International Journal of Trend in Scientific Research and Development (IJTSRD)
Volume 4 Issue 6, September-October 2020 Available Online: www.ijtsrd.com e-ISSN: 2456 – 6470

Succession of Arthropods on White Rat Carcasses in Ile-Ife, Southwestern Nigeria

Aminat Adeola Adesina, Olalekan Joseph Soyelu

Department of Crop Production and Protection, Obafemi Awolowo University, Ile-Ife, Nigeria

ABSTRACT

The forensic information provided by decomposition of small carcasses often goes unnoticed, even in advanced economies, due to frequent neglect. This paper reports the succession pattern of arthropod species that associated with carcasses of white rat, Rattus norvegicus (Berkenhout) (Rodentia: Muridae), in Ile-Ife, southwestern Nigeria. Four bushy sites were chosen for the study and nine rat carcasses were placed at each site once a season for two seasons. The carcasses were monitored daily until the process of decay was over. The visiting and colonizing invertebrates were collected daily and identified. Immatures were also collected and reared in the laboratory till adult emergence for easy identification. The carcasses went through five stages of decay and the arthropods arrived in the order Diptera (early fresh stage), Hymenoptera (late fresh stage), Coleoptera and Dermaptera (active decay stage), and Araneae and Oribatida (advanced decay stage). Dipteran flies were the first arthropods to interact with the remains but ants were the only arthropods that associated with all the five stages of decay. A total of 9828 arthropods (4415 adults and 5413 immatures) belonging to six orders in two classes of the phylum were collected in the study. The proportion of faunal abundance was Diptera (75.10%), Hymenoptera (22.90%), Coleoptera (1.80%), Dermaptera (0.10%), Oribatida (0.08%) and Araneae (0.02%). Rate of decay was faster and faunal population was higher on carcasses during the dry season compared to the wet. Faunal population was also higher on carcasses placed in close proximity to the Zoological garden. The implications of these results on accuracy of estimated postmortem interval (PMI) and applicability in law were discussed.

***KEYWORDS:** carrion; decay stages; forensic entomology; necrophagous arthropods; postmortem interval*

***How to cite this paper**:* Aminat Adeola Adesina | Olalekan Joseph Soyelu "Succession of Arthropods on White Rat Carcasses in Ile-Ife, Southwestern Nigeria" Published in International Journal of Trend in Scientific Research and Development (ijtsrd), ISSN: 2456-6470, Volume-4 | Issue-6, October 2020, pp.1761-1765, URL: www.ijtsrd.com/papers/ijtsrd35737.pdf

IJTSRD35737

INTRODUCTION

Arthropods, especially insects, are usually present as silent witnesses at crime scenes where they serve as biological indicators of time elapsed since death of an organism, sometimes referred to as postmortem interval (PMI) [1-2]. Accurate estimation of the PMI and excellent understanding of faunal succession timelines in a given location has assisted entomologists in solving criminal cases [3-6]. The area of insect science (Forensic entomology) that is concerned with region-dependent arthropod succession pattern, growth and development, and interspecific interactions among arthropods on human and animal remains has a wide application in homicide investigation [1, 7], child abuse and neglect [8] and wildlife poaching [4-5]. The discipline is, therefore, broadly viewed as the application of knowledge of insects and other arthropods in investigating crimes or civil disputes and presenting verifiable evidence in law courts [9].

King [10] reported that carcasses go through five main stages of decay, namely the fresh stage, bloated stage, active decay stage, advanced decay stage and dry or skeletal stage. Each decay stage is infested by its associated arthropods at specific life stages which are correlated with multiple circumstantial and environmental factors to determine the PMI. Members of orders Diptera and Coleoptera are reported to account for at least 60% of fauna visiting decomposing carcasses and, they are, therefore, considered very important in forensic science [11]. Generally, Diptera is associated with the early stages of decomposition while coleopterans tend to be associated with the advanced stages [12]. Other taxonomic groups often associated with decomposing remains are Lepidoptera, Hymenoptera, Blattodea, Hemiptera, Isoptera, Dermaptera, spiders, harvestmen, centipedes, millipedes, isopods and mites although the roles played by some of them in the process of decomposition are not well understood [11]. Some arthropods are attracted to the remains for the purpose of feeding (either as a flesh eater or as a predator on other visiting arthropods) while others visit for oviposition purposes [13]. However, species of fauna and time of arrival on carrion vary with many factors such as geographical location, season, habitat, vegetation, soil type and meteorological conditions [14].

