, UK).

Isolation of yeasts and moulds

The carriage of yeasts and moulds on cockroaches was determined by suspending a known number of German cockroaches in 0.1% peptone water. The bottles containing cockroaches were thoroughly agitated for *c.* 60 s before plating onto dichloran rose bengal chloramphenicol agar (DRBC), a medium suited for the isolation of fungi from moist environments (King *et al.*, 1979). One hundred microlitres of the peptone diluent was plated in duplicate on DRBC agar after serial dilution up to 10^{-3}. All plates were incubated for 5 days at 25°C in the dark.

All yeasts isolated from DRBC were streaked onto CHROMagar *Candida* (Larone, 1993). The non-*Candida* species were identified according to the method of Pitt and Hocking (1994). The yeasts were purified by plating onto malt extract agar (MEA) supplemented with chloramphenicol and incubated for 48–72 h at 25°C. After growing the yeasts on MEA for 72 h, a loopful of cells was suspended in 2 ml of 0.1% peptone water. This was then used to inoculate (i) Czapek agar to assess ability of any yeast to utilize nitrate as a sole nitrogen source; (ii) two MEA plates: one for colony morphology and the second incubated at 37°C to assess growth at elevated temperatures; (iii) malt acetic agar to assess preservative resistance; (iv) malt-yeast extract with 50% glucose agar (MY50G) for growth at reduced water activity in the presence of high carbohydrate levels; and (v) malt-yeast extract with 19% salt in 12% glucose agar (MY10-12) for growth at reduced water activity in the presence of sodium chloride. Faecal pellets were seeded on DRBC agar and the resultant growth examined microscopically for the presence of yeasts.

Identification of moulds

Cultures were identified based on macro- and micro-morphology and reverse and surface coloration of colonies grown on MEA prepared according to Pitt and Hocking (1994). Identification of the isolates was based on mycological texts (Pitt and Hocking, 1985; Samson and van Reenen-Hoekstra, 1999). *Penicillium* and *Aspergillus* species were further characterized following the procedures of Pitt (1979) and Pitt and Hocking (1985).

Electron microscopy studies

Samples of various body parts and faecal pellets were placed in a sealed container and vapour fixed at 20°C overnight. The samples were gold sputter coated under special conditions in an SPI sputter coater. We utilized the Phillips XL30 ESEM in low vacuum mode between 0.1 and 0.4 torr.

Results and Discussion

A German cockroach weighed on the average 14 mg and carried on its surface an average bacterial load of $\log_{10}$ 5.8–7.4 CFU depending on the locality from where it was trapped. More samples of cockroaches from the UB community had higher counts than those from Naledi and Tlokweng communities (Table 1). The microbial load of the cockroaches may be a direct reflection of food remnants that may be available in the kitchen at homes belonging to the UB community and not in the other communities. This was because of the large number of samples with higher counts in UB community homes as compared with the others. It was surprising to see low counts of sporeformers, indeed less than 0.3% of the total count, although the soil in this part of Botswana is rich in sporeformers (Mpuchane and Gashe, 1996; Mpuchane *et al.*, 2000). Cockroaches secrete a variety of chemical substances from their dermal glands, which are rubbed onto the wings and cuticles. Some of these chemical substances are suspected to have repellent or depressive properties (Rose and Eisner, 1962; Brossut, 1983). Components of these secretions might also serve as a selective force against some members of the microbial community associated with cockroaches. This may explain why few sporeformers were encountered on the surface of the cockroaches.

Coliforms are monitored to assess the overall hygienic quality and safety of foods and other materials (Jay, 1992). Coliforms were present on the surfaces of almost all of the cockroaches sampled (Table 1); however, faecal coliforms (thermostable coliforms) were present only in 40–89% of the samples. *Escherichia coli*, the

Table 1. Average bacterial population found on the surface of German cockroaches trapped from the kitchen from different communities in Gaborone

Test	$\log_{10}$ bacterial population/cockroach		
	UB community	Old Naledi	Tlokweng
Aerobic mesophilic count	7.4 (100%)[+]	7.3 (100%)	5.8 (100%)
Total spore count	3.3 (86%)	2.0 (27%)	3.4 (73%)
Total coliform count	3.9 (100%)	4.8 (87%)	4.5 (93%)
Faecal coliform count	3.6 (89%)	4.5 (60%)	4.0 (40%)
Escherichia coli	2.3 (35%)	4.0 (40%)	1.5 (20%)

