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Impact of Exposure Status on the Diversity and Successional Pattern of Cadaverous Arthropods on Slaughtered Juvenile Pig (*Sus scrofa* Linn.) Carcasses in Wukari, Nigeria

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Abstract

Knowledge of successional colonization of cadaver is important in medico-legal studies especially with regards to postmortem interval (PMI) estimation. Paucity of data especially as it relates to juveniles has limited the appropriate application of this knowledge for the benefit of man. To bridge this knowledge gap, juvenile human cadaver was modeled using 2 slaughtered juvenile pigs – *Sus scrofa* Linn. (≈ 10 kg mean weight) at the study site. One pig was exposed to sunlight while the other shaded under a tree. Both pigs were protected from scavengers and allowed through the decay stages and sampling for adult arthropods continued till the dry-remain stage of decomposition. Data collected were used to compute frequency of occurrence and relative abundance. Paleontological Statistical Tool ($Past_3$) was used to compute diversity indices. Of the 2032 arthropods of 20 species, across 17 families retrieved, the exposed carcass attracted 44.1% comprising 16 species within 15 families while the shaded carcass attracted 14 species within 12 families. Over 50% species similarity on the contrasting carcasses was observed. Calliphoridae, Muscidae, Dermestidae, Histeridae and Formicidae made-up the dominant families sampled. While *Musca domestica* L. (Muscidae) and *Anochetus* sp. (Formicidae) were exclusively dominant for the shaded carcass, *Crematogaster* sp. (Formicidae) was exclusively dominant for the exposed carcass. Both carcasses completed decomposition in 14 days but exhibited a shorter advanced-decay stage for the shaded carcass and shorter dry remain stage for the exposed carcass. We thus conclude that, there was little distinction in the diversity and succession pattern of the arthropods colonizing both carcasses (shaded and exposed).

Keywords: Cadaverous arthropods, Decomposition, Juvenile insects, Succession

1. Introduction

Arthropods play inestimable roles in nature. One of which is the decomposition of carcasses which aids natural recycling of organic matter (Alboshabaa & Al-Musawy, 2016; Timothy, Okrikata, & Tidi, 2022). Decomposition of carrion is reported to occur in five distinct stages which are fresh, bloated, early decay, advanced decay and the dry remain stages, each of which attracts a specific array of arthropods (Timothy et al., 2022). The knowledge of this successional pattern by which arthropods, insects in particular, invade a carrion is referred to as Forensic Entomology. It is instrumental in determining the minimum post mortem interval (PMI_{min}) of a cadaver, hence strategic in medico-legal investigations (Ojianwuna, Odibo, Akpan, & Egwaoje, 2019).

With accessibility and favorable weather conditions, insects are first to arrive on dead bodies (Byrd & Tomberlin, 2019). Larval development of dipterans on a carrion can be used to estimate the PMI_{min} of a carrion with great accuracy within the first 72 hours or more, while the successional pattern of invading arthropod species is engaged, particularly, at the advanced stages of decomposition (Griffiths, Krosch, & Wright, 2020; Maisonhaute & Forbes, 2021; Timothy et al., 2022). Byrd and Tomberlin (2019) showed that, successional studies of invading cadaverous entomofauna is important in providing valuable information with regards habitat of the corpse, surrounding circumstances of death among others, which can aid police investigation and justice services.

Due to the anatomical, physiological and decompositional similarities of pigs with humans, pigs are the best used animal models for studying the successional pattern of necrophagous arthropods associated with human cadavers (Keshavarzi, Zaimy, Yusuf, Shahriarinamadi, & Parkhideh, 2019; Matuszewski et al., 2020). Although factors such as geographic location, temperature, humidity, exposure to sunlight, size of

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carrion as well as manner of death among others have been identified to influence species diversity and richness on a carrion (Sonker, Rawat, & Singh, 2018), "the size" factor has largely been undermined in Nigeria and most developing countries as hardly has any forensic entomofaunal study modeled for juvenile human cadaver been conducted; despite the menace of juvenile homicide experienced in Africa, and Nigeria in particular. This investigation is thus designed to fill this knowledge gap by assessing the impact of exposure status on the abundance, diversity and successional pattern cadaverous arthropods attracted to slaughtered juvenile pig carrion in the study area.