Majority of available literature investigated corpses in United States, Europe and Australia [14] while information regarding insects associated with animal carrion and human corpses in Africa is relatively scarce. This is because application of forensic entomology in most African countries is still in its infancy. For instance, it was embraced in Nigeria as recently as 1988 [15] despite its origin dating back to the

13th century in China [16]. The size of carcass affects rate of decomposition and colonization of insects [10], and this might be responsible for the preference for large animals in previous studies. Animals like pig [1, 17], mona monkey, forest genet and greater cane rat [9] have been used as experimental models. Though frequently neglected, the decomposition of small carcasses may provide information of forensic importance [11] especially in cases involving small mammals. The present study was, therefore, designed to gather forensic information on the white rat, *Rattus norvegicus* (Berkenhout), with a view to understanding the succession pattern of arthropods on a small carcass in this ecological zone.

MATERIALS AND METHODS

The experiment was carried out in September 2018 (wet season) and January 2019 (dry season). Four study sites (Table 1) were selected within Obafemi Awolowo University (OAU), Ile-Ife, a town situated in the tropical rainforest zone of southwestern Nigeria. The experimental white rats were obtained from the Animal Health Unit of the Faculty of Pharmacy, OAU and frozen to death in a deep freezer before being placed in the field. Three dead rats, in triplicate, were placed at each site and they were monitored daily until decomposition was completed, leaving only the dry skeleton. The stages of decay and their duration, sequence of arthropod arrival, taxonomic categories of visiting fauna and population of each arthropod group around rat carcasses were recorded during the period of decomposition. Immature and adult stages of insects and other invertebrates present at the carrion site, either on the body, surroundings or underneath the body were collected. Flying insects were collected using a sweep net while immature and other adult arthropods were either handpicked or collected using a pair of forceps. All immature stages were reared till adult emergence for easy identification. The faunal collections were preserved in 70% ethanol and identified under a dissecting microscope using established taxonomic keys. Care was taken to reduce the amount of disturbance each time the carcasses were assessed. Population data for each taxonomic category were subjected to natural log transformation before analysis of variance was carried out and mean values were separated among experimental sites and between seasons using Tukey's HSD at 0.05 level of probability.

Table 1: Description of experimental sites where white rat carcasses were placed

No.	Nature of site	Nearest structure	Coordinate	Approximate distance from a reference point
1	Bushy	Academic block	7°31'22"N 4°31'33"E 287 m asl	100 m
2	Bushy	Zoological garden	7°31'21"N 4°31'18"E 299 m asl	1080 m
3	Bushy	Computer centre	7°31'08"N 4°31'49"E 256 m asl	1200 m
4	Bushy	Residential block	7°31'09"N 4°30'58"E 268 m asl	2200 m

asl: elevation above sea level.

RESULTS AND DISCUSSION

Prevailing conditions and process of decay

The average values of five weather parameters, weight of carcass and number of days taken for the rats to decay in each season are presented in Table 2. There was a significant variation between the two seasons, resulting in a reduction in the rate of decay by at least 48 h during the wet season. This corroborated [11] who reported a faster rate of rat and mouse decay during the warm compared to cold seasons. Generally, warmer conditions promote decay while colder climates delay the process [18] because the former is more favourable for bacterial activities that aid decomposition. Also, low temperatures often discourage activities of insects and scavengers which are important agents of decay [19]. In establishing the timeline for PMI estimate, investigators often take note of environmental temperature around the carcass. Arthropods that aid carcass decay are very sensitive to variation in temperature; development of insect larvae, for instance, is delayed at temperatures below 10°C and wide fluctuations in daily temperatures can be lethal to certain larvae [20]. The rate of decay and appearance of forensic signs also varied slightly with location and size of carcass. Variation in the nature of bushes surrounding the rats, with corresponding sun or shade exposure, may be responsible for the location effect. In addition, thinner bodies tend to skeletonize more rapidly than individuals with higher body fat [21]. This was evident in the present study with shorter days to skeletisation recorded for lighter rats.

