Forensic insects attracted to human cadavers in a vehicular environment in Riyadh, Saudi Arabia

Abdulmani H. Al-Qahtnia, Ashraf M. Mashalyb,⇑, Reem A. Alajmia, Adel A. Alshehric, Zeinab M. Al-Musawia, Mohammed S. Al-Khalifaa

a Department of Zoology, College of Science, King Saud University, P.O. Box: 2455, Riyadh 11451, Saudi Arabia
b Department of Zoology, Faculty of Science, Minia University, El Minia 61519, Egypt
c Medico Legal Center, King Saud Medical City, Riyadh, Saudi Arabia

Article info
Article history:
Received 5 February 2019
Revised 30 March 2019
Accepted 11 April 2019
Available online 11 April 2019

Keywords:
Post mortem intervals
Decomposition
Human cadavers
Insects
Cars

Abstract
Insect fauna attracted to cadavers at the crime scene can be identified and used to estimate the post-mortem interval (PMI). In the current study, insects associated with two human cadavers in a vehicular environment were collected and analysed. The first cadaver was found five days’ post mortem in a garage. The second cadaver was found in a car ten days after his death. The weather conditions were obtained from the nearest weather station located to the scenes of the death. During the study, six adults, 32 larvae and egg batches were collected from case 1 and identified as Chrysomya albiceps Wiedemann (Diptera: Calliphoridae). From the second case, two larvae of Megaselia scalaris Loew (Diptera: Foridae) and seven larvae of Musca domestica L. (Diptera: Muscidae) were identified. mPMI ranged from five to twelve days. This information expands the knowledge on the insect fauna in the vehicular environment, which could be used to assist estimation of the PMI.

© 2019 Production and hosting by Elsevier B.V. on behalf of King Saud University. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).

1. Introduction
Arthropods usually attack a corpse shortly after death and their succession follows predictable patterns (Anderson and VanLaerhoven, 1996; Shalaby et al., 2000). Environmental factors such as temperature, moisture and rainfall are known to affect the rates and patterns of insect invasion and thus should be taken into account when estimating the post mortem interval (PMI). Studies have also highlighted other factors related to the characteristics of the cadaver and its environment, such as body mass, geographical region, season and habitat of decomposition (Perez et al., 2015; Iancu et al., 2016; Mashaly 2016; Mashaly and Al-Mekhlafi, 2016; Martin-Vega et al., 2017; McIntosh et al., 2017; Wang et al., 2017). In addition to the abovementioned factors, drugs and toxins in the decomposing tissues, burning and hanging of cadavers, or wrapping them in several layers of clothing have been found to affect both initial time of appearance of insects and their succession (Goff et al., 1991; Catts and Goff, 1992; Avila and Goff, 1998).
Cars and other vehicles provide an interesting environment that may affect the decomposition of bodies and associated succession patterns of insects. Vehicles act as a shelter which protects insects from rain and predators, and also affect temperature and humidity (Anderson, 2001). The warm temperature inside vehicles encourages insect development and oviposition. It has been reported that the temperature within a vehicle parked in the sun can be up to 20°C higher than the ambient temperature. This difference in temperature varies depending on the colour and the location of the vehicle, which in turn affect PMI estimates (Dadour et al., 2011).
Insects collected from different parts of the car such as the radiator grill, bonnet or the windshield may provide details of a cadaver movement. The number of adult flies accessing the vehicle is dependent on the population size, fly species and the available portal for flies’ entry into the cabin (Dadour et al., 2011). In a vehicle environment, the access to the corpse is delimited to the holes in the windshield, cracks in a car trunk, or openings of ventilation. Smaller dieptera are therefore likely to be able to get into the vehicle and colonize the corpse in larger numbers than coleoptera. Nonetheless, factors other than size may influence access because in many cases medium to large size adult sarcophagids have been reported in large numbers in indoor cadavers (Byrd and Castner, 2010).
Although Anderson (2010) observed that large numbers of blowflies can access a vehicle, the numbers are still usually less than would be expected on exposed remains and oviposition takes a longer time. For example, flies belonging to the Calliphoridae usually take only one hour to reach outdoor carcasses and oviposition occurs within six to eight hours after death (Voss et al., 2008). In contrast, the same fly species takes some 16–18 h to reach carcasses inside vehicles and oviposition takes 24–28 h in total. Regarding the succession pattern of insects, Voss et al. (2008) reported very similar succession patterns between vehicle and outdoor environments, although the colonization time varied between the two environments.