[+] Numbers in parentheses indicate the percentage of samples that harboured the group of test bacteria. UB, University of Botswana.

indicator of faecal contamination, was isolated from 20 to 35% of the samples. Previous investigations have also found members of coliforms on cockroaches (Cloarec *et al.*, 1992; Bennet, 1993). Cockroaches can spread coliforms, including those that are responsible for certain diseases, while foraging in the kitchen. Coliforms, such as *Enterobacter*, *Escherichia* and *Erwinia* species, and *Pseudomonas* species are also responsible for food spoilage. During the investigation, we also isolated pathogenic (*Salmonella* sp., *Staphylococcus aureus* and *Bacillus cereus*) and/or opportunistic bacteria (*Klebsiella*, *Pseudomonas* species) from cockroaches.

Both rods and cocci were isolated from the body surfaces of cockroaches (Table 2). A qualitative assessment of the bacterial flora revealed that Gram-negative bacteria were the predominant types (Table 2). Most belonged to the Enterobacteriaceae or Pseudomonadaceae families. This corroborates previous studies carried out by researchers in other countries (Branscone, 2002; Prado *et al.*, 2002). Among the Gram-positive organisms, members of the order Bacillales and Lactobacillales were isolated. Electron microscopy studies demonstrated that the bacteria were positioned on different parts of the cockroaches (Fig. 1A,B,C,D). The deposition of these micro-organisms on foods cannot therefore be excluded particularly where food is left exposed overnight.

Most of the saccharolytic isolates belonged to the Bacillaceae and Enterobacteriaceae families (Table 3); but Gram-negatives were more prevalent than the Gram-positives on the surface of cockroaches. Starchy foods could serve as nutrients for these bacteria with eventual spoilage of the food (Jay, 1992). They may also contribute to development of biofilms on solid surfaces in the kitchen, such as the sink and cutting boards.

Proteolytic bacteria play a role in the reduction of quality of meat and other proteinaceous products (Glazer and Nikaido, 1995). We found high numbers of *Pseudomonas* spp. and *Serratia* spp. on the cockroaches (Table 3).

While lipolytic activities were not determined, the presence of *Pseudomonas* and *Aspergillus* species among the isolates would lead us to speculate the presence of such activities in addition to the saccharolytic and proteolytic activities demonstrated in this study. Species of the two genera of bacteria and mould are known to be strongly lipolytic and contribute to the spoilage of foods (Glazer and Nikaido, 1995).

These activities not only change the organoleptic (flavour, colour and odour) quality of foods, but also alter the nutritional status as well as downgrading the aesthetic value of foods (Jay, 1992; Glazer and Nikaido, 1995).

Pathogenic or potentially pathogenic microorganisms have been isolated and documented previously (Kim Kitae *et al.*, 1995). In this study, we were able to isolate pathogens, emerging pathogens (for example, some *Serratia* species) and/or opportunistic pathogens like *Pseudomonas* species (Table 4). The cockroaches carrying these microorganisms can very easily deposit them on foods or on surfaces where food is prepared. The present immunosuppressed status of a large number of individuals in the population resulting from the HIV/AIDS pandemic calls for extreme vigilance about food quality and safety.

Yeasts belonging to the genera *Candida*, *Pichia*, *Schizosaccharomyces*, *Brettanomyces*, *Torulopsis*, *Trichosporon* and *Zygosaccharomyces* were found in association with the cockroaches. The most prevalent yeasts isolated were *Candida* sp. (62.5%), followed by *Trichosporon* sp. (10.2%) and *Zygosaccharomyces* sp. (6.8%) (Table 5). Lemos *et al.* (2006) also found *Candida* spp. to be the most dominant yeasts associated with cockroaches. Clusters of yeasts were also found on faecal pellets of cockroaches (Fig. 2A,B,C,D). Several of these yeasts are associated with spoilage of various types of food commodities (Jay, 1992). Their prevalence on cockroach surfaces and as components of cockroach internal flora suggests that cockroaches are ideal vectors of food spoilage yeasts.