2. Materials and Methods

2.1 Study site

The study was carried out in the Research Garden of Biological Sciences Department, Federal University Wukari, Taraba State, Nigeria within the months of March and April, 2022. Wukari Local Government Area is a semi-urban environment in the Southern guinea savanna zone which has a land area of 4,308 square kilometers, an altitude of 187m above sea level, an average annual rainfall of 1205 mm, average temperature of 26.8ºC and lies between latitude 7.89N and longitude 9.77E (Timothy & Emmanuel, 2020).

2.2 Specimen acquisition and preparation

Two male pig (*Sus scrofa* Linn.) specimens (average weight: 10 kg; approximate age: 4 months) were bought from a piggery in Wukari town and were killed by slaughtering. The pigs were kept at 25 m distance apart with one specimen placed under a tree shade while the other was left exposed to sunlight throughout the research period. Each specimen was placed on a metal mesh and covered with a metal cage which only permitted access by arthropods (Figure 1).

2.3 Animal research ethics

At the time of the study, there was no ethical committee in relation to animal use in research in the University. However, all the principles of 3Rs (Replacement, Reduction and Refinement) of the Guidance on the Operation of the Animals (Scientific Procedures) Act 1986 were strictly followed.

Figure 1. Juvenile pig carcasses: **A.** Fresh exposed carcass, **B.** Fresh shaded carcass, **C.** Shaded advanced decay stage of carcass.

2.4 Sampling protocol

The day the specimens were slaughtered was recorded as Day 0 while sampling commenced from Day 1 to the dry remain stage of the carrion (between 1400 hrs - 1800 hrs daily) following the procedure described by Grassberger and Frank (2004). Only adult arthropods were sampled. Aerial insects were sampled using two standard sweeps of the sweep net while ground insects were sampled by manual searching and picking (Griffiths et al., 2020; Tembe & Mukaratirwa, 2021; Timothy et al., 2022). A pitfall trap which was ¾ filled with soapy water was also kept within 1m distance around the carrion for sampling mostly nocturnal and other ground arthropods and was serviced daily. Care was taken to sample arthropods using the same sampling intensity, to ensure that sampling intensity does not become a confounding factor. Daily information collected from visual observation and photographs from the carrion and its surroundings include: odour and intensity, physical changes of the carrion and the presence of arthropods during each stage of the carrion (Tembe & Mukaratirwa, 2021). All sampled insects were

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collected in collecting bottles containing 70% alcohol and were transported to the Biological Sciences Laboratory of Federal University Wukari for morphological identification and sorting while sample specimens were sent to the insect museum of Institute of Agricultural Research (IAR) in Ahmadu Bello University Zaria, Nigeria, for confirmatory identification.

2.5 Data analysis

Pooled data of species abundance collected using the different sampling techniques was used to compute frequency of occurrence (FO) as well as the relative abundance (RA) vis-à-vis exposure status and decomposition stages. Taxa with FO ≥ 25% and RA ≥ 1% were regarded as dominant species and were categorized into feeding guilds while those with FO < 25% and/or RA < 1% were regarded as rare species as described by Emmanuel, Emmanuel Oludele and Monday Unwabunne (2019). Diversity indices such as Shannon-Weiner diversity indices (H), Margalef's species richness (R) and Buzas and Gibson's Evenness (E) for the different stages of decomposition were computed using the Paleantological Statistical Tool – $Past_3$ (Hammer, Harper, & Ryan, 2001). Similarity of arthropods in the contrasting environment was computed using Jaccard's similarity model:

$$Jaccard\ index = X \cap Y / X \cup Y \times 100$$

Where:
X∩Y = Number in both sets,
X∪Y = Number in either set.

