



Contents lists available at ScienceDirect

Asian Pacific Journal of Tropical Disease

journal homepage: www.elsevier.com/locate/apjtd



Document heading doi: 10.1016/S2222-1808(12)60083-8 © 2012 by the Asian Pacific Journal of Tropical Disease. All rights reserved.

Cockroaches' bacterial infections in wards of hospitals, Hamedan city, west of Iran

Nejati Jalil^{1*}, Keyhani Amir², Moosa-Kazemi Seyed Hasan³, Mohammadi Mahdi⁴, Mahjoob Monireh⁴, Boostanbakhsh Atefeh⁵

¹Center of Disease Control & Prevention, Province Health Center, Zahedan University of Medical Sciences, Iran, Department of Medical Entomology & Vector control, School of Health, Tehran University of Medical Sciences, Iran

²Department of Medical Parasitology, School of Health, Tehran University of Medical Sciences, Iran

³Department of Medical Entomology & Vector Control, Tehran University of Medical Sciences, Iran

⁴Health Promotion Research Center, Zahedan University of Medical Sciences, Iran

⁵Department of Nursing, Hamedan University of Medical Science, Iran

ARTICLE INFO

Article history:

Received 15 July 2012

Received in revised form 19 July 2012

Accepted 28 October 2012

Available online 28 October 2012

Keywords:

Cockroach

Blattella germanica

Periplaneta Americana

Klebsiella oxytoca

Escherichia coli

Bacteria

Hospital

Western Iran

ABSTRACT

Objective: To identify the relationship between different species of cockroaches with their bacterial infection in different wards of Hamedan county hospitals, western Iran. **Methods:** Using sticky trap, hand collection and glass trap, 250 cockroaches were collected from 14 wards of 5 hospitals. After having their identification determined by detection key, all of them were used to isolate bacteria from cuticle and alimentary tract. **Results:** From four identified species, *Blattella germanica* were the most common in all of the wards (88.8%) and next was the *Periplaneta Americana* (8%). 20 bacteria species isolated from cockroaches' surface and 21 from digestive organ. *Escherichia coli* were the most predominant bacteria isolated from external surface (26.5%) as well as alimentary tract (30.8%). The frequency of investigated bacteria on cockroaches' body surface was not significantly different between *Periplaneta Americana* and *Blattella germanica* except for *Klebsiella oxytoca* ($P < 0.001$) and *Providencia Spp* ($P = 0.035$). Also, frequency of detected bacteria in cockroaches' digestive organ was not significantly different between these two species. Furthermore, the frequency of bacteria isolated from the cockroaches' external surface was not significantly different from that of digestive organ except for *shigella disantery* ($P < 0.001$), *Pseudomonas aeruginosa* ($P < 0.001$) and *Klebsiella oxytoca* ($P = 0.013$). **Conclusions:** Since cockroaches can carry pathogenic bacteria, so their existence in the hospitals could be a serious public health problem. It is suggested to compile programs in order to control cockroaches especially in the hospitals.

1. Introduction

Nowadays, may be less found the secured places from cockroach presence[1]. They are one of the most important agents in transmission of almost 150 bacteria species, 60 species of yeast, 90 species of protozoa and 45 species of parasite worms to human life either mechanically or biologically. They are one of the most important agents that normally get infected with pathogenic bacteria causing leprosy, bubonic plague, dysentery, urinary infections, Hungarian, pimples, and abscesses[2]. According to the esearches, bacteria species can stay alive on cockroaches' body surface for a few days[3].

Cockroaches are omnivorous[4] and the hatred habit of

vomiting part of eaten food in nutrition place as well as their contaminated surface body can infect patients' food and hospital equipments[1,3].

Cockroaches excrement is a compound such as xanthurenic acid, cinnamic acid and 8-hydroxy-quinaldic acid. These compounds are tryptophan derivatives and property mutagenesis and carcinogens[2]. Nocturnal activity and nutritional behaviors are important to increase the potential of diseases transmission by them[1].