Table 2: Prevailing environmental conditions during the period of study and effect on duration of decay

Season	*Weather data					Carcass weight (g)	Duration of decay (day)
	Sun hour (h)	Temp. (°C)	Rainfall (mm)	R.H. (%)	Cloud cover (%)	(mean ± standard error)	
Wet (Sep. 2018)	177.50	Max: 29 Ave: 24 Min: 21	100.74	90.00	77.00	153.33 ± 1.78	11.42 ± 0.54
Dry (Jan. 2019)	270.00	Max: 39 Ave: 32 Min: 23	29.20	52.00	28.00	152.50 ± 1.99	9.00 ± 0.48

*Source: WWO [22]

Stages of decay and sequence of arthropod arrival on experimental white rats

In agreement with King [10], five stages of decay were observed in this study and each is presented with its associated details in Table 3. A number of postmortem changes which adhere to a relatively strict timeline usually occur within the first 36 h of death and they aid in accurate estimation of the PMI [23]. However, these changes might neither be evident nor helpful in a situation where the victim was frozen to death and investigators would need to develop an insect-based evidence to create a timeline in determining the time elapsed since death. This could be achieved by applying the succession-based approach which requires knowledge regarding the composition and residency pattern of necrophagous insects in a given location [24].

Table 3: Details of each stage of decay and sequential arrival of associated arthropods

Stage	Description	Duration of stage	Succession of arthropods	Taxonomic category
Fresh	Skin remained firm No foul odour was emitted No changes in colour	Wet season: 0-1 d Dry season: 0-1 d	(i) Flies (ii) Ants	(i) Calliphoridae, Muscidae and Sarcophagidae (ii) Formicidae
Bloat	Gases accumulated in the abdominal region Carcass became dark in colour Dipteran eggs were present	Wet season: 2-3 d Dry season: 1-2 d	(i) Flies (ii) Ants	(i) Diptera: *Musca domestica*, *Chrysomya albiceps*, *C. marginalis,* sarcophagids (ii) Hymenoptera: *Lasius niger*, *Paraponera clavata*, *Oecophylla longinoda*
Active decay	Dipteran larvae were more abundant Dipteran larvae broke the skin and gases escaped Presence of foul odour Maggots and coleopterans fed on the carrion Decomposition became more pronounced around the orifices in the head and anal regions Gradual loss of fur on the rats commenced	Wet season: 3-4 d Dry season: 2-3 d	(i) Flies (ii) Ants (iii) Beetles (iv) Earwigs	(i) Diptera: *Musca domestica*, *Chrysomya albiceps*, *C. marginalis*, *Sarcophaga africa*. *Drosophila* spp. were also present during the dry season. (ii) Hymenoptera: *Lasius niger*, *Paraponera clavata*, *Oecophylla longinoda*, *Trichomyrmex destructor* (iii) Coleoptera: *Coccinella magnifica*, Scarabaeidae, Silphidae (iv) Dermaptera: Forficulidae
Advanced decay	Body fluid oozed from the carcass Intensity of foul odour became less Most of the flesh had been consumed The skeleton became visible Most of the maggots had advanced to the pupal stage Coleopterans were more abundant and more active	Wet season: 5-9 d Dry season: 4-7 d	(i) Flies (ii) Ants (iii) Beetles (iv) Mites & Spiders	(i) Diptera: *Musca domestica*, *Chrysomya albiceps*, *C. marginalis*, *Sarcophaga africa* (ii) Hymenoptera: *Lasius niger*, *Paraponera clavata*, *Oecophylla longinoda* (iii) Coleoptera: *Coccinella magnifica*, Scarabaeidae, Silphidae (iv) Arachnida: unidentified mites and spiders
Dry or skeletal	Bones, cartilages and very little skin remained	Wet season: 10-13 d Dry season: 8-11 d	Ants	Hymenoptera: *Lasius niger*, *Oecophylla longinoda*

The process of decay lasted over one week in wet and dry seasons and the sequence of arthropod arrival on rat carcasses was similar in both. Flies were the first to infest the carcass while hymenopterans, coleopterans and arachnids joined at the late fresh, active decay and advanced decay stages, respectively. Calliphorid flies were the first arthropods to detect and interact with rat carcasses; adults lay eggs in open wounds and natural orifices with the ensuing larvae aiding decomposition by feeding on interior of the body and destroying soft tissues. Necrophagous dipterans usually get attracted to a body within minutes of its deposition in the field because of the presence of special receptors which are sensitive to putrefactive gases [25]. The dipterans were followed by the ants which consumed the carrion and created holes that served as entry points for other organisms, thus, enhancing the rate of decay. The process of decay was further enhanced by the coleopterans and dermapterans which fed on the carrions. The only arthropods found on rat carcasses at the skeletal phase were the ants. Although the arachnids (mites and spiders) contributed to the process of decay by feeding on the carrion, they were considered incidental by Lord and Rodriguez [26] while Bass [27] identified insect activity as the primary process accelerating decomposition. The possibility of synchronising presence of different life stages of arthropods with specific time enables the investigators to establish timelines and determine the PMI in solving crime cases. The time of arrival of an arthropod on a carcass is adaptive in nature, relating to biology, behaviour and habit of the infesting group. A more detailed representation of arthropods encountered in this study (Table 4) shows that members of six orders from two classes were represented. Among them were carrion feeders and predators while adults, especially dipterans, oviposited on carcasses thereby increasing the population of larvae which drove the process of decay.