3. Results

3.1 Stages of decomposition and associated arthropods

Although both carcasses completed the decomposition process in 14 days as seen in Table 1, there was a longer advanced decay stage experienced in carcass exposed to sunlight (4 - 9 days) in contrast with its shaded counterpart (4 - 6 days). However, the shaded carcass took longer (7 days) to complete the dry-remain stage (from 7^{th} - 14^{th} day) as compared to the exposed carcass whose dry-remain stage lasted for 4 days (from 10^{th} - 14^{th} day). Each stage of decomposition attracted different species composition vis-à-vis exposure status, even though some dipterans, coleopterans and hymenopterans were sampled all through the stages of decomposition as observed in Table 1 where; *Chrysomya chloropyga* Wied. (Diptera: Calliphoridae) and *Anochetus* sp. (Hymenoptera: Formicidae) colonized the shaded carcass from the fresh to dry remain stage while for the exposed carcass; *Hister monitor* Lewis (Coleoptera: Histeridae), *Dermestes maculatus* Deg. (Coleoptera: Dermestidae) and *C. chloropyga* (Diptera: Calliphoridae) occurred all through the decomposition stages. Apart from Histeridae, Dermestidae and Tenebrionidae which occurred at either the fresh or bloated stage of either or both carcasses, other coleopteran families such as Curculionidae, Staphylinidae, Cleridae and Scarabaeidae occurred either at late advanced-decay stage and/or dry-remain stage of either or both carcasses.

For Diptera; Calliphoridae and Muscidae had up to 80% colonization of the decomposition stages for both carcasses while other families such as Syrphidae and Asilidae were sampled either at the advanced-decay stage or dry-remain stages of either or both carcasses as seen in Table 1. *Stenocoris southwoodi* Ahmad (Hemiptera - Alydidae) was sampled at the advanced-decay and dry-remain stages of the exposed carcass while the hymenoptera (constituted by the formicid family) occurred at different stages of decomposition of both carcasses. In addition, Termitidae (Isoptera) and Gryllidae (Orthoptera) were sampled at the dry remaining stages of the exposed and shaded carcass, respectively (Table 1).

3.2 Abundance and frequency of occurrence of arthropods associated with slaughtered juvenile pig carcasses

A total of 2,032 arthropods consisting of 20 identified arthropod species across 17 Families from 7 Orders were sampled from both carcasses, with the exposed carcasses attracting 44.1% (896) of the total arthropods retrieved. As shown in Table 2, 16 identified insect species across 15 families from 6 orders were sampled from the exposed carcass while 14 species across 12 families from 5 orders were sampled from the shaded carcass. *Crematogaster* sp. (Formicidae – Hymenoptera) had the highest relative abundance (RA) (45.76%) for the exposed carcass while *Ommatius* sp. (Asilidae – Diptera), *Anomala resplendens* Fahr. (Scarabaeidae – Coleoptera), *Korynetes analis* Klug. (Cleridae – Coleoptera) and *Philonthus* sp. (Staphylinidae – Coleoptera) had the least RA (0.11%). For the shaded carcass, *Anochetus* sp. (Formicidae – Hymenoptera) had the highest relative abundance (47.45%) while *Endustomus senegalensis* Cast. (Tenebrionidae – Coleoptera) had the RA (0.09%).

Result for frequency of occurrence (FO) of species across the decomposition stages as also shown in Table 2 indicates that although *Crematogaster* sp. had the highest RA value, *D. maculatus* (Dermestidae – Coleoptera) with RA value of 7.81% had the highest FO value (100%) for the exposed carcass, with *Ommatius* sp.,

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A. resplendens, *K. analis* and *Philonthus* sp. having the least FO values (7.14%). For the shaded carcass, *Anochetus* sp. had 100% FO value while *E. senegalensis* had the least value (7.14%).

Table 1. Arthropodal presence on slaughtered juvenile pig carcasses at different stages of decomposition.

