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Insect diversity and succession pattern on different carrion types

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ABSTRACT:

Insect fauna attracted on four different types of carrion; beef, chicken, pork, and fish were conducted in a cassava growing field on the campus of the University of Ghana for a period of twenty-eight days between February and March, 2005. Four stages of decomposition were recognized; fresh, bloated, decay and dry. A total of 19 insect species belonging to five orders and thirteen families were recorded. Coleoptera represented 23% of the total number of species. Diptera and Hymenoptera constituted 35% and 41% respectively while Collembola and Heteroptera a mere 1% of the insect orders that dominated the carrion fauna. Caliphoridae were the first to arrive on all four types of carrion. Five species of Histeridae, three of Formicidae and one each from Dermestidae, Scarabaeidae, Cleridae, Mycetophagidae, Scolytidae were recorded on beef, chicken, pork and fish. Representatives of four Dipteran families; Calliphoridae, Muscidae, Sarcophagidae and Tachinidae were also recorded. One species each of the families Pyrrhocoridae and Isotomidae were unique to pork and chicken respectively.

Keywords:
Insect diversity, succession pattern, carrion, decomposition, forensic entomology, Ghana.

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INTRODUCTION

Decomposing carrion supports a wide diversity of several organisms, many of which are insects. Although a decomposing carcass is a temporary, rapidly changing resource (Grassberger and Frank, 2004), it can support a large, dynamic insect community. Apart from ecological interest, carrion decomposition and succession studies have proven important in forensic entomology. When the sequence of insects colonising carrion is known, an analysis of the arthropod fauna on a carcass can be used to determine time since death in legal investigations (Anderson and van Laerhoven, 1996). In addition, if an insect can be found exclusively in a rural or urban habitat, analysis of the carrion associated fauna may help to determine whether the remains have been moved from an urban to a rural environment or vice versa (Erzinclioglu, 1983; Catts and Haskell, 1990; Grassberger and Frank, 2004)

It is known that insects are usually the first organisms to arrive on a body after death, and they colonise in a predictable sequence. The body progresses through a recognised sequence of decomposition stages, from fresh to skeletal, over time (Peters, 2003). Each of these stages of decomposition is attractive to a different group of sarcosaprophagous arthropods, primarily insects (Anderson and van Laerhoven, 1996). The occurrence of the insects forms a succession of colonising species which are eliminated as carrion decay progresses. Succession is the idea that as each organism or group of organisms feeds on the body, the corpse changes thereby making it more attractive to another group of organisms (Goff and Flynn, 1991). The first generation of initial colonizers can provide a biological clock that more precisely measures the time of death for up to two or more weeks; medical examiner's estimates are limited to about a day or two (Greenberg and Kunich, 2002; Peters, 2003).

The nature and time of the insects succession depends on several factors including the size of the carrion, seasonal and climatic conditions, and the surrounding non-biological environment, such as soil type (Snodgrass, 1967; Erzinclioglu, 1983; Carvalho and Linhares, 2001). The organisms involved in the succession vary according to whether they are upon or within the carrion, in the substrate immediately below the carrion or in the soil at an intermediate distance below or away from the carrion and finally the kind of carrion (Gullan and Cranston, 2010). This stems from the fact that carrion of different animals have different fat and muscle composition that affect the pattern and length of decomposition. Furthermore, each succession will comprise of different species in different geographic areas, even in places with similar weather factors. This is because few species are very widespread in distribution and each biogeographic area will have its own specialist carrion fauna. Blow flies are the most common dipterans seen in abundance around carcasses, which serve as oviposition sites and larval food sources. Adult flies are attracted to the carrion until it is nearly dry, but other species visit the carcasses only during specific stages of decomposition; thus a succession of species can be observed (Goddard and Lago, 1985).