Relative abundance of arthropods found on white rat carcasses

A total of 9828 arthropods (4415 adults and 5413 immatures) were collected over the period of rat decay. The collections were made of insects in orders Diptera (75.10%), Hymenoptera (22.90%), Coleoptera (1.80%), Dermaptera (0.10%), Oribatida (0.08%) and Araneae (0.02%). Dipterans, mainly of families Sarcophagidae, Calliphoridae and Muscidae, are critically important in forensic investigations [28]. Of these three, calliphorids are the initial and main consumers of carrion [29], thus considered the most important group of flies in Forensic entomology. Although Diptera and Coleoptera are discussed more often in literature, ants were present in all stages of decomposition (as similarly observed by Ekanem and Dike [17] and Paula et al. [30]) in a higher proportion than the beetles. Campobasso et al. [31] also reported a higher number of ants, than beetles, on corpses. While dipterans may be consistently more abundant on animal and human remains, the relative population of coleopterans and hymenopterans may depend largely on the habitat where the carcass is found. Ants can speed up or slow down the process of decomposition of carcasses by feeding directly on them or preying on necrophagous insects [30].

Table 4: Description of arthropods found on carcasses of white rat in the study

Class	Order	Family	Scientific name	Common name	Activity on carcass
Arachnida	Oribatida	Phthiracaridae	ND	Beetle mite	Carrion feeder
	Araneae	ND	ND	Spider	Carrion feeder, predator
Insecta	Coleoptera	Coccinellidae	*Cynegetis impunctata* (L.)	Ladybird	Unknown
			Coccinella magnifica Red.	Ladybird	Predator
		Scarabaeidae	ND	Scarab beetle	Carrion feeder, recycler
		Silphidae	*Phosphuga atrata* L.	Carrion beetle	Carrion feeder
	Dermaptera	Forficulidae	ND	Earwig	Carrion feeder
	Diptera	Drosophilidae	*Drosophila* spp. Fallén	Fruitfly	Carrion feeder, oviposition
		Calliphoridae	*Chrysomya albiceps* (Wied.)	Blowfly	Carrion feeder, oviposition
			Chrysomya marginalis (Wied.)	Blowfly	Carrion feeder, oviposition
		Muscidae	*Musca domestica* L.	House fly	Carrion feeder, oviposition
		Sarcophagidae	*Sarcophaga africa* Wied.	Fleshfly	Carrion feeder, oviposition
	Hymenoptera	Formicidae	*Lasius niger* (L.)	Black garden ant	Predator
			Paraponera clavata (F.)	Bullet ant	Predator
			Oecophylla longinoda Latreille	Weaver ant	Predator
			Opisthopsis spp. Dalla Torre	Strobe ant	Forager
			Trichomyrmex destructor (Jerdon)	Destructive trailing ant	Predator

ND: Not determined

A significantly higher number of arthropods was collected in the dry- compared to the wet season (5655 vs. 4173; $F = 3.84$; $P < 0.0212$). This could be due to the fact that warmer temperatures support abundance and wider species diversity as well as activities of different stages of arthropods. This is contrary to cooler temperatures which deter insect activities [25, 32]. The number of arthropods collected from rat carcasses varied significantly ($F = 7.25$; $P < 0.0059$) among locations, being consistently higher at the site in close proximity to the Zoological garden. An average of 66.19% of total arthropods was collected from rat remains placed in this site while the proportion of collections from the other three locations ranged between 7.50 and 15.69%. Insects, especially dipterans, are known to be numerous in areas with a large animal population due to the presence of abundant faecal matter and other decaying materials which they consume as food and utilize as breeding sites [33-34]. It is, therefore, imperative that a broad description of a crime site is taken into consideration when interpreting faunal data.