Order	Family	Genus/Species	Shaded carcass					Exposed carcass				
			FSH (0-1d)	BLT (2d)	Ac. Decay (3d)	Ad. Decay (4-6d)	Dry (7-14d)	FSH (0-1d)	BLT (2d)	Ac. Decay (3d)	Ad. Decay (4-9d)	Dry (10-14d)
Arachnida	Araenae	***	-	-	X	X	-	-	-	-	X	-
Coleoptera	Histeridae	*Hister monitor* Lewis		X	X	X	X	X	X	X	X	X
	Dermestidae	*Dermestes maculatus* Deg.	-	X	X	X	X	X	X	X	X	X
	Tenebrionidae	*Zophosis* sp.	-	X	X	X	X	-	X	X	X	X
	Cleridae	*Korynetes analis* Klug	-	-	-	-	-	-	-	-	X	-
	Staphylinidae	*Philonthus* sp.	-	-	-	-	-	-	-	-	X	-
	Curculionidae	*Sclerocardius* sp.	-	-	-	-	X	-	-	-	X	X
	Scarabaeidae	*Anomala resplendens* Fahr.	-	-	-	-	X	-	-	-	X	-
	Tenebrionidae	*Endustomus senegalensis* Cast.	-	-	-	-	X	-	-	-	-	-
Diptera	Calliphoridae	*Chrysomya chloropyga* Wied.	X	X	X	X	X	X	X	X	X	X
	Syrphidae	*Mesembrius* sp.	-	-	-	-	-	-	-	-	X	-
	Muscidae	*Musca domestica* L.	-	X	X	X	X	X	X	X	X	-
	Asilidae	*Ommatius* sp.	-	-	-	-	X	-	-	-	X	-
Hemiptera	Alydidae	*Stenocoris southwoodi* Ahmad	-	-	-	-	-	-	-	-	X	X
Hymenoptera	Formicidae	*Camponotus perrisii* For.	-	X	-	-	X	X	X	-	-	-
	Formicidae	*Camponotus maculatus* Fab.	-	X	X	X	-	-	-	-	-	-
	Formicidae	*Crematogaster* sp.	-	-	-	-	-	X	X	X	X	X
	Formicidae	*Anochetus* sp.	X	X	X	X	X	-	-	-	-	-
	Formicidae	*Pheidole* sp.	-	-	X	X	X	-	-	-	X	X
Isoptera	Termitidae	*Macroterma* sp.	-	-	-	-	-	-	-	-	-	X
Orthoptera	Gryllidae	*Gymnogryllus lucens* Walk.	-	-	-	-	X	-	-	-	-	-

FSH = Fresh stage, BLT = Bloated stage, Ac. Decay = Active decay stage, Ad. Decay = Advanced decay stage, d = day/days, (-) = Absent, (X) = Present, (***) = unidentified Araneaen species and are herein treated as a single population/taxon.

Table 2. Abundance and frequency of occurrence of arthropods associated with slaughtered juvenile pig carcass.

Order	Family	Genus/Species	Shaded carcass			Exposed Carcass		
			Abundance	RA (%)	FO (%)	Abundance	RA (%)	FO (%)
Arachnida	Araenae	***	3	0.26	21.43	1	0.11	7.14
Coleoptera	Histeridae	*Hister monitor* Lewis	119	10.47	78.57	109	12.17	71.43
	Dermestidae	*Dermestes maculatus* Deg.	59	5.19	92.86	70	7.81	100
	Tenebrionidae	*Zophosis* sp.	19	1.67	57.14	91	10.16	85.71
	Cleridae	*Korynetes analis* Klug	-	-	-	1	0.11	7.14
	Staphylinidae	*Philonthus* sp.	-	-	-	1	0.11	7.14
	Curculionidae	*Sclerocardius* sp.	10	0.88	35.71	5	0.56	28.57
	Scarabaeidae	*Anomala resplendens* Fahr.	2	0.18	14.29	1	0.11	7.14
	Tenebrionidae	*Endustomus senegalensis* Cast.	1	0.09	7.14	-	-	-
Diptera	Calliphoridae	*Chrysomya chloropyga* Wied.	236	20.77	78.57	145	16.20	64.29
	Syrphidae	*Mesembrius* sp.	-	-	-	3	0.33	14.29
	Muscidae	*Musca domestica* L.	19	1.67	35.71	7	0.80	28.57
	Asilidae	*Ommatius* sp.	4	0.35	14.29	1	0.11	7.14
Hemiptera	Alydidae	*Stenocoris southwoodi* Ahmad	-	-	-	3	0.33	21.43

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Hymenoptera	Formicidae	*Camponotus perrisii* For.	6	0.53	14.29	2	0.22	14.29
	Formicidae	*Camponotus maculatus* Fab.	17	1.50	28.57	-	-	-
	Formicidae	*Anochetus* sp.	539	47.45	100	-	-	-
	Formicidae	*Crematogaster* sp.	-	-	-	410	45.76	92.89
	Formicidae	*Pheidole* sp.	101	8.90	42.86	27	3.01	35.71
Isoptera	Termitidae	*Macroterma* sp.	-	-	-	19	2.12	7.14
Orthoptera	Gryllidae	*Gymnogryllus lucens* Walk.	1	0.09	7.14	-	-	-
TOTAL			**1136**	**100**		**896**	**100**	

RA = Relative abundance, FO = Frequency of Occurrence, (***) = unidentified Araenaen species and are herein treated as a single population/taxon.