Some researchers have shown that the cockroaches can potentially carry pathogenic bacteria and play an important role in their spread in the hospitals and environments [3,4,5]. Fakoorziba *et al* showed that the bacteria carried by cockroaches are responsible for nosocomial infections, which is unfortunately paid less attention to this issue in the hospitals[5].

In addition, the researches carried out in Iran indicated the decrease of susceptibility level to pyrethroid insecticides in cockroaches[6,7] that it reveals how hard is controlling of cockroaches.

So, considering the importance of cockroaches in mechanical and biological transmission of pathogenic

*Corresponding author: Nejati Jalil, Center of Disease Control & Prevention, Province Health Center, Zahedan University of Medical Sciences, Iran, Department of Medical Entomology & Vector control, School of Health, Tehran University of Medical Sciences, Iran.

Tel: +98-9373394328

Email: jalilnejati@yahoo.com

Fundation Project: Supported by Hamedan University of Medical Sciences, grant number is P16/33/1185.

bacteria in hospitals, the current investigation was carried out in Hamedan hospitals, west of Iran, in order to study bacteria carried by cockroaches in relation to their distribution in different hospital wards.

2. Materials and methods

This descriptive–analytic study was performed in 2009 in five public hospitals (Mobasher, Ecbatan, Imam khomeini, Sina, Fatemiyeh) which were located in Hamedan city, west of Iran. The statistical samples included the collected cockroaches from 14 sites of above hospitals involving Orthopedics, Emergency, Operation room, ICU, Surgery, Dialysis, Urology, Eye, Burn, Infectious, Psychiatry, Elective ward, Postpartum and Cook house (Kitchen).

The cockroaches were collected by direct collection, sticky traps and glass traps^[3,8,9]. The collected cockroaches were carried in sterile tubes to a reference laboratory affiliated to the Hamedan University of Medical Science. It is noteworthy that each sterile tube was allocated to only one cockroach in order to prevent incorporation of cockroaches' contamination.

The glass trap was formed from glass or plastic narrow drum within a wide mouth and with a height of about 20 – 15 cm and was constricted by funnel paper. The inside lib of the drum was lubricated with oil for prevention of cockroaches coming up. The attractant material, which was used as bait inside the glass traps, was bread and cake. There are two ways for guidance of cockroaches into this trap: set the trap on the earth at the same surface, this is not feasible due to stone or ceramic floor in the hospitals, and the second way, which was used in this study, is using paper strips to help roaches move up and fall into trap^[2].

Sticky traps were formed from a tile with approximate size of 15 cm×15 cm. Bread or cake used as bait in center of circular dry adhesive. Cockroaches caught on the tape, placed as attraction bait, when came for eating. These traps were embedded after sunset in the appropriate places such as corners of the patient's room, under dresser, under refrigerators. The samples were collected at the next night. After transferring the samples to the laboratory, each of them was anesthetized by chloroform. Firstly, their genera and species with stereo–microscope were identified using specific detection key^[2,3]. Then each of the samples washed into sterile glass containing 2 mL sterile saline and the resulting suspension was cultured. Next, samples washed in ethylic alcohol lasting 2 min for removing the external contamination. Finally, their intestines isolated from mouth to anus and after washing and crushing into 2 mL, sterile saline was used for culturing.

In this study the internal and external samples were inserted to bacterial culture media including Eosin Metilin Blue (EMB), blood agar (BA), salmonella shigella agar (SS), chocolate agar, Macconkey agar, Hekton Enteric agar, Xylose–Lysin–Decarboxychole–agar (XLD), Brilliant Green agar , Selenite F, and bacterial diagnostic tests such as Mannitol salt agar, Lysine decarboxylase broth, Simmons citrate, Urea and Orthonitro Phenul –β–D–galacto Pyramside (ONPG), MR, Sulfide–Indol–Motility (SIM), Simmons Citrate agar, Methylred–Vegeproskauere broth (MR–VP), Triple Sugar Iron Agar (TSI) , DNAase, Coagulase Test, Catalase Test and Oxidase Test. The collected data were recorded on special forms and were analyzed using SPSS software. The infection rate of cockroaches was determined with 95% coefficient interval.