According to Gullan and Cranston (2010) during decomposition, the first wave of insects involves certain blowflies (Diptera: Calliphoridae) and house flies (Diptera: Muscidae) that arrive within hours or few days at the most. The second wave is of flesh flies (Diptera: Sarcophagidae) with additional house flies and blowflies that follow shortly thereafter, as the carrion develops an odour. All these flies either lay eggs or oviposit on the carrion. At this stage blowfly activity ceases as their larvae leave the carrion and pupate in the ground. When the fat of the carrion turns rancid, a third wave of species enter this modified substrate, notably more dipterans, such as Phoridae, Drosophilidae and Syrphidae (especially *Eristalis* sp., the rat-tailed maggots) in the liquid parts. As the carrion becomes butyric, a fourth wave of Diptera, Piophilidae and related

Table 1 Insect orders, families and species from Carrion

Order	Family	Species	Chicken	Beef	Pork	Fish
Coleoptera	Cleridae	*Necrobia rufipes*	29	44	0	5
Coleoptera	Dermestidae	*Dermestes frischii*	46	37	20	83
Coleoptera	Histeridae	*Carcinops pumilio*	52	0	0	26
Coleoptera	Histeridae	*Gnathoncus* sp.	0	0	0	21
Coleoptera	Histeridae	*Hister* sp.	0	0	16	18
Coleoptera	Histeridae	*Platysoma carolinus*	45	38	0	0
Coleoptera	Histeridae	*Teratosoma* sp.	0	0	0	32
Coleoptera	Mycetophgidae	*Typhaea stercorea*	0	0	0	6
Coleoptera	Scarabaeidae	*Geotrupes* sp.	0	0	0	14
Coleoptera	Scolytidae	*Xyleborus* sp.	35	0	0	0
Collembola	Isotomidae	*Isotoma* sp.	18	0	0	0
Diptera	Caliphoridae	*Lucilia rufifacies*	55	86	48	88
Diptera	Muscidae	*Musca domestica*	81	99	73	84
Diptera	Saracophagidae	*Sarcophaga* sp.	56	62	35	52
Diptera	Tachinidae	*Tachinid* sp.	18	37	0	11
Heteroptera	Pyrrhocoridae	*Dysdercus superstitious*	0	0	9	0
Hymenoptera	Formicidae	*Oecophylla longinoda*	183	159	0	498
Hymenoptera	Formicidae	*Monomorium* sp.	86	0	0	0
Hymenoptera	Formicidae	*Solenopsis xyloni*	0	0	0	75
Total			704	542	211	1013

flies also eat the body. A fifth wave occurs as the ammonic smelling carrion dries out, adult and larvae of Dermestidae and Cleridae (Coleoptera) become abundant, feeding on the keratin. In the final stage of dry decay, some Tineid larvae (clothes moths) feed on the remnant hair. The rather predictable sequence of colonisation and extinction of carrion insects allows forensic entomologist to estimate the age of corpse, which can have medico-legal application in homicide investigation. Differences in decomposition of carrion in relation to biogeography and ecology of necrophagous insect communities have been the subject of several field studies. However, most of these studies have used single animal species (Bornemissza, 1957; Arnaldos *et al.*, 2001; Grassberger and Frank, 2004). Forensic entomology research is nascent in Ghana and as such no work on decomposition and insect attractions have been done. The data obtained from this study will therefore provide basic information regarding carrion decomposition fauna of this area. The objective of this work therefore was to evaluate the attractiveness of four carrion types to insects and the species diversity and succession pattern of the insects.

MATERIALS AND METHOD

Study site

The study was conducted on a crop farm growing cassava on the campus of the University of Ghana, Legon (05º39′ N, 000º11′W). Legon is located in the coastal savanna vegetation belt of Ghana. The annual rainfall ranges from 740-890 mm. Relative humidity is however high (60%-75%) throughout the year and thus compensates for the scanty annual rainfall. There are two rainfall maxima but the dry seasons are more marked (Hall and Swaine, 1981).

Carrion placement

A kilogram each of four carrion types was used; namely, pork, beef, chicken and fish. The fresh meat and fish were obtained from a local abattoir and the market respectively. These carrion were placed separately in rectangular wire cages (size: 23 x 23 x 90 cm; mesh sizes: 1 cm x 1 cm) to prevent dogs, rodents and other vertebrates from eating them. The four cages were placed on the ground in a crop farm on the campus of the University of Ghana, Legon. The cages were so placed to facilitate the entry of both crawling and flying insects to access the carrion through the wire mesh. The cages

Table 2 Total number of orders, families, species and insects collected during the study.