This study aimed to investigate the insect species attracted to two human cadavers in a vehicular environment in Riyadh, Saudi Arabia.

2. Materials and methods

2.1. Study procedures

All procedures were performed in accordance with the terms of the Committee of Graduate Studies and Scientific Research, Department of Zoology, College of Sciences, King Saud University. The characteristics of the cadavers were recorded in Table 1 including cause of death, sex, age, estimated PMI, location, latitude and longitude, and the stage of insect development.

Samples were collected from cases during autopsy procedures conducted at the Institute of Legal Medicine at King Saud Hospital. Samples were preserved in 70% ethanol in vials labelled with the date and time of collection. The collected insect specimens were sorted and initially identified in the entomology laboratory in the Department of Zoology, College of Sciences, King Saud University using specialized taxonomic keys; for flies Büttiker et al. (1979), Greenberg and Kunich (2002) and Setyaningrum and Al Dhafer (2016) and for beetles Borror et al. (1989) and Catts and Haskell (1990). Further molecular identification was performed in order to confirm the morphological identification (see Alajmi et al., 2016). Climatic data were obtained from the meteorological stations closest to the scenes of death (Figs. 1 and 2). Different photos of cases were given with approval by the Institute of Legal Medicine at King Saud Hospital.

3. Case Reports:

3.1. Case report 1

On 15/12/2016, a 35-year-old man (Fig. 3a) was found in the early stage of decay in the garage of his house in Qurtubah district in the north east of Riyadh. He was lying on the floor under an old car. He was wearing a white shirt, undershirt, white trousers, underpants, black socks and blue plastic gloves. The door of the garage was open. He was alone since his family had travelled for a vacation. The average temperature recorded in the week before the body's discovery, was 21 ± 2.0 °C, with a maximum of 25.0 °C. The corpse was transferred to the Institute of Forensic Medicine at King Saud Hospital. According to police investigations, death was caused by the car falling on the upper part of the body whilst it was being repaired. Examination of the body showed restriction to the chest leading to difficulty breathing and cardiac arrest, respiratory failure and shock. From the police investigation, the time of death was estimated as about five days before the discovery of the body.

3.2. Case report 2

A 53-year-old man (Fig. 3b) was found dead in his car in the area beside King Khalid International Airport in the north of Riyadh. The body was found on the driver’s seat dressed in a long dress and long trousers. One of the front windows of the car was opened about 10 cm. The body was at the early stage of decomposition. The cause of death was presumed to be natural. The mean surrounding ambient temperature was 32 ± 2 °C. The corpse was taken to the Institute of Legal Medicine at King Saud Hospital on the 23rd March 2017. According to police investigations, the time of death was estimated as having occurred ten days before the body was discovered.

4. Results

The two human corpses with insect specimens were referred to the Institute of Forensic Medicine at King Saud Hospital. The age distribution of the referred corpses was between 35 and 53 years old. Medical or scientific evidence other than entomological data determined PMIs ranging from five to twelve days for the corpses, and this difference could affect the diversity of insects found on the cadavers (Table 1).

The morphological identification of insects concurred with the identification based on partial sequencing of the mt COI gene. A total of 6 adults, 41 larvae and egg batches specimens representing two orders and four families were recorded on the two human cadavers. The flies comprised one Calliphoridae species, Chrysomya albiceps (Wiedemann 1819), one Phoridae species, Megaselia scalaris (Loew 1866), and one Muscidae species; Musca domestica (Linnaeus, 1758).

The entomological evidence from the cadaver in the first case was collected during an autopsy performed on the 16th December
Details of the human cadavers and the insects found on them in Riyadh, Saudi Arabia. 2016 (the body had been maintained at 4 °C before the autopsy). Fly eggs and alive larvae (L1, post-feeding 3 mm, N = 32) were present on the neck area and inside the oral cavity, and from the inside of the bag used to transport the corpse to the autopsy room. Dead adult flies (N = 6) were collected from the folds of the clothes on the corpse. Specimens were identified as C. albiceps. The mPMI was estimated according to the police investigation to have occurred five days before the discovery of the corpse.

Entomological evidence was collected from the second human cadaver during the autopsy performed on 24th March 2017 (the body had been maintained at 4 °C before the autopsy). Alive fly larvae (N = 9) were present inside the oral cavity, eyes and nose. Larvae were identified as M. domestica (L1, post-feeding 3 mm, N = 7) and M. scalaris (L1, post-feeding 4 mm, N = 2). The legal investigation estimated the mPMI as about ten days prior to the discovery of the corpse.

