

ASSOCIATION BETWEEN GERMAN COCKROACHES (*BLATTELLA GERMANICA*) AND STREET FOOD VENDING: IMPLICATIONS FOR FOOD SAFETY IN BOTSWANA

¹S. MPUCHANE, ¹J. ALLOTEY, ¹B.A. GASHE, ¹M.I. MATSHEKA, ²S.I. COETZEE, ²A. JORDAAN AND ¹M. OTENG

¹Department of Biological Sciences, University of Botswana, Pr Bag 0022, Gaborone, Botswana.

²Department of Physics, Electron Microscope Unit, University of Botswana, Pr Bag 0022, Gaborone, Botswana

Abstract As a result of the rapid rate of urbanization in Botswana, street food vending has become very popular as it supports a large number of the population with affordable, nutritious foods. There has been an associated increase in the number of cockroaches around vending sites in the streets. Cockroaches are also abundant in the homes, some of which serve as food preparation areas for street foods by ambulatory vendors. German cockroaches (*Blattella germanica*) have become a common site all over the city. German cockroach egg cases, nymphs and adults were trapped in homes in various localities of Gaborone; the capital city of Botswana using traps. Traps were also set up in street food vending sites. In the homes, a mean trap catch of 422 cockroaches per week per locality was recorded from 1844 traps. The prevalence of cockroach infestation in the home can be given as kitchen 19 %; food storage room 16 %; bathroom 15 %; bedroom 15 %; lounge 14.8 %; toilet 12 %; dining room 6.6 %; passage 1.7 %. Insects trapped from street food vending sites in November/December 2003: German cockroach 88 %; *Crematogaster* sp. 2.6 %; *Lucilia* sp. 2.5 %; *Musca domestica* 2.2 %; *Calliphora* sp. 2.0; sugar ant 1.2 %; *Platotherus* sp. 0.8 %; *Apis mellifera* 0.5 %; *Tribolium* spp. 0.1 %; cricket 0.09 %; *Drosophila melanogaster* 0.05 %. The distribution of German cockroaches trapped in January/February, 2005 from street food vending sites in four localities was: Nymph 68.1 %; adults 31.9 %. The sex ratio of males to females was 1.3: 1. A different insect profile appears to exist in non-food vending sites.

Cockroaches were subjected to microbiological tests using various media, for culturing and API and BIOLOG systems for identification. Scanning electron microscopy was used to determine the nature of contaminants associated with their body surfaces and fecal pellets. A large distribution of pathogenic and non-pathogenic bacteria, yeasts and moulds were identified. Some of the moulds associated with the cockroaches are mycotoxin producers. Concerns about the safety of street foods that are provided particularly by ambulatory vendors are raised and suggestions on the management of the problem are presented.

Key Words Cockroaches, street foods, microorganisms, ambulatory and stationary vendors, sticky-trap, food safety.

INTRODUCTION

The urban population in Botswana has increased dramatically since attaining independence in 1966. Currently, over 50% of the population resides in urban areas (CSO, 2001). This influx has placed great strains on the food service outlets to provide convenient, affordable and nutritious food to the consumers. Unemployment in the urban areas and a new drive of entrepreneurship has resulted in a boom in the street food vending activity. Consumers are provided with moderately priced, ready to eat and tasty food at convenient locations.

Basic infrastructure (water, roads, proper sewage disposal) has unfortunately not been developed at the same fast pace and urban planners and the municipalities have been overwhelmed. Vending sites have mushroomed all over the towns regardless of provision of the requisite infrastructure for their trade. As a result, efforts have been increased to ward off agents that may have negative impacts on the vended foods. These include microorganisms, rodents, insects and various pollutants that could be carried by air, soil or water.

Botswana has both ambulatory and fixed (stationary) vendors. The former group generally prepare their food at home and transport it to the vending sites. Cooking and storage utensils are, therefore, shuttled from home to vending sites. Various food commodities prepared by ambulatory vendors have been shown to contain a higher microbial load of aerobic mesophilic counts and total spore counts (Letsholo, 2004) than that prepared at the sites. Also, bacterial contamination of street foods has been demonstrated in many countries in Africa (Murindamombe et. al., 2005; Mosupye and von Holy, 2000; El-Sherbeeney et. al., 1985; Jermini et. al., 1997).