Conclusion

The estimation of PMI as a tool for solving crime cases should be embraced by nations, such as Nigeria, where neighbourhood policing by way of closed-circuit television and personnel is lacking or generally poor. However, the intricacies should be well understood for the sake of accuracy and this would necessitate additional studies. Entomologists should be familiar with techniques and distinctive features applicable to both early and late postmortem periods, succession pattern and development of arthropods on animal remains and how these vary with geographical location and meteorological parameters. Accurate entomological evidence would complement testimonies given by witnesses excellently.

Acknowledgment

The authors wish to appreciate Messrs Rasaq Ajibade, Samuel Oyebiyi and Paul Odesola of Obafemi Awolowo University, Ile-Ife for assisting with arthropod collection and identification.

References

[1] J. A. Kelly, T. C. van der Linde and G. S. Anderson, "The influence of clothing and wrapping on carcass decomposition and arthropod succession during the warmer seasons in central South Africa," J. Forensic Sci., vol. 54, pp. 1105-1112, 2006.

[2] J. Isaac, G. M. Deepu, S. Pradeesh and V. Geetha, "The use of insects in forensic investigations: an overview on the scope of forensic entomology," J. Forensic Dent. Sci., vol. 3, pp. 89-91, 2011.

[3] J. F. Wallman, "The application of entomology to criminal investigations," in Practice of crime scene investigation, J. Horswell, Ed. Florida: CRC Press, pp. 347-360, 2003.