Table 3. Abundance, diversity (H), evenness (E) and richness (R) of dominant cadaverous arthropod orders associated with slaughtered juvenile pig carcasses at different stages of decomposition.

	Shaded carcass			**Exposed carcass**		
Stages/Order	**Coleoptera**	**Diptera**	**Hymenoptera**	**Coleoptera**	**Diptera**	**Hymenoptera**
Fresh	0	11	15	5	16	1
Bloated	17	73	197	43	53	32
Active Decay	26	47	151	40	38	15
Advanced Decay	97	59	59	151	47	252
Dry Remain	70	69	241	39	2	139
Total	210	259	663	278	156	439
Shannon (H)	1.185	1.49	1.366	1.247	1.362	1.003
Evenness (E)	0.818	0.888	0.784	0.696	0.781	0.545
Richness (R)	0.561	0.72	0.616	0.711	0.792	0.657

Table 4. Jaccard's similarity index for all sampled and dominant species collected from slaughtered Juvenile pig carcasses exposed/shaded from sunlight.

Description	**All sampled species**	**Dominant species**
/Exposed ∩ Shaded/	11	5
/Exposed U Shaded/	21	9
Jaccard similarity (%)	52.4	55.6

/Exposed ∩ Shaded/ = similar species shared by both carcasses.

/Exposed U Shaded/ = total number of sampled species.

3.3 Abundance, diversity, evenness and richness of dominant insect orders associated with slaughtered juvenile pig carcasses exposed or shaded from sunlight

Three insect Orders; Coleoptera, Diptera and Hymenoptera constituted the dominant species sampled from both carcasses. The abundance for the respective orders of insects were 278, 156 and 439 on carcass exposed to sunlight while the corresponding values on shaded carcass were 210, 259 and 663 (Table 3). Results of diversity indices as shown in Table 3 shows that Dipterans sampled from both carcasses has the highest values of Shannon diversity (H = 1.362 and 1.49), evenness (E = 0.781 and 0.888) and Richness (R = 0.792 and 0.72) for the exposed and shaded carcasses, respectively. Overall, diversity of insects on shaded carcass were > those on exposed carcass. The evenness index generally followed the same trend. Species richness was however generally higher on exposed carcass (Table 3).

3.4 Species similarity

Jaccard's similarity index shows high similarity in arthropod species diversity retrieved from the shaded and exposed carcass as the similarity index were > 50% irrespective of species being considered (all species sampled or dominant species) (Table 4).

3.5 Feeding guild of dominant Insects colonizing slaughtered juvenile pig carcasses

Tables 5 and 6 show the dominant insect species colonizing the exposed and shaded carcasses and their feeding guilds, respectively. As shown in Table 5, the exposed carcass had 6 dominant insect species from 3 orders (Coleoptera - 3, Diptera - 1 and Hymenoptera - 2) colonizing the carcass. Two of the insects are necrophagous (*D. maculatus* and *C. chloropyga*), one primarily

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predaceous (*Zophosis* sp.), another one (*Hister monitor*) both predaceous and saprophagous while the other two which are Hymenopterans were omnivorous in nature as they were found to be primarily predaceous and phytophagous.

Table 5. Feeding guild of dominant insects associated with slaughtered juvenile pig carcass exposed to sunlight.