Cockroaches are commonly found in households of varying socio economic brackets in Botswana. The German cockroach (*Blattella germanica*) is more prevalent inside the home while the American cockroaches (*Periplaneta americana*) are common around the home and are associated with water drainage systems and water pipes. The presence of cockroaches in large numbers in homes could serve as a source of these insects in vending sites by being transported on the utensils. At the vending sites, such populations could thrive due to the poor disposal of left-overs, lack of proper sanitation and ideal temperature conditions.

A large population of cockroaches at vending sites has health implications for the consumers. Cockroaches harbour microbes on their rough body parts, cuticle, gut, vomitus and feces. Microbes are also liberated from cockroaches upon death when they disintegrate. Food spoilage microbes have been identified from surfaces of cockroaches (Fotedar and Banerjee, 1992). They have been shown to be vectors of pathogenic microbes (Bennett, 1993) and to be associated with various nosocomial infections (Prado et al., 2002). Their association with allergies has been widely demonstrated (Bernton and Brown, 1969). These authors discovered an allergen from cockroaches that remains allergenic after heating for 1 hr at 100° C. Cockroach allergy occurs widely around the world (Mendoza and Snyder, 1970). The presence of cockroaches in street food vending sites is therefore a concern.

It has been reported that because of the increasing environmental concerns and more regulatory restrictions on the use of insecticides, there will be an increased interest in environmentally acceptable concepts, including trapping, the latter not only for monitoring infestations, but also as an integral part of the cockroach management program (Fleet et al., 1978; Piper and Frankie, 1978). Sticky traps are primarily used as sampling, detecting and monitoring tools for German cockroach. However there has been an interest in the study of sticky traps as control tools (Ballard and Gold, 1983; Moore and Granovsky, 1983). Traps have been advocated as an alternative to chemical methodologies (Kaakeh and Bennett, 1997) and their use has increased with the implementation of IPM programmes (Gold, 1995). Baits and traps limit the opportunity for misapplication or misuse by the consumer and are perceived as 'safe' and easy to use indoors (Ebeling, 1978; Kaakeh and Bennett, 1997; Kaakeh et al., 1997).

This paper covers the occurrence of cockroaches in household and food vending sites through a trapping survey, using sticky-bait traps and the microorganisms associated with them. Management strategies are also suggested.

MATERIALS AND METHODS

The populations of German cockroaches in human dwellings and food preparation areas in Gaborone were monitored using sticky-bait traps. In the home, cockroaches were trapped over 9 month period in 2000 at various locations (kitchen, food storage room, bathroom, lounge, toilet, dining and passage) and in four localities (Central, Thlofelo, Old Naledi, Tlokweng) in Gaborone. At the food vending sites, traps were set at six locations (BBS mall, Broadhurst, Marina, Industrial) in January/February, 2005 for two consecutive weeks. The monitoring of the cockroach population with sticky-bait trap is still in progress to get a better picture through the seasons.

The traps used were Dyroach Traps (Roberts Pty Ltd, South Africa) which contains cyclotene as an active ingredient in tablet form and used as an attractant. The tablet is inserted in the center of a flat sticky surface of a card board delta-shaped trap with side openings. Cockroaches thus become ensnared. Four hundred and thirty-two traps were set in the homes and a total of 60 traps at the food vending sites in 2003, and 50 traps in January/February, 2005.

The attractant caused inward movement of cockroaches toward the center of the trap and being immobilized by the sticky surface. The traps were left in place for one week and then retrieved and brought to the laboratory in the Department of Biological Sciences, University of Botswana. The content of each trap was examined under a stereo microscope and the cockroaches and other insect species present were counted using a tally counter. Thereafter, the traps were stored in 4° C cold room for up to a week before being analyzed for microbial load on the cockroaches.

The microbial load of the cockroaches were determined on appropriate microbiological media following standard procedures. Electron microscopic studies were done using a Phillips XL30 ESEM.

RESULTS

Trapping Studies

An average of 1689 cockroaches were trapped from homes and counted per week (Table 1). The distribution of the German cockroaches in terms of decreasing numbers from the locations sampled can be summarized as follows: kitchen 19 %, food storage room 16 %; bathroom 15 %; bedroom 15 %; lounge 14.8 %; toilet 12 %; dining room 6.6 %; passage 1.7 %. Thus kitchens had the most cockroaches followed by food storage room. A mean trap catch of 422 (range: 245-716) of German cockroach per week per locality was recorded from 1844 traps.