Moulds were found all over the body of cockroaches (Fig. 3A,B,C,D). The most frequently isolated mould species was *Chrysonilia crassa*

Table 2. Most common genera of Gram-positive and Gram-negative bacteria isolated from the surface of German cockroaches

Gram-positive	Gram-negative
Arthrobacter sp.	*Burkholderia* sp.
Bacillus spp.	*Buttiauxella* sp.
Brevibacterium spp.	*Citrobacter* sp.
Corynebacterium spp.	*Enterobacter* spp.
Leuconostoc sp.	*Erwinia* spp.
Micrococcus spp.	*Escherichia* spp.
Rhodococcus sp.	*Hafnia* sp.
Staphylococcus spp.	*Kingella* sp.
	Klebsiella spp.
	Kluyvera sp.
	Proteus spp.
	Pseudomonas spp.
	Salmonella sp.
	Serratia spp.
	Shigella sp.
	Xanthomonas spp.

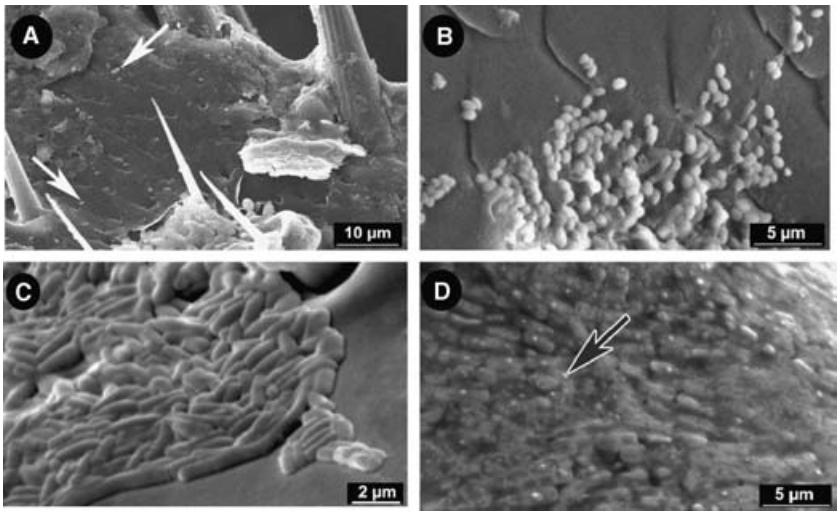

Fig. 1. A, Bacterial cocci and rods on abdominal surface of cockroaches. B, Aggregates of cocci on cockroach body. C, Bacilli on legs of cockroach and with spores (D)

Table 3. Predominant saccharolytic and proteolytic bacteria isolated from the surface of German cockroaches

Saccharolytic		Proteolytic	
Gram-positive	Gram-negative	Gram-positive	Gram-negative
Bacillus amyloliquefaciens	*Enterobacter* spp.	*B. cereus*	*Pseudomonas aeruginosa*
B. cereus	*Erwinia* spp.	*B. licheniformis*	*P. fluorescens*
B. halodurans	*Escherichia coli*	*B. megaterium*	*P. fragi*
	Klebsiella spp.	*B. halodurans*	*P. fulva*
	Kluyvera spp.		*P. putida*
			Proteus mirabilis
			Serratia ficaria
			S. liquefaciens
			S. marcescens
			Xanthomonas campestris
			X. oryzae

(24.1%). On the other hand, Lemos *et al.* (2006) found *Aspergillus* spp. to be the most dominant mould associated with cockroaches. However, in the present study, when species were considered at the genus level, it was *Penicillium* (37.8%) that was predominant, followed by *Trichoderma* sp. (9.5%) and *Aspergillus* (8.8%). In addition, *Fusarium* sp., *Mucor* sp., *Rhizopus* sp. and *Chaetomium* sp. were also isolated (Table 6). Some of these fungal isolates are associated with various types of food spoilage while others, such as *Aspergillus* spp., *Penicillium* spp. and *Fusarium* spp. are known mycotoxin producers or pathogens, and still others are responsible for spoilage (Fotedar and Banerjee, 1992; Abdel-Aal and Mazen, 1995; Siame *et al.*, 1998).