Order	Family	Genus/Species	Feeding guild
Coleoptera	Histeridae	*Hister monitor*	Predaceous/Saprophagous
	Dermestidae	*D. maculatus*	Necrophagous
	Tenebrionidae	*Zophosis* sp.	Predacious
Diptera	Calliphoridae	*C. chloropyga*	Necrophagous
Hymenoptera	Formicidae	*Crematogaster* sp.	Predaceous/Phytophagous
	Formicidae	*Pheidole* sp.	Predaceous/Phytophagous

The shaded carcass had 8 dominant insects across 3 orders (Coleoptera - 3, Diptera - 2 and Hymenoptera - 3) colonizing it as shown in Table 6. Of the dominant species, two (*D. maculatus* and *C. chloropyga*) are necrophagous, one (*H. monitor*) is both predaceous and saprophagous, and another (*Musca domestica* L.) is saprophagous, coprophagous and necrophagous. The three hymenopteran species (*Anochetus* sp., *C. maculatus* and *Pheidole* sp.) are, however, primarily predaceous and phytophagous.

Table 6. Feeding guild of dominant insects associated with slaughtered juvenile pig carcass shaded from sunlight.

Order	Family	Genus/Species	Feeding guild
Coleoptera	Histeridae	*H. monitor*	Predaceous/Saprophagous
	Dermestidae	*D. maculatus*	Necrophagous
	Tenebrionidae	*Zophosis* sp.	Predacious
Diptera	Calliphoridae	*C. chloropyga*	Necrophagous
	Muscidae	*M. domestica*	Saprophagous/Coprophagous/Necrophagous
Hymenoptera	Formicidae	*C. maculatus*	Predaceous/Phytophagous
	Formicidae	*Anochetus* sp.	Predaceous/Phytophagous
	Formicidae	*Pheidole* sp.	Predaceous/Phytophagous

3.6 Physical characteristics of decomposition of exposed and shaded slaughtered juvenile pig carcasses.

Table 7 shows that the fresh, bloated and active-decay stages occurred within 3 days with each stage taking place in a successive day. The advanced-decay stage lasted the longest (6 days) while the dry remain stage lasted for 5 days before gradual disintegration of the dry skin into soil particles was observed. In contrast, that of the shaded carcass as shown in Table 8 indicates that the fresh, bloated and active-decay stages also lasted one day each while the advanced-decay and dry remain stages took 3 and 8 days respectively before a gradual disintegration of the dry skin into soil particles.

Table 7. Physical characteristics of slaughtered juvenile pig carcass exposed to sunlight at the decomposition stages.

Stages of decomposition	Period (days)	Sampling time	Physical changes	Odor presence and intensity	Dominant species
Fresh (day 0 - 1)	1	2.00 pm - 6.00 pm	Soft torsos and flexible limbs	None	*H. monitor and C. chloropyga*
Bloated (day 2)	1	2.00 pm - 6.00 pm	Inflation of abdomen and blue-green changing of body color	Present but not intense	*Hister monitor, D. maculatus, Zophosis* sp., *C. chloropyga and Crematogaster* sp.
Active decay (day 3)	1	2.00 pm - 6.00 pm	Bursting of the abdomen to expose intestinal tissues, deflation of the body, gradual peeling of the skin.	Present and intense	*Hister monitor, D. maculatus, Zophosis*sp., *C. chloropyga and Crematogaster* sp.
Advanced decay (day 4 - 9)	6	2.00 pm - 6.00 pm	Loss of soft tissues, exposure of ribs, extensive peeling of skin, skin getting drier	Present but not intense	*Hister monitor, D. maculatus, Zophosis* sp., *C. chloropyga, Crematogaster* sp. *and Pheidole* sp.
Dry remain (day 10 - 14)	5	2.00 pm - 6.00 pm	No moisture on skin, skin very dry	None	*Hister monitor, D. maculatus, Zophosis* sp., *Crematogaster* sp. *and Pheidole* sp.

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Table 8. Physical characteristics of slaughtered juvenile pig carcass shaded from sunlight at the decomposition stages.