Carrion	Order	No. of families	No. of species	Total no. of insects
Fish	Coleoptera	5	8	205
	Diptera	4	4	235
	Hymenoptera	1	2	573
Chicken	Coleoptera	4	5	207
	Diptera	4	4	210
	Hymenoptera	1	2	269
	Collembola	1	1	18
Beef	Coleoptera	3	3	119
	Diptera	4	4	264
	Hymenoptera	1	1	159
Pork	Coleoptera	2	2	36
	Diptera	3	3	156
	Heteroptera	1	1	9

were separated 10 m apart to avoid the same insects moving from one cage to other.

Care was taken to protect the data collectors from any pathogens, pollutants or contaminants by wearing protective clothing. Sign posts warning passersby about the potential hazards of the experiment were erected at three locations, about five metres from the experimental set-up.

Adult and developing immature insects were carefully collected with a sweep net, forceps gloved hands and camel hair brush twice daily at 6:00 AM and 5:00 PM for 28 days. Adult beetles and flies were killed in an ethyl acetate kill jar. Pupae collected from soil were placed into empty vials, while larvae were put in 70% alcohol. These were returned to the laboratory for further processing. Soil samples of about 300 g were also collected from beneath each of the carrion and taken to the laboratory for any possible insect emergence. Temperature and relative humidity were recorded with Tinytag datalogger (Gemini Dataloggers, UK). Detection of gasses given off during decay was done by testing for SO_2, NH_3, CO_2 and H_2S.

RESULTS

Five insect orders; Coleoptera, Diptera, Hymenoptera, Collembola and Heteroptera were recorded on the four carrion types. The most diverse order was Coleoptera as several insects recorded belonged to six families of this order (Table 1) with five of the insect species collected belonging to the family Histeridae. *Oecophylla longinoda* (Hymenoptera: Formicidae) was the most abundant insect on all carrion types except pork. In all, the fish carrion attracted the highest number of insects (1013), followed by chicken (704), with pork attracting the least number of insects (211) (Table 1).

Insect diversity was highest on fish with fourteen species from ten families followed by chicken with twelve species from ten families and then beef with eight species from eight families (Table 2). Pork attracted the lowest diversity of five species from five families. The most abundant insects were the Hymenoptera with over 1000 individuals followed by Diptera with more than 800 individuals (Table 2). Rare insects collected were from the orders Collembola and Heteroptera on chicken and pork carrion respectively.

The fish carrion consistently attracted the highest insect numbers throughout the four-week period (Table 3). Chicken also attracted higher numbers of insect from first to third week than were recorded on beef, but lower numbers were attracted to chicken than to the beef in the fourth week. There were no insect records for pork in the third and fourth week because it was taken away by an unidentified animal.

Fig-1 shows the number of insects collected daily during the time of decomposition for each carrion type. Varied amounts of insects were collected on the carrion types throughout the 28 days the study lasted. The initial numbers of colonizing insects decreased on the second day but the most drastic reduction occurred on chicken, decreasing by about 79%. The numbers increased on the third and fourth days for all carrion reaching 86 and 104

Fig 1 Chronology of total insects attracted to the carrion types

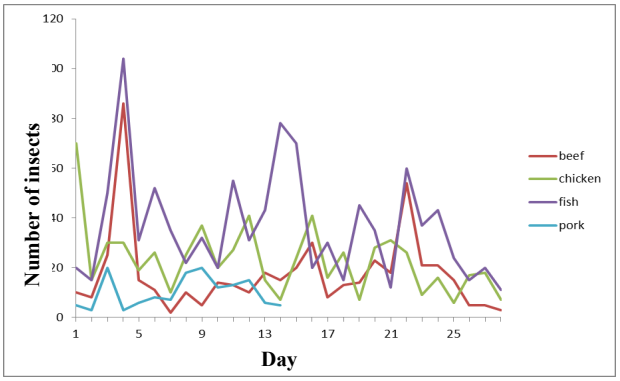

Table 3 Total number of insects attracted weekly by various carrion types

Carrion	Week 1	Week 2	Week 3	Week 4
Fish	337	223	243	210
Chicken	230	187	183	99
Beef	187	100	141	114
Pork	97	104	-	-

for beef and fish respectively. The numbers again fluctuated until day 22 before decreasing gradually to the end of the study.