Table 4. Pathogens, emerging pathogens and opportunistic pathogens associated with German cockroaches

Bacteria		
Gram-positive	Gram-negative	Fungi
Bacillus cereus	*Salmonella* spp.	*Aspergillus* spp.
Corynebacterium spp.	*Shigella* spp.	*Fusarium* spp.
Staph. aureus	*Klebsiella* spp.	*Penicillium* spp.
	Citrobacter spp.	
	Pseudomonas spp.	

Over 100 bacterial isolates were tested against 11 antibiotics showing varying sensitivities. Twenty-four of these, which were regarded as pathogens or spoilage bacteria, are presented in Table 7. Resistance was widespread from this

Table 5. Yeast species isolated from cockroaches trapped from homes

Species	No. of isolates	%
Brettanomyces bruxellensis	3	3.4
Candida parapsilosis	10	11.4
C. tropicalis	17	19.3
C. krusei	28	31.8
Debaromyces hansenii	1	1.1
Pichia membranaefaciens	4	4.5
Schizosaccharomyces pombe	5	5.7
Torulopsis holmii	5	5.7
Trichosporon spp.	9	10.2
Zygosaccharomyces bailii	6	6.8
Total	88	

limited representation, especially among the Gram-positive bacteria. In a few cases, there was resistance to two or more antibiotics. A *Salmonella* sp. (a single isolate) was found to be resistant to cephalothin, a β-lactam antibiotic and sulphatriad, a folic acid analogue, while a *Staphylococcus* species was found to be resistant to as many as four antibiotics, including vancomycin. Previous study had also confirmed the presence of resistant bacteria from cockroaches (Cotton *et al.*, 2000). Antibiotic resistance and transfer of genetic material for resistance horizontally have become major issues, especially when dealing with health institutions and eating places.

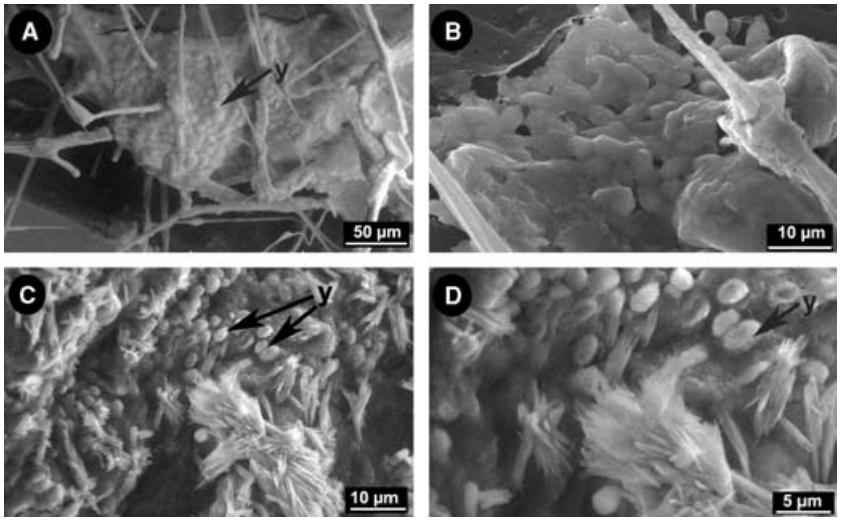

Fig. 2. A–D, Clusters of yeasts on faecal pellets of cockroaches among uric acid crystals

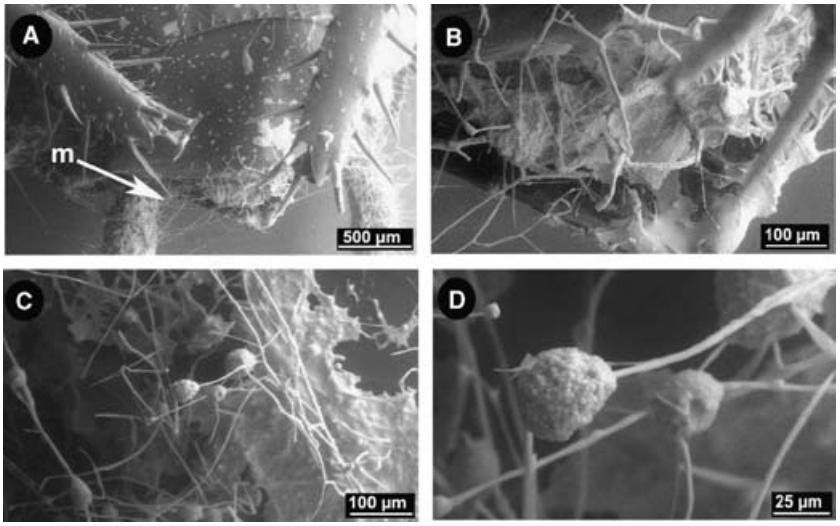

Fig. 3. A and B, Filamentous fungi growing on the cercal area, some with sporangia borne by the cockroaches (C,D)