Stages of decomposition	Period (days)	Sampling time	Physical changes	Odor presence and intensity	Dominant species
Fresh (day 0 - 1)	1	2.00 pm - 6.00 pm	Soft torsos and flexible limbs	None	*C. chloropyga and Anochetus* sp.
Bloated (day 2)	1	2.00 pm - 6.00 pm	Inflation of abdomen and blue-green changing of body color	Present but not intense	*H. monitor, D. maculatus, C. chloropyga, M. domestica, Anochetus* sp*. and C. maculatus*
Active decay (day 3)	1	2.00 pm - 6.00 pm	Bursting of the abdomen to expose intestinal tissues, deflation of the body, gradual peeling of the skin.	Present and intense	*H. monitor, D. maculatus, C. chloropyga, M. domestica, Anochetus* sp*., C. maculatus and Pheidole* sp.
Advanced decay (day 4 - 6)	3	2.00 pm - 6.00 pm	Loss of soft tissues, exposure of ribs, extensive peeling of skin, skin getting drier	Present and intense	*H. monitor, D. maculatus, C. chloropyga, M. domestica, Anochetus*sp*., C. maculatus and Pheidole* sp.
Dry remain (day 7 - 14)	8	2.00 pm - 6.00 pm	No moisture on skin, skin very dry	None	*H. monitor, D. maculatus, C. chloropyga, Anochetus* sp*., and Pheidole* sp.

4. Discussion

Five distinct decomposition stages on adult pig models and their associated arthropods have been reported in literature (Barton, Archer, Quaggiotto, & Wallman, 2019; Maisonhaute & Forbes, 2021; Ojianwuna et al., 2019; Timothy et al., 2022). The period of each decomposition stage as well as the associated cadaverous entomofauna have also been reported to be affected by factors such as geographical area, climate, body mass, cause of death among others. The decomposition of the carcasses (shaded and exposed) used for this study lasted for 14 days which is in a reasonable range for low body mass carcasses (Griffiths et al., 2020; Timothy et al., 2022; Viana et al., 2022). At the fresh stages of decomposition which lasted 0 – 1 day for both carcasses, the exposed carcass was colonized by insects from 5 families; Histeridae, Dermestidae, Calliphoridae, Muscidae and Formicidae while the shaded carcass was colonized by insects from 2 families; Calliphoridae and Formicidae. The presence of dipterans (Calliphoridae and Muscidea) as well as hymenopterans (Formicidae) at this stage buttresses the findings of Tembe and Mukaratirwa (2021). who reported sampling dipterans (largely Calliphoridae and Muscidae) and Ekanem & Dike (2010) who largely retrieved formicid hymenopterans at the fresh stage of decomposition. That more species colonized the exposed carcass at this stage may be attributed to the ease of visualization and accessibility by the insects as contrasted with the shaded carcass which may not have been as initially visible to the insects even though it was equally accessible. Both carcasses at this stage of decomposition had flexible limbs, soft torsos with no odor present as was also reported by Kelly, Van der Linde, & Anderson (2011) and Tembe & Mukaratirwa (2021).

The bloated stage for both carcasses was observed on day 2, corroborating the report of Barton et al. (2019) and also lasted only for the second day. At this stage both carcasses were slightly inflated, turned slightly blue-green especially at the abdominal region and had foul odors, which supports documented findings on the physical characteristic of carcasses at this stage of decomposition (Ojianwuna et al., 2019; Taleb, Tail, & Açıkgöz, 2017; Tembe & Mukaratirwa, 2021). Dominant insects colonizing both carcasses at this stage were from 3 orders: Coleoptera – Histeridae, Dermestidae and Tenebrionidae; Diptera – Calliphoridae and Muscidae; and Hymenoptera – Formicidae. Of interest is the fact that among the Formicidae family colonizing both carcasses, while *Crematogaster* sp. colonized the exposed carcass all through the decomposition stages, *Anochetus* sp. colonized the shaded carcass in the same manner. Although the activities of these ant species on pig carcasses have been documented (Bonacci, Zetto Brandmayr, Brandmayr, Vercillo, & Porcelli, 2011; Viana et al., 2022), their colonization of the respective carcasses which is hardly reported in this manner may be attributed to the proximity of their nests from the carcasses as *Anochetus* sp. was found to have nested on the tree serving as a shade for the colonized carcass. The observed increase in colonizing species at the boated stage vis-à-vis the fresh stage can be attributed to the presence of odor exhumed by the carcasses, as odor has been reported to play a vital role in the attraction of necrophagous insects (Timothy et al., 2022 Verheggen et al., 2017).