Table 1
Details of the human cadavers and the insects found on them in Riyadh, Saudi Arabia.

| Case no. | Gender | Age (yr) | Location | Cause of death | PMI estimation (day) | Decomposition stage | Development stage of insects | Order/Family | Species | Reference accession No |
|---------|--------|----------|----------|---------------|---------------------|---------------------|--------------------------|-------------|---------|----------------------|
| 1       | Male   | 35       | Córdoba district | Cardiac arrest, respiratory failure | 5–6 | Early decay | 6 adult, 32 larvae (L1), egg-batches 2 larvae (L1) | Diptera/Calliphoridae | Chrysomya albiceps | KM407601.1 |
| 2       | Male   | 53       | Airport district | Natural death | 10–12 | Early decay | 7 larvae (L1) | Diptera/Phoridae | Megaselia scalaris | JQ041745.1 |

Fig. 3. Indicates the two cases: A: Case 1; B: Case 2.

In the second case, the corpse was inside the car with only one window opened. In this case the temperature inside the car would be expected to be higher than outside the vehicle.

The vehicle provided some degree of a barrier, although a number of adult flies had obviously entered the vehicle for oviposition. Due to solar radiation absorption, the interior of a vehicle usually has an elevated temperature than the ambient. The degree of elevated temperature varies based on the composition and colour of the vehicle. Cadavers will also have an elevated temperature outdoors if they are exposed to direct sunlight and thus the body will cool more slowly than those in partial or full shade (Joy et al., 2006). The mechanism by which the heat is entrapped within the vehicle is similar to that of a greenhouse. The glass of the windshield and windows permits short wavelengths of visible light to get inside the vehicle and be absorbed by the seats, dashboard, and other objects (Dadour et al., 2011).

This study indicated that the two cadavers did not attract any insect species in common. This is likely to be due to the differences in the habitats between the two sites. Previous studies have indicated that the habitat type has an effect on the species richness on cadavers (Campobasso et al., 2001; Anderson, 2010; Mashaly and Al-Mekhlafi, 2016). Insects attracted to the first case were Ch. albiceps, which are widely distributed in different regions of the world (Zumpt, 1965; Laurence, 1981; Grassberger et al., 2003; Charabidze et al., 2014; Benecke, 2015; Moemenbellah-Fard et al., 2018). This species has been reported previously in Saudi Arabia (Büttiker et al., 1979; Al-Eneszy, 2012), and is also recognized as being among the first wave of the faunal succession on human cadavers (Smith, 1986; Anderson, 2001; Higley and Haskell, 2009; Bugelli et al., 2015). Musca domestica and Me. scalaris were collected from the second cadaver, with many previous studies having recorded both species as forensic insects on human bodies (Reibe and Madea, 2010; Bugelli et al., 2015; Bernhardt et al., 2018).

5. Discussion

The rate of decomposition of cadavers is controlled by several environmental and non-environmental factors (Soon et al., 2017). Factors of environmental origin include weather conditions (e.g. temperature, moisture) and cadaver conditions (e.g. indoor or outdoor, buried, underwater, above ground). Non-environmental factors are mostly related to the cadaver itself such the body mass/size, wrapped or unwrapped, and entomological effects. In the current study, the impact of a vehicular environment on the insect species attracted to the human cadavers was investigated.

The effect of vehicle environment was evaluated in the two cases, noting that there was a degree of exposure to the air in each case. In the first case, the door of the garage was found opened, and the body was outside the car but located beneath it. In the second case, the cadaver was inside the car but the front car window was opened, allowing relatively easy access to insects. Any location that restricts entry without preventing all insect colonization has the capacity to affect the species composition of the forming carrion community (Dadour et al., 2011). The rate of decomposition in the first case may have been affected by the higher temperature of the cadaver because half of the corpse was under the vehicle.

6. Conclusion

Habitat is one of the factors that affects insect attraction to cadavers. The habitat within a vehicle is characterized by an
increased temperature, which affects insect prevalence on the corpses. In the presented cases there was no temperature data from the body recovery sites themselves, so we used the data from the closest meteorological station. In the current study, two human cadavers in the vehicle habitat were studied. Results indicated the presence of insect species which are known as forensic insects from many previous studies. These insects include Ch. albiceps, Me. scalaris and M. domestica from Diptera, which could be used as forensic indicators in crime scene investigation.