Table 1. German cockroaches trapped weekly in homes from four localities in Gaborone, Jan-Feb. and July-Dec. 2000.

Loc- ation	Sampling area								Total	%
	Kitchen	Food Storage room	Bath room	Bed room	Lounge	Toilet room	Dining room	Passage		
Central	147 (160)*	114 (101)	72 (67)	116 (34)	67 (63)	66 (10)	107 (26)	29 (2)	718 (463)	42 (25.1)
Tsh	57 (119)	62 (2)	6 (1)	36 (97)	47 (169)	37 (135)	0 (0)	0 (0)	245 (523)	15 (28.4)
Old Nal	61 (115)	71 (2)	111 (3)	44 (71)	73 (55)	52 (130)	0 (0)	0 (0)	412 (376)	24 (20.4)
Tlk	54 (157)	29 (4)	56 (70)	59 (96)	63 (11)	49 (143)	4 (1)	0 (0)	314 (482)	19 (26.1)
Total	319 (551)	276 (109)	245 (141)	255 (298)	250 (298)	204 (418)	111 (27)	29 (2)	1689 (1844)	
%	19 (29.8)	16 (5.9)	15 (7.6)	15 (16.2)	14.8 (16.2)	12 (22.6)	6.6 (1.5)	1.7 (0.1)		

* Figures in parentheses denote number of traps, Tsh = Tsholofelo; Old Nal = Naledi; Tlk = Tlokweng.

The results of the trappings from the street vending sites in Gaborone during November/December, 2003 (Table 2) can be summarized as: German cockroach 88 %; *Crematogaster* sp. 2.6 %; *Lucilia* sp. 2.5 %; *Musca domestica* 2.2 %; *Calliphora* sp. 2.0; sugar ant 1.2 %; *Platotherus* sp. 0.8 %; *Apis mellifera* 0.5 %; *Tribolium* spp. 0.1 %; Gryllidae, cricket 0.09 %; *Drosophila melanogaster* 0.05 %. German cockroaches were the most numerous insects trapped during this period. The distribution of German cockroaches trapped in January/February, 2005 (Table 3) from street food vending sites in the four localities was: Nymph 68.1 %; adults 31.9 %. The sex ratio of males to females was 1.3 (Table 3). The percent traps containing cockroaches from the four localities were: Station 51 %; Marina 22 %; Industrial 15 %. Broadhurst 7.0 %; BBS mall 4 %. More than 50 % of the cockroaches trapped were from the station locality.

Table 2. Prevalence of insects in street food vending sites, in Gaborone, Nov/Dec 2003.

Location	Ger coc	Hou	Gre	Blu	Pla	Cre	Cri	Dro	Sug	Tri	Bee	Total	%
Central	960	26	43	30	10	48	0	4	13	0	16	1150	10.4
Main Mall	1018	40	34	34	22	0	4	0	22	0	9	1183	10.7
BBS Mall	1129	33	38	23	0	0	0	0	21	8	4	1256	11.3
Taxi Rank	1108	43	43	32	27	78	3	0	22	5	11	1372	12.4
Bus Stat.	2636	45	50	45	0	80	0	2	23	0	6	2887	26.1
Bont- leng	2887	59	71	56	28	85	3	0	28	0	6	3223	29.1
Total	9738	246	279	220	87	291	10	6	129	13	52	11071	
% Distribution	88	2.2	2.5	2.0	0.8	2.6	0.09	0.05	1.2	0.1	0.5		

Hou = *Musca domestica*, Gre = *Lucilia* sp., Blu = *Calliphora* sp., Pla = *Platothereus* sp., Cre = *Crematogaster* sp., Cri = cricket (Gryllidae), Dro = *Drosophila melanogaster*, Sug = Sugar ant, Tri = *Tribolium castaneum/confusum*, Bee = *Apis mellifera*

Table 3. German cockroaches trapped from street food vending sites, Jan/Feb 2005.