The active-decay stage for both carcasses was observed on the 3rd and also lasted for that day only. This contradicts reported findings of 5 - 10 days (Ojianwuna et al., 2019; Maisonhaute &

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Forbes, 2021), and 7 - 12 days (Joseph, Mathew, Sathyan, & Vargheese, 2011). However, while our observation fairly agrees with the average of 2.33 days reported by Viana et al. (2022), it corroborates the reports of Griffiths et al. (2020) for carrion decomposition in tropical regions. Disparities in the period of occurrence of this stage can be largely attributed to body mass of the carcasses we used as well as differences in climatic and biogeographic factors. Supporting the report of Comstock, Desaulniers, LeBlanc, and Forbes (2015) the active-decay stage of both carcasses was characterized with bursting of the abdomen resulting to deflation of the carcass, intense putrefaction odor, massive maggot activities, slight peeling of the skin and massive invasion of cadaverous arthropods. Dominant arthropod families sampled from both carcasses at this stage included; Histeridae, Dermestidae, Tenebrionidae, Calliphoridae, Muscidae, and Formicidae (for exposed carcass). The aforementioned arthropod families, araenaens inclusive, were retrieved from the shaded carcass. Similar observations have been reported by Joseph et al. (2011), Griffiths et al. (2020) and Viana et al. (2022).

For both the shaded and exposed carcasses, the advanced-decay stage commenced on the 4th day. This stage lasted till day – 6 in the shaded carcass and till day – 9 in the exposed carcass. Observed differences in period length between the carcasses (exposed and shaded) might be attributed to differences in sun intensity to which the carcasses were exposed to. High sun intensity on the exposed carcass was also observed to have suppressed the abundance of visiting insects and the resulting rate of deterioration of the carcass due to reduced larval activities as the arthropods obviously avoided the upper portion of the carcass during the day but congregated underneath. Early commencement of this stage buttresses the findings of Griffiths et al. (2020) for carrion decomposition in tropical regions. Physical characteristics of the carcasses at this stage also agrees with the report of Tembe and Mukaratirwa (2021). who observed massive peeling of skin, loss of soft tissues, gradual drying of the skin and reduced odor intensity. Although both carcasses shared similar physical characteristics, the odor intensity in the shaded carcass at this stage was more intense. This may be attributed to higher aeration of the exposed carcass vis-à-vis the shaded. Dominant insect families associated with the carcasses at this stage include: Histeridae, Dermestidae, Tenebrionidae, Calliphoridae, Muscidae and Formicidae. Similar colonization of carrion by these insect families have been documented (Joseph et al., 2011; Matuszewski, Konwerski, Frątczak, & Szafałowicz., 2014; Viana et al., 2022).

The dry remain stage which was characterized by dry skin and relatively no odor for both carcasses was observed from day 10 - 14 for the exposed carcass and day 7 - 14 for the shaded carcass. Longer dry remain stage for the shaded carcass may also be attributed to sunlight intensity which is higher on the exposed carcass leading to its reduced dry remain period than in the shaded carcass. Dominant families associated with both carcasses at this stage were Histeridae, Dermestidae, Tenebrionidae, Calliphoridae and Formicidae. Consistency in represented dominant families for most of the decomposition stages can be attributed largely to the rapid decomposition of the carcasses favored by their relatively low body mass and the tropical climatic condition.

5. Conclusion

We observed that the dominant insect species colonizing the carcasses were *C. chloropyga*, *M. domestica* and *D. maculatus* (necrophagous), *Zophosis* sp. (predominantly predaceous), and *H. monitor*, *Anochetus* sp., *Crematogaster* sp. and *Pheidole* sp. (largely omnivorous). While it took 14 days for both carcasses to complete decomposition, the exposed carcass had a longer advanced-decay stage while the shaded carcass had a longer dry remain stage. Over 50% similarity exists between total sampled species from both carcasses. Little distinction exists on the succession pattern of invading carrion arthropods. This work will be helpful in estimating PMI for juvenile human remains and also provide information on the associated insects which could be useful for criminal investigations.

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Conflict of Interest

The authors do not report any financial or personal connections with anyone.

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Ethical Approval

At the time of the study, there was no ethical committee in relation to animal use in research in the Federal University Wukari, Nigeria. However, all the principles of 3Rs of the Guidance on the Operation of the Animals (Scientific Procedures) Act 1986 were observed.

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