DISCUSSION

Decomposition

Throughout the period of study all the four carrion types were observed to follow the normal pattern of decomposition as seen in most carrion decomposition studies. These were divided into four stages as fresh, bloated, decay and dry (Reed, 1958; Tantawi *et al.*, 1996). The decomposition stages are a convenient means to summarize physicochemical changes; they are subjective and do not typically represent discrete series (Schoenly and Reid, 1987). The carrion stayed fresh for about a day or two and several insects, mainly calliphoridae, were attracted to all of them (Galal *et al.*, 2009). Usually, fresh stage begins at the moment of death and continues until bloating is first evident. During this stage the process of autolysis; the breakdown of complex proteins and carbohydrate molecules to simpler chemical compounds (Gill-King, 1997) primarily due to the action of digestive enzymes or ferments occurs (Smith, 1986). Neither gross morphological changes nor odour of the decay was detected in the fish, chicken, beef and pork at this stage.

The bloated stage, which lasted for about a week, commenced with the onset of noticeable swellings on the carrion and ended when they deflated. Putrefaction, the principal component of decomposition process, began at this stage. The first visible signs of the bloating were observed in the fish; chicken and beef showed slight inflation due to buildup of gasses from the metabolic activities of anaerobic bacteria. The pork did not bloat due probably to the part that was used for the experiment.

The decay stage began with the detection of gases especially carbon dioxide, ammonia and hydrogen sulphide. The carrion deflated and cracks were observed in the fish, chicken and beef carrion in one or more places by feeding dipterous larvae. The stage ended when most of the remnants were relatively dry (Reed, 1958). The dry stage was the final stage of decomposition. The carrion at this stage consisted of only dry skin, cartilage, and bones. Odour was typically of dried animal skin.

Insect Succession

The resource-driven selection of the decomposer community was repeatedly observed as the insect succession associated with carrion decomposition on the soil surface (Carter *et al.*, 2007) As reported in most arthropod succession studies on carrion (Reed, 1958; Payne, 1965; Coe, 1978; Abell *et al.*, 1982; Anderson and van Laerhoven, 1996; Tantawi *et al.*, 1996); the three insect orders, Diptera, Coleoptera, and Hymenoptera, dominated the carrion communities in the present study as well. The house flies and the blow flies were the first to arrive on all four carrion types just within hours of the set up (Gullan and Cranston, 2010). They dominated the carrion for the first three days. The second wave was of Sarcophagids and the muscids and calliphorids that followed shortly thereafter as the carrion

started to develop odours. The Tachinids (Diptera) appeared on the 2nd, 3rd and the 4th days on the chicken, fish and the beef respectively and kept revisiting up to the ninth day on all three carrion while there were few on the pork. The low numbers of insects on the pork may have been due to the fact that the part used (pig feet) was not comparatively succulent and fleshy and did not have much body fluids to attract and allow oviposition by these dipterans. All the flies either laid eggs or oviposited on the carrion (Gullan and Cranston, 2010). The larvae later left the carrion especially the chicken and the fish and pupated in the ground.

As the ammonia smell from the fish, chicken and the beef minimized, coleopteran adults and larvae, mainly Dermestids and Clerids, became abundant from the second week onwards feeding on the keratin and the maggots. A single clerid species belonging to the genus *Necrobia* was recovered from the fish, beef and chicken carrion. Adults were observed to feed on dipteran larvae as well as on carrion (Braack, 1987). The pork experienced slow decay possibly due to its high fat content that melted slowly down the whole carrion in the scotching sun. The flies and ants that attempted to feed on the pork carrion were trapped by the sticky nature of the melting fat and subsequently died.