3. Results

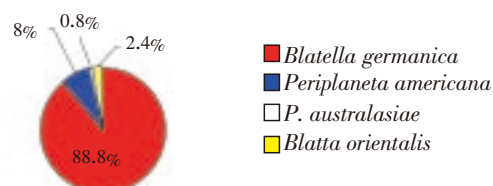


Figure 1. Percentage of the cockroaches' species collected from Hamedan hospitals.

In this investigation, totally 250 cockroaches were collected from five hospitals of Hamedan County. Four cockroach's specimens were identified including: *Periplaneta Americana*, *Blattella germanica*, *Blatta orientalis* and *P. australasiae*. The most predominant specie was *Blattella germanica* (88.8%), and the less was *Blatta orientalis* (0.8%) (Figure 1). Table 1 shows the number of cockroaches' species collected from various sites of the Hospitals. The samples were collected from 14 different places. The maximum numbers of cockroaches were collected from cook house (32.4%) and the minimum were collected from surgery ward (1.2%).

Table 1

Distribution of cockroaches in hospital wards.

| Hospital wards | <i>Blattella germanica</i> | | <i>Periplaneta americana</i> | | <i>Blatta orientalis</i> | | <i>P. australasiae</i> | | Total | |
|----------------------|----------------------------|------|------------------------------|-----|--------------------------|------|------------------------|-----|-------|-------|
| | No | % | No | % | No | % | No | % | No | % |
| Orthopedics | 6 | 2.7 | 6 | 30 | 3 | 50 | 0 | 0 | 15 | 9.6 |
| Emergency | 9 | 4.1 | 3 | 15 | 0 | 0 | 0 | 0 | 12 | 4.8 |
| Operation room | 6 | 2.7 | 1 | 5 | 0 | 0 | 0 | 0 | 7 | 2.8 |
| ICU | 4 | 1.8 | 0 | 0 | 0 | 0 | 0 | 0 | 4 | 1.6 |
| Surgery | 2 | 0.9 | 1 | 5 | 0 | 0 | 0 | 0 | 3 | 1.2 |
| Cook house (Kitchen) | 76 | 34.2 | 3 | 15 | 0 | 0 | 2 | 100 | 81 | 32.4 |
| Dialysis | 1 | 0.5 | 6 | 30 | 1 | 16.7 | 0 | 0 | 8 | 3.2 |
| Urology | 30 | 13.5 | 0 | 0 | 1 | 16.7 | 0 | 0 | 31 | 12.4 |
| Eye | 29 | 13.1 | 0 | 0 | 1 | 16.7 | 0 | 0 | 30 | 12.0 |
| Burn | 20 | 9 | 0 | 0 | 0 | 0 | 0 | 0 | 20 | 8.0 |
| Infectious | 5 | 2.3 | 0 | 0 | 0 | 0 | 0 | 0 | 5 | 2.0 |
| Psychiatry | 9 | 4.1 | 0 | 0 | 0 | 0 | 0 | 0 | 9 | 3.6 |
| Elective ward | 20 | 9 | 0 | 0 | 0 | 0 | 0 | 0 | 20 | 8.0 |
| Postpartum | 5 | 2.3 | 0 | 0 | 0 | 0 | 0 | 0 | 5 | 2.0 |
| Total | 222 | 100 | 20 | 100 | 6 | 100 | 2 | 100 | 250 | 100.0 |

All of the collected cockroaches were used for detection of bacterial contamination. 76.1% of German cockroaches and 75% of American cockroaches had at least one bacteria species on their external surface while all of the *P. australasiae* and *Blatta orientalis* had external bacterial infection. Also, 86.5% of *Blattella germanica* and 95% of *Periplaneta Americana* had at least one bacteria species on their digestive organ (Table 2).