Location	German cockroach				Total cockroach	%
	adult mm	adult f f	adult Total	Nymphs		
BBS Mall	32	20	52	43	95	4
Broad- hurst	18	31	49	104	153	7
Marina	58	45	103	373	476	22
Industrial	83	71	154	181	335	15
Station	206	129	335	777	1112	51
Total	397	296	693	1478	2171	
%	18.3	13.6	31.9	68.1		

m:f = 1.3:1

m = male, f = female

Microbial studies

Several pathogenic bacteria (Table 4) food spoilage yeasts (Table 5) and food spoilage moulds (Table 6) and mycotoxigenic moulds (Table 7) were isolated. Scanning electron micrographs showed microorganisms were found on various parts of the bodies (Fig. 1 A-D) and in the fecal pellets (Fig. 2 A & B).

Table 4. Bacterial pathogens (and emerging pathogens) isolated from cockroaches.

Bacillus spp.; *Corynebacterium* spp.; *Staphylococcus* spp.; *Burkholderia* sp.; *Citrobacter* sp.; *Enterobacter* spp.; *Escherichia* spp.; *Kingella* sp.; *Klebsiella* spp.; *Pseudomonas* spp.; *Salmonella* sp.; *Shigella* sp.

Table 5. Spoilage yeasts isolated from cockroaches.

Brettanomyces spp.; *Candida* spp.; *Debaromyces* spp.; *Picchia* spp.; *Schizosaccharomyces* spp.; *Torulopsis* spp.; *Trichosporon* spp.; *Zygosaccharomyces* spp.

Table 6. Spoilage moulds isolated from cockroaches.

Aspergillus spp.; *Cladosporium* spp.; *Fusarium* spp.; *Monilia* spp.; *Mucor* spp.; *Rhizopus* spp.; *Penicillium* spp.; *Verticillium* spp.; *Trichoderma* spp.; *Crysonilia* sp.

Table 7. Mycotoxigenic moulds isolated from cockroaches.

Aspergillus flavus, *Aspergillus ochraceus*, *Fusarium graminearum*, *Penicillium variable*, *Penicillium viridicatum*

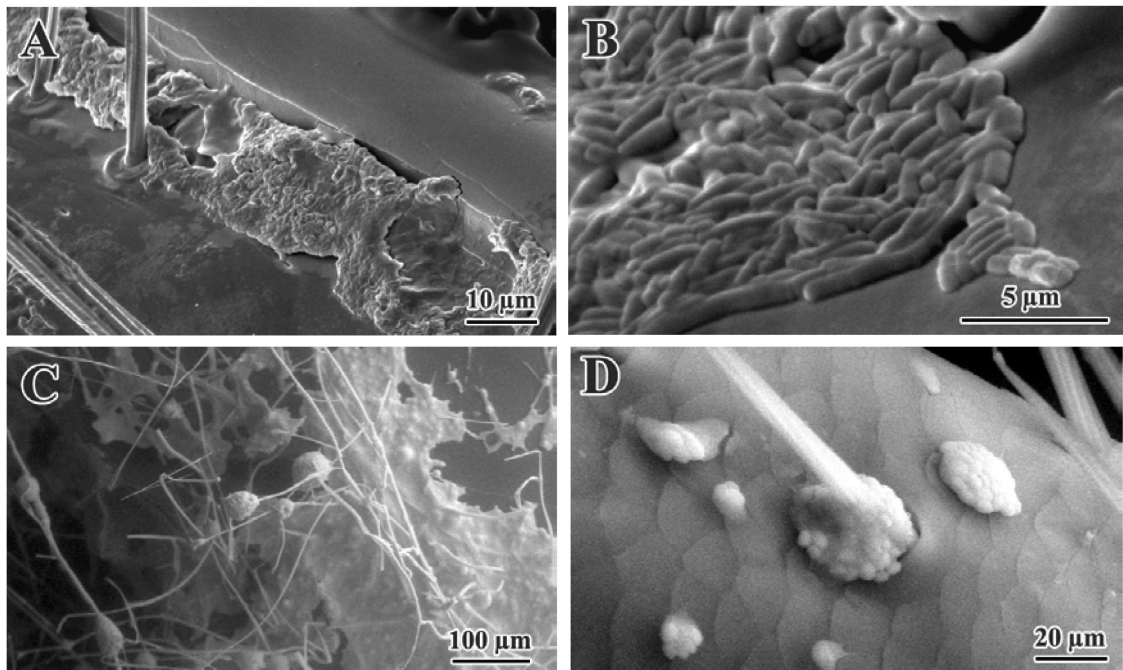


Figure 1 A-D. SEM micrographs of microorganisms on various body parts. A, Bacteria embedded in a biofilm in crevice of ventral abdomen. B, Bacilli on thorax. C, Fungal growth on dorsal abdomen. D, Yeasts on leg