Acknowledgments

Authors thank King Abdulaziz City for Science and Technology, Saudi Arabia for supporting this research by means of a grant (No. 1-18-01-001-0001).

References

Alajmi, R.A., Al-Jefry, H., Farrukh, A., Aljohani, H., Mashaly, A.M.A., 2016. First report of necrophagous insects on human corpses in Riyadh, Saudi Arabia. J. Med. Entomol. 53 (6), 1276–1282.

Al-Eneszy, R.N.F., 2012. Numerical dynamics and species composition of some families of dipterous flies in Hail City [Master thesis]. Kingdom of Saudi Arabia, Riyadh: King Saud University.

Anderson, G., 2001. Insect succession on carrion and its relationship to determining time of death. In: Castner, J., L., Jason, H., Byrd, J. (Eds.), Forensic Entomology: The Utility of Arthropods in Legal Investigations. CRC Press, Boca Raton, pp. 143–177.

Anderson, G.S., 2010. Factors that influence insect succession on carrion. In: Byrd, J. H., Castner, J.L. (Eds.), Forensic Entomology: The Utility of Using Arthropods in Legal Investigations. CRC Press, Boca Raton, FL, pp. 201–250.

Anderson, G., VanLarenoven, S., 1996. Initial studies on insect succession on carrion in southwestern British Columbia. J. Forensic. Sci. 41, 617–625.

Avila, F., Goff, M.L., 1998. Arthropod succession patterns onto burnt carrion in two contrasting habitats in the Hawaiian Islands. J. Forensic. Sci. 43, 581–586.

Benecke, M., 2015. So arbeitet die moderne Kriminalbiologie. Cologne: Lübbe, 10th ed.

Bernhardt, V., Bälint, M., Verhoff, M.A., Amendt, J., 2018. Species diversity and tissue specific dispersal of necrophagous Diptera on human bodies. Forensic Sci. Med. Pathol. 14 (1), 76–84.

Borror, D.J., Triplehorn, C.A., Johnson, N.F., 1989. An Introduction to the Study of Insects. Saunders College Publishing, Philadelphia.

Bugelli, V., Forni, D., Bassi, L.A., Di Paolo, M., Marra, D., Lenzi, S., Toni, C., Giusiani, M., Domenici, R., Gherardi, M., Vanin, S., 2015. Forensic entomology and the estimation of the minimum time since death in indoor cases. J. Forensic. Sci. 60 (2), 525–531.

Büttiker, W., Attiah, M.D., Pont, A.C., 1979. Insects of Saudi Arabia Diptera: synanthropic flies. Fauna Saudi Arabia 1, 352–367.

Byrd, J.H., Castner, J.L., 2010. Forensic Entomology: The Utility of Arthropods in Legal Investigations. CRC Press, Boca Raton, FL.

Campobasso, C.P., Di Vella, C., Introna, F., 2001. Factors affecting decomposition and Diptera colonization. Forensic Sci Int. 120, 18–27.

Catts, E.P., Goff, M.L., 1992. Forensic entomology in criminal investigations. Annu. Rev. Entomol. 37, 253–272.

Catts, P., Haskell, N., 1990. Entomology and Death a Procedural Guide. Joyce's Print Shop, South Carolina.

Charabidze, D., Colar, T., Vincent, B., Pasquerault, T., Hedouvin, V., 2014. Involvement of larder beetles (Coleoptera: Dermentidae) on human cadavers: a review of 81 forensic cases. Int. J. Legal Med. 128, 1021–1030.

Dadour, I.R., Almanjahie, I., Fowkes, N.D., Keady, G., Vijayan, K., 2011. Temperature variations in a parked vehicle. Forensic. Sci. Int. 207, 205–211.

Goff, M.L., Brown, W.A., Hewadikaram, K.A., Omori, A., 1991. Effect of heroine in decomposing tissue on the development rate of Boettcherisca peregrine (Diptera: Sarcophagidae) and implications to the estimation of postmortem intervals using arthropod development patterns. J. Forensic. Sci. 36, 537–542.

Grassberger, M., Friedrich, E., Reiter, C., 2003. The blowfly Chrysomya albiceps (Wiedemann) (Diptera: Calliphoridae) as a new forensic indicator in Central Europe. Int. J. Legal Med. 117, 75–81.

Greenberg, R., Kunich, J.C., 2002. Entomology and the Law: Flies as Forensic Indicators. Cambridge University Press; first ed. (October 2002), 356 pp.