[4] E. J. Watson and C. E. Carlton, "Spring succession of necrophilous insects on wildlife carcasses in Louisiana," J. Med. Entomol., vol. 40, pp. 338-347, 2003.
[5] E. J. Watson and C. E. Carlton, "Insect succession and decomposition of wildlife carcasses during fall and winter in Louisiana," J. Med. Entomol., vol. 42, pp. 193-203, 2005.
[6] I. R. Dadour and B. Morris, "Forensic entomology: the use of insects in legal cases" in Expert evidence: law, practice, procedure and advocacy, I. R. Freckelton and H. Selby, Eds. 4th ed. Pyrmont: Lawbook Company, 1368 pages, 2009.
[7] J. H. Byrd, "Forensic entomology: explore the science," www.forensic-entomology.com, 2020.
[8] M. Benecke and R. Leggig, "Child neglect and forensic entomology," Forensic Sci. Int., vol. 120, pp. 155-159, 2001.
[9] S. N. Okiwelu, I. Ikpamii and O. C. Umeozor, "Arthropods associated with mammalian carcasses in River State, Nigeria," Afr. J. Biomed. Res., vol. 11, pp. 339-342, 2008.
[10] J. E. King, "Carrion insects and their application to forensic investigations in Richmond, NSW with particular reference to significant Coleoptera," PhD Thesis, University of Western Sydney, 2012.
[11] T. C. Moretti, O. B. Ribeiro, P. J. Thyssen and D. R. Solis, "Insects on decomposing carcasses of small rodents in a secondary forest in Southeastern Brazil," Eur. J. Entomol., vol. 105, pp. 691-696, 2008.
[12] Q. Zhuang, J. Cai, M. Zhang, H. Feng and Y. Guo, "Molecular identification of forensically significant beetles (Coleoptera) in China based on COI gene," Rev. Colomb. Entomol., vol. 37, pp. 95-102, 2011.
[13] R. A. Alajmi, H. Al-Ghufaili, A. Farrukh, H. Aljohani and A. M. A. Mashaly, "First report of necrophagous insects on human corpses in Riyadh, Saudi Arabia," J. Med. Entomol., vol. 53, pp. 1276-1282, 2016.
[14] M. Nyasha, M. Ron and M. Gilbert, "An initial study of insect succession on decomposing rabbit carrions in Harare, Zimbabwe," Asian Pac. J. Trop. Biomed, vol. 4, pp. 561-565, 2014.
[15] T. Ekrakene and B.N. Iloba, "One death, many insects' species, yet one insect's generation," J. Entomol., vol. 8, pp. 27-39, 2011.
[16] B. E. McKnight, "The washing away of wrongs: forensic medicine in 13th Century China," Michigan: The University of Michigan Press, 196 pages, 1981.
[17] M. S. Ekanem and M. C. Dike, "Arthropod succession on pig carcasses in southern Nigeria," Pap. Avulsos Zool., vol. 50, pp. 561-570, 2010.
[18] M. B. Horenstein, B. Rosso and M. D. García, "Seasonal structure and dynamics of sarcosaprophagous fauna on pig carrion in a rural area of Cordoba (Argentina): their importance in forensic science," Forensic Sci. Int., vol. 217, pp. 146-156, 2012.
[19] M. I. Arnaldos, E. Romera, J. J. Presa, A. Luna and M. D. García, "Studies on seasonal arthropod succession on carrion in the southeastern Iberian Peninsula," Int. J. Legal Med., vol. 118, pp. 197-205, 2004.
[20] F. Introna, T. Suman and J. Smialek, "Sarcosaprophagous fly activity in Maryland," J. Forensic Sci., vol. 36, pp. 238-243, 1991.
[21] A. Sutherland, J. Myburgh, M. Steyn and P.J. Becker, "The effect of body size on the rate of decomposition in a temperate region of South Africa," Forensic Sci. Int., vol. 231, pp. 257-262, 2013.
[22] WWO, "World Weather Online, Ile-Ife Monthly Climate Averages," https://www.worldweatheronline.com/ile-ife-weather-averages/oyo/ng.aspx, 2020.
[23] A. M. Dautartas, "The effect of various coverings on the rate of human decomposition," Master of Arts Thesis, University of Tennessee, 2009.
[24] M. Jarmusz, A. Grzywacz and D. Bajerlein, "A comparative study of the entomofauna (Coleoptera, Diptera) associated with hanging and ground pig carcasses in a forest habitat of Poland," Forensic Sci. Int., dx.doi.org/10.1016/j.forsciint.2020.110212, 2020.
[25] C. P. Campobasso, G. DiVella and F. Introna, "Factors affecting decomposition and Diptera colonization," Forensic Sci. Int., vol. 120, pp. 18-27, 2001.
[26] W. D. Lord and W. C. Rodriguez, "The body and decomposers are telling you what happened, if you can only understand the language," www.forensicentomolgyindia.com, 2020.
[27] W. M. Bass, "Outdoor decomposition rates in Tennessee," in Forensic taphonomy: the postmortem fate of human remains, M. H. Sorg, W. D. Haglund and K. Marden, Eds. 2nd ed. New York: Productivity Press, 704 pages, 2020.
[28] L. Ren, Y. Shang, W. Chen, F. Meng, J. Cai, G. Zhu, L. Chen, Y. Wang, J, Deng and Y. Guo, "A brief review of forensically important flesh flies (Diptera: Sarcophagidae)," Forensic Sci. Res., vol 3, pp. 16-26, 2018.
[29] C. P. Castro, J. P. Sousa, M. I. Arnaldos, J. Gaspar and M. D. García, "Blowflies (Diptera: Calliphoridae) activity in sun exposed and shaded carrion in Portugal," Ann. Soc. Entomol. Fr. (n.s.), vol. 47, pp. 128-139, 2011.
[30] M. C. Paula, G. M. Morishita, C. H. Cavarson, C. R. Gonçalves, P. R. A. Tavares, A. Mendonça, Y. R. Súarez and W. F. Antonialli-Junior, "Action of ants on vertebrate carcasses and blow flies (Calliphoridae)," J. Med. Entomol., vol. 53, pp. 1283-1291, 2016.
[31] C. P. Campobasso, D. Marchetti, F. Introna and M. F. Colonna, "Postmortem artifacts made by ants and the effect of ant activity on decomposition rates," Am. J. Foren. Med. Pathol., vol. 30, pp. 84-87, 2009.
[32] S. Matuszewski, D. Bajerlein, S. Konwerski and K. Szpila, "Insect succession and carrion decomposition in selected forests of Central Europe. Part 1: Pattern and rate of decomposition," Forensic Sci. Int., vol. 194, pp. 85-93, 2010.
[33] E. Abba, M. Amina, Y. Lamogo, A. Rejoice, A. Jemimah and K.P. Yoriyo, "Survey of insect vectors in some selected dumpsites in Gombe metropolis, Nigeria, Western Africa," Asian J. Res. Zool., vol. 2, pp. 1-9, 2019.
[34] H. Sanchez-Arroyo and J.L. Capinera, "House fly, *Musca domestica* Linnaeus, (Insecta: Diptera: Muscidae)," Publication Number: EENY-048, UF/IFAS Extension, University of Florida. https://edis.ifas.ufl.edu/in205, 2017.