Table 6. Filamentous fungi isolated from the surface of cockroaches from kitchens

Species	No. of isolates	% prevalence
Aspergillus flavus	3	1.9
A. ochraceus	2	1.3
A. terreus	5	3.2
A. carbonarius	1	0.6
A. niger	1	0.6
A. wentii	1	0.6
A. fumigatus	1	0.6
Chrysonilia crassa	38	24.1
Cladosporium cladosporoides	7	4.4
Chaetomium globosum	1	0.6
Fusarium moniliforme/proliferatum	6	3.8
F. graminearum	1	0.6
F. oxysporum	1	0.6
F. subglutinans	1	0.6
F. avenaceum	1	0.6
Moniliella acetoabutans	1	0.6
Mucor plumbeus	1	0.6
M. circinelloides	4	2.5
Paecilomyces lilacinus	1	0.6
Pestalotiopsis guepinii	1	0.6
Rhizopus oryzae	1	0.6
Verticillium lecanii	1	0.6
Neosartorya fischeri	4	2.5
Trichoderma harzianum	15	9.5
Penicillium glabrum	6	3.8
P. funiculosum	22	13.9
P. oxalicum	4	2.5
P. variable	11	7.0
P. brevicompactum	4	2.5
P. commune	4	2.5
P. hirsutum	2	1.3
P. viridiatum	3	1.9
P. aurantiogriseum	1	0.6
P. chrysogenum	1	0.6
P. solitum	1	0.6
P. verruculosum	1	0.6
Total number of isolates	159	

Conclusions and recommendations

We believe that the control of cockroaches wherever they occur is the key to preventing contamination of food by micro-organisms associated with cockroaches or their shed body parts and faecal pellets. The use of an integrated pest management system that incorporates cultural methods, good sanitation, use of environmentally sensitive insecticides and baits should be advocated and promoted. The need for education of food handlers cannot be overemphasized. At home level, this should include general cleanliness, proper discarding of leftover food, timely washing up of dishes and pots, rinsing of cans or bottles before disposal and use of cockroach-proof garbage bins. Outside the home, control should include proper management of landfills, use of proper disposal facilities in public vending and eating sites, proper sanitation and the use of environmentally friendly chemicals to control the cockroaches. Special attention needs to be given to cockroach infestations in food processing and handling environments.

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Table 7. Antibiotic resistance of selected groups of bacteria

	Genera of bacteria							
Antibiotics	A (2)	B (8)	C (3)	D (3)	E (2)	F (1)	G (4)	H (1)
Chloramphenicol	0	1	3					
Erythromycin	2	1	2					
Fusidic acid	2	3	2					
Methicillin	2	2	2					
Novobiocin	2	4	2					
Penicillin G	2	7	3					
Streptomycin	1	2	3	1	0	nd	0	0
Tetracycline	1	0	2	1	1	nd	1	0
Vancomycin	1	2	2	nd	nd	nd	0	0
Cefepime	1	4	1	1	2	nd	0	0
Cefprozil	1	2	1	1	2	nd	1	1
Ampicillin				2	2	0	1	1
Cephalothin				3	2	1	4	1
Colistin sulphate				0	2	0	1	0
Gentamicin				1	2	0	0	0
Sulphatriad				2	2	1	2	0
Cotrimoxazole				1	2	0	2	1

nd, not determined; Numbers in parentheses indicate the number of isolates tested; A, *Arthrobacter* spp.; B, *Bacillus* spp.; C, *Staphylococcus* spp.; D, *E. coli*; E, *Proteus* spp.; F, *Salmonella* sp.; G, *Vibrio* spp.; H, *Pseudomonas aeruginosa*.

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