Totally, 24 bacteria species were extracted and identified. Twenty bacteria species were isolated from the cockroaches' body surface after having the suspension cultivated. The most predominant species of bacteria was *E.coli* (26.4%), and the lowest found was *Edwardsiella* (0.4%).The frequency of investigated bacteria on cockroaches' body surface was not significantly different between *Periplaneta Americana* and *Blattella germanica* except for *Klebsiella Oxytoca* ($P<0.001$)

and *Providensia Spp* (P: 0.035) (Table 3, Table 4).

Table 2

Distribution of bacterial infection on surface and in digestive organ of the collected cockroaches.

| Species | Roaches' body | No/ Percent | Isolated bacteria | | | | | Total |
|------------------------------|-----------------|----------------|-------------------|------------|------------|-----------|---|-------|
| | | | 0 | 1 | 2 | 3 | 4 | |
| <i>Blattella germanica</i> | Surface | No % | 53 23.9 | 96 43.2 | 68 30.6 | 5 2.3 | 0 | 222 |
| | Digestive organ | No % | 30 13.5 | 111 50 | 73 32.9 | 8 3.6 | 1 | 222 |
| <i>Periplaneta Americana</i> | Surface | No % | 5 25 | 7 35 | 4 20 | 3 15 | 5 | 20 |
| | Digestive organ | No % | 1 5 | 10 50 | 7 35 | 2 10 | 0 | 20 |
| <i>Blatta orientalis</i> | Surface | No % | 0 0 | 2 50 | 0 50 | 0 0 | 0 | 2 |
| | Digestive organ | No % | 0 0 | 2 33.3 | 2 33.3 | 2 33.3 | 0 | 6 |
| <i>P. australasiae</i> | Surface | No % | 0 0 | 2 100 | 0 0 | 0 0 | 0 | 100 |
| | Digestive organ | No % | 1 5 | 0 0 | 1 50 | 0 0 | 0 | 100 |

Table 3

The frequency of bacteria isolated from cockroaches' outer surface and digestive organ.

| Bacteria spp. | Outer surface | Digestive organ |
|-----------------------------------|---------------|-----------------|
| <i>Escherichia coli</i> | 26.4 | 30.8 |
| <i>Shigella Sonnei</i> | 0.8 | 2.0 |
| <i>Shigella dysentery</i> | 0 | 4.8 |
| <i>Staphylococcus aureus</i> | 4.0 | 1.6 |
| <i>Staphylococcus epidermidis</i> | 13.6 | 3.6 |
| <i>Citrobacter freundiii</i> | 8.0 | 8.4 |
| <i>Citrobacter diversus</i> | 3.2 | 1.2 |
| <i>Pseudomonas aeruginosa</i> | 12.4 | 4.4 |
| <i>Proteus mirabilis</i> | 0.8 | 3.2 |
| <i>Proteus vulgaris</i> | 2.0 | 1.6 |
| <i>Salmonella typhi</i> | 2.4 | 4.4 |
| <i>Salmenella paratyphi A</i> | 0.6 | 1.2 |
| <i>Entrobacter aeruginosa</i> | 6.0 | 15.2 |
| <i>Entrobacter cloacae</i> | 3.2 | 2.8 |
| <i>Kllebsiella acesitca</i> | 1.2 | 5.6 |
| <i>Kllebsiella peunomoniae</i> | 2.4 | 3.6 |
| <i>Strptococcus peunomoniae</i> | 3.2 | 1.6 |
| <i>Providencia</i> | 2.0 | 2.4 |
| <i>Serratia marcescens</i> | 10.8 | 12.4 |
| <i>Enterococcus</i> | 10.8 | 17.2 |
| <i>Edwardsiella</i> | 0.4 | 0 |
| <i>Entrobater agglomerans</i> | 0 | 1.2 |
| <i>Morganella morganii</i> | 0 | 0.8 |

Also, twenty one bacteria species were detected from the samples' digestive organ (Table 3). Furthermore, the body surface of *E.coli* (30.8%) was the most frequently isolated from cockroaches' alimentary tract while the least contamination approved to *Morganella morganii* (0.8%). Frequency of detected bacteria in cockroaches' digestive organ was not significantly different between *Periplaneta Americana* and *Blattella germanica* (Tables 3, Table 4).