In the fourth week, the final stage of dry decay was observed; the larvae and adult of the beetle families, Scarabaeidae, Histeridae and Dermestidae and Scolytidae were abundant on the fish, beef and the chicken. *Oecophylla longinoda* (Hymenoptera: Formicidae) however made short the work of the fish. They were mainly attracted by the abundance of maggots. The beetles and ants dominated the carrion especially the fish.

Insect Abundance

During the first week of the set-up, the fish carrion attracted the highest number of insects dominated by the Dipterans, the first insect order to normally invade carrion. This was probably due to the high water content as well as the freshness and also the strong odour emitted by the rotten fish. A drop of about 33% (114 insects) was observed in the second week and increased slightly to 243 insects in the third week. This was attributed to the fact that some of the flies had laid their eggs or l oviposited and left. Also, the beetles that appeared afterwards may have fed on the larvae of the flies (Nuorteva, 1970). The invasion of the carrion by *O. longinoda* was also a major contributory factor to fluctuation in the insect population. They dominated in the third week because there was an abundance of food i.e. maggots and larvae of flies and beetles. This food resource was depleting by the fourth week and so lower insect numbers were recorded on the fish carrion.

Insect composition recorded on the chicken in the first week was dominated by flies (Dipterans) due to the tenderness and the strong odour of the chicken carrion. Concomitantly, blow flies (Calliphoridae) and flesh flies (Sarcophagidae) colonize carrion to find a suitable site for the development of their offspring (Carter *et al*., 2007). The insect population dropped slightly in the second week and remained constant throughout the third week. It was observed that, the tender nature of the chicken was conserved due to a downpour in the later part of the second week. This was helpful in retaining much of the water content thereby constantly attracting the flies to the carrion. In the fourth week, the insect population dropped sharply to 99 insects when the chicken started drying up and at this stage it attracted a new wave of insect fauna mainly the Coleopterans and the Formicids. This is consistent with (Wasti's 1972) study on arthropod succession patterns.

The total number of insects attracted to the beef carrion lagged behind those of fish and chicken, with the singular exception of the fourth week. The pork did not experience much decay due to its hard skin and high content of fat. Houseflies and blowflies were the most abundant in the first six days. The *Dermestes frischii* and the *Hister* sp., became predominant from the seventh day

throughout the second week. However the cage was destroyed and the carrion was taken away by an unknown animal after the second week.

Comparing the four types of carrion, fish recorded the highest number of insects during the period of study. This number was dominated by *O. longinoda*. Chicken carrion followed in terms of insect abundance, and then beef and pork in that order. This order of insect abundance was observed to be related to tenderness and water content of the carrion. This is due to the fact that water content is highest in the fish which increases attraction of insects especially flies, and also because it gives off strong odour during the bloated stage. The stinking liquid that seeped out also attracted more crawling insects. On the other hand, a lower number of insects are attracted to the carrion when the water content is quite low. Diptera, Coleoptera and Hymenoptera dominated the carrion fauna. This is consistent with most of the previous studies on carrion decomposition (Rodriguez and Bass, 1983; Anderson and van Laerhoven, 1996). Coleoptera represented 23% of the total number of species. Diptera and Hymenoptera represented 35% and 41% respectively while Collembola and Heteroptera constituted a mere 1%. Of all the insect fauna, Hymenoptera belonging to the family Formicidae and to a lesser extent Sarcophagidae, along with other Diptera larvae, Dermestid and Histerid beetles were mainly responsible for soft tissue decomposing in all the carrion with the exception of the pork.

CONCLUSION

The four carrion types attracted diverse insect species; in all, insects belonging to five orders and thirteen families were recorded. Most of the insect fauna attracted belonged to Diptera, Hymenoptera and Coleoptera. Decomposition of different carrion followed the normal stages and succession of insects changed as the quantity and resource quality of the carrion types changed over time.

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