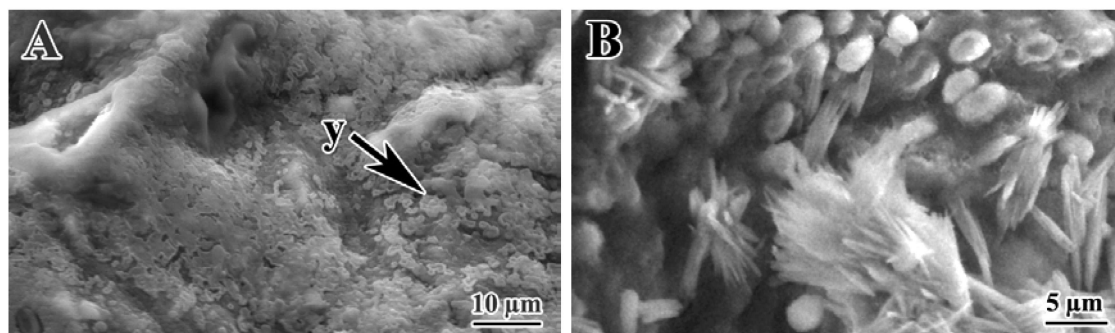


Figure 2 A, B. SEM micrographs of fecal pellets. A, large numbers of yeasts (y) forming a plaque-like covering on fecal pellet. B, Higher magnification showing individual yeasts.

DISCUSSION

Trapping studies

The exploratory drive of German cockroaches is never satisfied. Cockroach activity is also increased by hunger, thirst, and deprivation of accustomed harborage, pointing to the importance of sanitation. Barak et al. (1997) recommended that traps be used for the following purposes: 1) To detect low-level populations. The existence of a potential problem can be confirmed before a population explosion occurs. 2) To locate problem areas or harborages. This can greatly enhance control efforts, allowing the PCO (Pest control officer) to intensify treatments in certain areas and perhaps solve continuing problems. 3) To monitor population increases. Thus the need for frequent and exposure applications or treatments can be minimized. 4) To reduce or control infestations, as a primary method in certain instances but, more commonly, integrated with current methods of chemical treatment to improve efficacy.

Cockroach populations are successful in the human living space, because they have access to adequate amounts of water, food and harborage. Eliminating or significantly reducing only one of these biological requirements will have some effect on the size and survival of a domestic or peri-domestic pest populations. The survival strategies of cockroaches can be attributed to certain biological characteristics such as high reproductive potential, omnivory, secretive habits that protect them from detection and destruction and great speed in escaping to their out-of-sight and often narrow harborages (Ebeling, 1991).

The present study shows that the kitchen (19%) is the most important habitat for German cockroaches in homes followed by the food storage room (16%). These two important areas provide food and source of water together as well as harborage for the cockroaches more readily than the bathroom (15 %) or bedroom (15 %). More cockroaches were recorded from the lounge (14.8% compared with the toilet (12%). The lowest number of cockroaches trapped was recorded from the passage, perhaps for obvious reasons i.e. frequent human traffic and care to remove food pieces, and regular sweeping. Cockroaches were found in all the locations sampled. In any cockroach management strategy, the whole house or apartment should be treated instead of concentrating on particular areas such as the kitchen and the food store.

Concerning the German cockroach, Gould and Deay (1938) reported that in an infested house, it is confined to kitchens and lavatories where it hides behind baseboards, in cupboards, in boxes, and dark corners and around water pipes. The German cockroach generally becomes widely distributed throughout the building only after it has reached a high population in the kitchen (Gorham, 1991). Numerical data have been gathered that support this observation (Zungoli, 1982). In the apartments with low infestation levels, 79 % of cockroaches were in the kitchen and 16 % in bathrooms and adjacent linen closets. In apartments with high infestations, 36% were in kitchens, 31 % in bathrooms and/or linen closets, and 33 % in bedroom and or /or linen closets (Zungoli, 1982). In the present study, most building have the food storage room with the kitchen and a door from the food store opens to the kitchen; hence, the close percent trapping recorded for the kitchen and the food store.