Our results showed that frequency of bacteria isolated from the cockroaches' external surface was not significantly different from that of digestive organ except for *Shigella*

disantery (P<0.001), *Pseudomonas aeruginosa* (P<0.001) and *klebsiella oxytoca*.

Table 4

The frequency of bacteria isolated from the outer surface and digestive organ of German and American cockroaches.

| Bacteria spp. | <i>Blattella germanica</i> | | <i>Periplaneta Americana</i> | |
|-----------------------------------|----------------------------|---------------|------------------------------|---------------|
| | Digestive organ | Outer surface | Digestive organ | Outer surface |
| | No | % | No | % |
| <i>Escherichia coli</i> | 65 | 29.3 | 57 | 25.7 |
| <i>Shigella Sonnei</i> | 4 | 1.8 | 1 | 5.0 |
| <i>Shigella dysentery</i> | 9 | 4.1 | 0 | 0 |
| <i>Staphylococcus aureus</i> | 4 | 1.8 | 9 | 4.1 |
| <i>Staphylococcus epidermidis</i> | 8 | 3.6 | 29 | 13.1 |
| <i>Citrobacter freundiii</i> | 16 | 7.2 | 18 | 8.1 |
| <i>Citrobacter diversus</i> | 3 | 1.4 | 8 | 3.6 |
| <i>Pseudomonas aeruginosa</i> | 10 | 4.5 | 29 | 13.1 |
| <i>Proteus mirabilis</i> | 6 | 2.7 | 1 | 5.0 |
| <i>Proteus vulgaris</i> | 3 | 1.4 | 4 | 1.8 |
| <i>Salmonella typhi</i> | 9 | 4.1 | 5 | 2.3 |
| <i>Salmenella paratyphi A</i> | 2 | 9.0 | 0 | 0 |
| <i>Morganella morganii</i> | 1 | 5.0 | 0 | 0 |
| <i>Entrobacter aeruginosa</i> | 33 | 14.9 | 12 | 5.4 |
| <i>Entrobacter cloacae</i> | 7 | 3.2 | 8 | 3.6 |
| <i>Kllebsiella Oxytoca</i> | 10 | 4.5 | 0 | 0 |
| <i>Kllebsiella peunomoniae</i> | 8 | 3.6 | 6 | 2.7 |
| <i>Strptococcus peunomoniae</i> | 4 | 1.8 | 6 | 2.7 |
| <i>Providensia Spp</i> | 5 | 2.3 | 2 | 9.0 |
| <i>Serratia marcescens</i> | 30 | 13.5 | 25 | 11.3 |
| <i>Enterococcus</i> | 41 | 18.5 | 26 | 11.7 |
| <i>Edwardsiella</i> | 0 | 0 | 1 | 5.0 |
| <i>Entrobater agglomerans</i> | 3 | 1.4 | 0 | 0 |