Higley, L.C., Dadour, I.R., 2009. Insect development and forensic entomology. In: Byrd, J.H., Castner, J.L. (Eds.), Forensic Entomology: The Utility of Arthropods in Legal Investigations. CRC Press, Boca Raton, Florida, USA, pp. 388–405.

Iancu, L., Sahlean, T., Purcarea, C., 2016. Dynamics of necrophagous insect and tissue bacteria for postmortem interval estimation during the warm season in Romania. J. Med. Entomol. 53, 54–66.

Joy, J.E., Liette, N.L., Harrah, H.L., 2006. Carrion fly (Diptera: Calliphoridae) larval colonization of sunlit and shaded pig carcasses. Forensic. Sci. Int. 164, 183–192.

Laurence, B.R., 1981. Geographical expansion of the range of Chrysomya blowsflies. Trans. R Soc. Trop. Med. Hyg. 75 (1), 130–131.

Martin-Vega, D., Martin Nieto, C., Cifrians, B., Baz, A., Diaz-Ortiz, L.M., 2017. Early colonization of urban indoor carcasses by blow flies (Diptera: Calliphoridae): an experimental study from central Spain. Forensic. Sci. Int. 278, 87–94.

Mashaly, A.M.A., 2016. Entomofacial succession patterns on burnt and unburnt rabbit carrion. J. Med. Entomol. 53 (2), 296–303.

Mashaly, A.M.A., Al-Mekhlafi, F.A., 2016. Differential Diptera succession patterns onto decomposed rabbit carcasses in three different habitats. J. Med. Entomol. 53 (5), 1192–1197.

Mcintosh, C.S., Dadour, I.R., Voss, S.C., 2017. A comparison of carcass decomposition and associated insect succession onto burnt and unburnt pig carcasses. Int. J. Leg. Med. 131, 835–845.

Moemenbehlah-Fard, M.D., Keshavarzi, D., Fereidooni, M., Soltani, S., 2018. First experimental study from central Spain. Forensic. Sci. Int. 278, 87–94.

Mashaly, A.M.A., 2012. Numerical dynamics and species composition of some families of dipterous flies in Hail City [Master thesis]. Kingdom of Saudi Arabia, Riyadh: King Saud University.

Mashaly, A.M.A., Al-Mekhlafi, F.A., 2016. Differential Diptera succession patterns onto decomposed rabbit carcasses in three different habitats. J. Med. Entomol. 53 (5), 1192–1197.

Moemenbehlah-Fard, M.D., Keshavarzi, D., Fereidooni, M., Soltani, S., 2018. First survey of forensically important insects from human corpses in Shiraz, Iran. J. Forensic. Sci. Med. 54, 62–68.

Perez, A.E., Haskell, N.H., Wells, J.D., 2015. Commonly used intercarcass distances appear to be sufficient to ensure independence of carrion insect succession pattern. Ann. Entomol. Soc. Am. 109, 72–80.

Reibe, S., Madea, B., 2010. Use of Megasis scalaris (Diptera: Phoridae) for postmortem interval estimation indoors. Parasitol. Res. 106, 637–640.

Seyyanungram, H., Al Dhafer, H.M., 2014. The Calliphoridae the blow flies (Diptera: Oestroidea) of Kingdom of Saudi Arabia. Egy. Acad. J. Biol. Sci. 7 (1), 49–139.

Shalaby, O., deCarvalho, L., Goff, M.L., 2000. Comparison of patterns of decomposition in a hanging carcass in contact with soil in a xerophytic habitat on the Island of Oahu, Hawaii. J. Forensic. Sci. 45, 1267–1273.

Smith, K.G.V., 1986. A manual of forensic entomology. The Trustees, British Museum, London.

Soon, L.P., See, K.L., Ahmad, N.W., Abdullah, K., Hasmi, A.H., 2017. A scoping review on factors affecting cadaveric decomposition rates. JFSIC 2 (2), 1–20.

Voss, S.C., Forbes, S.L., Dadour, I.R., 2008. Decomposition and insect succession on cadavers inside a vehicle environment. Forensic. Sci Med Pathol. 4 (1), 22–32.

Wang, Y., Ma, M.Y., Jiang, X.Y., et al., 2017. Insect succession on remains of human and animals in Shenzhen, China. Forensic. Sci. Int. 271, 75–86.

Zumpt, F., 1965. Myiassis in Man and Animals in the Old World: A Textbook for Physicians, Veterinarians and Zoologists. Butterworth, London.