In another study in 18 low income houses, visual estimates of the numbers of German cockroaches in different rooms were recorded as follow : kitchen > dining > hall > living > bed room > bath room (Wright and Hall, 1973). Robinson et al. (1980) reported that the presence of German cockroaches in bathrooms cannot be satisfactorily explained solely on the basis of either food (possibly hairs, dermal scales, mould) or hiding

places, but the bathrooms often does provide water, an important factor in cockroach survival. Many cockroaches can be sustained by food particles that fall to the floor where people eat their meals, snacks near television sets, which might be in the living room or bedroom. Modern homes may have two or three bathrooms, as well as air conditioners and refrigerators with evaporating pans to provide moisture (Ebeling, 1991).

Concerning the mobility of German cockroaches, it was demonstrated in experiments in which these cockroaches were marked and recaptured that they are more mobile than previously recognized (Bennett et al., 1984; Ishii and Kawahara, 1968). Plumbing connections to adjacent apartments were important avenues of movement. Male cockroaches are more mobile than females and normally all stages of the German cockroach are found in field situation. However, productivity of field populations of German cockroaches may be more severely restricted by water and/or humidity than by food (Ross and Wright, 1977). Buildings with food readily available, especially industrial kitchens favoured German cockroaches (Cornwell, 1976).

The habit that cockroaches have of occupying every available refuge emphasizes the importance of examining paper grocery bags and other containers of food, beverages and laundry that may be brought into home of food facility such as street food vending stalls to make sure that they are free of cockroaches, especially, the German cockroach. In this study, the German cockroach was the highest number of insects trapped from street food vending sites in Gaborone. From the on-going study (2005) of German cockroaches in street food vending sites, 68.1% of the cockroaches trapped were nymphs and the nymphs are known to enter cracks as narrow as 0.5mm, while adult males and females without egg cases require cracks at least 1.6 mm wide (Wile, 1920).

Ebeling (1975) reported that in a food storage room of a large "rest house" it was noted that thousands of German cockroaches had found harborage in a space of 2-3mm between a shelf and a wall. The bodies of the insects were completely hidden from view except for the continuous band of waving antennae that extended from the aperture and could be seen by looking beneath the shelf. From the foregoing the importance of German cockroaches in food preparation areas such street food vending sites cannot be over emphasized. It becomes imperative that all the knowledge that needs to be garnered by studying these ubiquitous insects especially with regard to the microorganisms, which they carry on their bodies should take pre-eminence. The wide popularity of street foods and the frequently poor sanitary conditions around the vending sites in urban areas of developing countries raise concerns about nutritional value and microbiological safety of such foods (Murindamombe et al., 2005) and as shown in the present study German cockroaches have a role in the distribution of microorganisms in unsanitary conditions as prevailed in some street vending sites.

No matter how closely standard cleaning and sanitizing protocols are followed, pests in food facilities will inevitably deposit spoilage organisms and occasionally pathogenic organisms on food and food-contact surfaces. German cockroaches regurgitate the partly digested food and leave behind their feces and a characteristic odour when they feed. The objective of the food processing manager and the food-service manager is clear: maintain pest free premises (Cohn, 1988).

The association of cockroaches with microorganisms has led to concerns about the safety of food in environments where these insects abound particularly at this time when the immune system of a substantial number in the population have compromised immune systems due to the HIV/AIDS scourge. Equal concerns have been raised about the quality of food supplied to consumers from vending sites. The presence of food spoilage organisms and mycotoxigenic fungi that are carried by cockroaches therefore raises the need for good hygiene not only in the vending sites but also in the homes where some of the food is prepared. The need to eradicate cockroaches in the home and vending sites is crucial.

CONCLUSION

Municipalities and planners and vendors have to come up with strategies to overcome the problems resulting from insect infestation in street food vending sites. These include the following: 1) Improvement of street vending infrastructure. This includes primary infrastructure (roads, water, sewage, lights) and vending booths. 2) Improvement in provision and disposal of packaging material. 3) Effective legislation and monitoring; Education of the vendors, consumers, legislators and law enforcement officers (to include HACCP principles). 4) Research into street foods. 5) Development and use of relevant and user friendly street vending icons that take cognizance of the educational level of the majority of the vendors. 6) Aggressive campaign against agents of food-borne diseases (microbes, insects and rodents) which could include the use of environmentally friendly insecticides. 7) National, regional and international networking to confront the problem of insect infestation in vending sites.

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