4. Discussion

Our study revealed that two identified species including *Blattella germanica* and *Periplaneta Americana* were the main active cockroaches in the studied hospitals. This result is in consistent with those of vahabi *et al.* carried out in two hospitals of Sanandaj city, west of Iran, indicated two cockroaches' specimens including *Periplaneta Americana* (44.4%) and *Blattella germanica* (55.6%)^[3]. Furthermore, Zarchi *et al.* in a study done in three hospitals of Tehran city, reported the three species composition involving *Periplaneta Americana* (65.6%), *Blattella germanica* (12.1%), *Blatta orientalis* (22.3%)^[10]. According to these researches and other similar studies in different parts of Iran, it seems that two species, *Blattella germanica* and *Periplaneta Americana*, are the predominant cockroaches in Iranian hospitals^[10]. Also, in a research conducted by Pai HH *et al.* in selected hospitals in China, they reported *Periplaneta Americana* and *Blattella germanica* as the most common species, respectively^[11]. Our investigation showed that the maximum numbers of collected cockroaches belonged to the cook house (kitchen) followed by Urology ward next. Also, this study shows that German cockroaches were the leading species in nine sites of the hospitals. These results are similar to those of Gliniewicz *et al.* They identified *Blattella germanica* in 70% of Poland hospitals, more in the kitchen, clothes storage, and in the elevator. Also, he

mentioned that outer body surface of roaches gets infected with several bacteria that cause nosocomial infection^[12]. Moreover, Pai *et al* in a study done on selected hospitals in China, found *P. Americana* more often in non-clinical areas (64.5%) and *B. germanica* in clinical areas (78.1%). He pointed out no significant difference between *P. americana* and *B. germanica*^[11]. The cockroaches' especial importance is their ability in contamination and transferring various potential pathogenic bacteria vectors in each area. The presence of cockroaches in a pathogenic and potentially pathogenic bacteria-rich environment, such as hospitals, is more serious than in a bacteria-poor environment^[3]. In our investigation, twenty bacteria species were isolated from the cockroaches' body surface. *E.coli* and *Edwardsiella* were found the most and the least bacteria species, respectively. In Vahabi's research the most frequent extracted bacterium from cockroaches' external body surface was *Escherichia coli* and the second was Proteus, which were potential pathogens^[3]. In the same researches, the bacteria species were isolated from the cockroaches' body surface as mostly identified in our investigation^[10,13]. In this study, twenty two bacteria species were isolated from the cockroaches' alimentary tract. In this regard, the body surface of *E.coli* was the most frequently isolated from cockroaches' intestines while the least contamination approved to *Morganella morganii*. The bacteria species identified in alimentary tract in this study are almost in consistent with the results of some other researches^[14,15]. Lin *et al.* reported the bacteria specimens isolated from cockroaches including *Escherichia coli*, *Pseudomonas Arinosa*, *Salmonella* and *Staphylococcus aureus*^[13]. Also, Zarchi and Vatani, detected *E. coli*, Streptococcus and Bacillus as the most isolated bacteria from hospital cockroaches^[10,18]. Different from our study, Vahabi *et al*, in an investigation carried out in Sanandaj hospitals, west of Iran, reported *E.coli* as the least bacteria species in cockroaches' digestive organ^[3]. According to our results, most of the isolated bacteria species were not significantly different between the external surface and digestive organ. These results also were indicated Olivia *et al.* about *Blattella germanica*^[14]. Moreover, Vahabi *et al* revealed that the most frequently presence of bacterial species, identified from collected hospital cockroaches, were gram-negative bacilli, especially in the Enterobacteriaceae family^[3] that can cause sepsis, gastroenteritis, urinary, biliary, pneumonia and wound infections. Since cockroaches can transfer pathogenic organisms from infected sources to uncontaminated material in the hospitals^[16,17]. Therefore, their existence in hospitals can be a serious public health problem. Based on these results, it is suggested to compile a national or international cockroaches' control program, especially in hospitals, in order to prevent nosocomial infection. Surely our findings and other similar studies will increase the awareness and susceptibility of health systems in removing this pest from hospitals' environment. Since in our study, cockroaches' collection was done usually during the night, because of patients' sleeping and prevented by hospitals' personnel, it was the major limitation for cockroaches' collection in that time. We solved this problem by coordination with the hospitals' authorities.

Acknowledgments

We are extremely grateful to all who facilitated our field work. Particular thanks are expressed to the officials and respected staff of Mobasher, Ecbatan, Imam khomeini, Sina,

Fatemiye hospitals.

Conflict of interest statement

We declare that we have no conflict of interest.

References

- [1] Bell WJ, Roth LM, Nalepa CA. *Cockroaches: ecology, behavior, and natural history*. The John Hopkins University Press; 2007.
- [2] Cochran DG. Cockroaches—biology and control. WHO/VBC/1982.856. 6
- [3] Vahabi A, Rafinejad J, Mohammadi P, Biglarian F. Regional evaluation of bacterial contamination in hospital environment cockroaches. *Iran J Environ Health Sci Eng* 2007; **4**(1): 57–60.
- [4] Xue1 FU, Lefu1 YE, Feng GE. Habitat influences on diversity of bacteria found on German cockroach in Beijing. *J Envir Sci* 2009; 249–254.
- [5] Fakoorziba MR, Eghbal F, Hassanzadeh J, Moemenbellah-Fard MD. Cockroaches (*Periplaneta Americana* and *Blattella germanica*) as potential vectors of the pathogenic bacteria found in nosocomial infections. *Annals Trop Med Parasit* 2010; **104**(6): 521–528.
- [6] Nasirian H. An Overview of German Cockroach, *Blattella germanica*, studies conducted in Iran. *Pak J Biol Sci* 2010; **13**(22): 1077–1084.
- [7] Nasirian H. The strategies of future researches are study of the susceptibility level of *B. germanica* and efficiency estimation of them to above-mentioned insecticides for control of this pest in Iran. *Pak J Biol Sci* 2010; **13**(22): 1077–1084.
- [8] Peterson CJ, Stout DM. Pesticides in household, structural and residential pest management. In: Wang C, Bennett GW, editors. *Least toxic strategies for managing German cockroaches*. ACS Symposium Series; 2009, p. 125–141.
- [9] Smith LM, Appel AG. Comparison of several traps for catching German cockroaches (Dictyoptera: Blattellidae) under laboratory conditions. *J Econ Entomol* 2008; **101**(1): 151–158.
- [10] Zarchi AA, Vatani H. A survey on species and prevalence rate of bacterial agents isolated from cockroaches in three hospitals. *Vector Borne Zoonotic Dis* 2009; **9**(2): 197–200.
- [11] Pai HH, Chen WC, Peng CF. Cockroaches as potential vectors of nosocomial infections. *Infect Control Hosp Epidemiol* 2004; **25**(11): 979–984.
- [12] Gliniewicz A, Sawicka B, Czajka E. Occurrence of insect pests in hospitals in Poland. *Przegl Epidemiol* 2003; **57**(2): 329–334.
- [13] Lin YZ, Cui YB, Yang W, Rao LY, Pan W, Chen JL. Investigation on species composition of cockroaches and bacteria-carrying on their bodies in five cities of Hainan. *Chin J Parasitol Parasit Dis* 2008; **26**(1): 77–78.
- [14] Oliva GR, Diaz C, Fuentes GO, Martinez MD, Fernandez C, Cordovi R, et al. *Blattella germanica* as a possible cockroach vector of micro-organisms in a hospital. *J Hosp Infect* 2010; **74**(1): 93–95.
- [15] Salehzadeha A, Tavacol P, Mahjub H. Bacterial, fungal and parasitic contamination of cockroaches in public hospitals of Hamedan, Iran. *J Vect Borne Dis* 2007; **44**: 105–110.
- [16] Brooks GF, Carroll KC, Butel JS, Morse SA, Mietzner TA. Jawetz, Melnick & Adelberg's medical microbiology. 25th ed. Mc Graw Hill; 2010.
- [17] Donnenberg MS. Enterobacteriaceae. In: Mandell GL, Bennett JE, Dolin R, editors. *Mandell, Douglas and Bennett's principles and practice of infectious diseases*. 7th ed. Churchill Livingstone Elsevier; 2009.
- [18] Khow O, Suntrarachun S. Strategies for production of active eukaryotic proteins in bacterial expression system. *Asian Pac J Trop Biomed* 2012; **2**(2): 159–162.