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Influence of the ecological zone on the necrophagous insects' activities involved in the process of decomposition of pig carcasses (*Sus scrofa domesticus* L.) exposed to the open air in the sub-sudanese zone of Côte d'Ivoire

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Abstract
The colonization of a corpse by insects and its degradation are two interrelated phenomena. These are influenced by many intrinsic and extrinsic factors to corpses. The most important factor is the biogeo-climatic zone, where the body is found. Its accessibility to insects can influence the cadaverous rate of decomposition. The objective of this work is to highlight the influence of the habitat type on the insects' activities in the process of decomposition of a corpse exposed to the open environment. This work took place in Korhogo, a town in the north of Côte d'Ivoire. Twelve pigs' carcass weighing 50 kg were used as bait in cages, exposing them in sunny and shady site. The follow-up of the corpses was carried out during 119 days. The necrophagous insects were collected from the cadavers and identified with the determination key. A total of 6872 specimens were collected of which 86.9% belong to the Diptera order and 13.1% to the Coleoptera order. On the sunny site, 3858 individuals of Diptera whether 60.65% belonging to 13 species and 3 families and on the shady site 2114 individuals whether 35.40% belonging to 11 species, were harvested. The *Chrysomya albiceps* was more abundant on the sunny site than on the shady site. The beetles collected on the sunny and shady sites were respectively 608 specimens whether 67.57% belonging to 7 species and 4 families and 292 specimens whether 32.44% belonging to 6 species and 4 families. The *Dermestes maculatus* was more abundant on the sunny site than on the shady site. Throughout the period of the experiment, the carcasses of the sunny and shady sites were respectively degraded by insects at 85.40% and 70.97%. At the end of this study, we noticed that the sunny site was richer in individuals than in species than the shady site. Exposed pig carcasses break down 1.20 times faster at the sunny site than at the shady site during the dry season in the sub-sudanese zone of Côte d'Ivoire.

Keywords: corpse, decomposition, necrophagous, insects, ecology, dry season

1. Introduction
The degradation of a body and its colonization by insects are two interrelated phenomena. These are influenced by many intrinsic and extrinsic factors to cadavers (Wells and LaMotte 1995, Campobasso *et al*., 2001) [1, 2]. Intrinsic factors, directly related to the deceased, are age, body mass, cause of death (drugs, infection, etc.), body hygiene, body integrity (injuries, wounds), and presence of clothing (Campobasso *et al*., 2001) [2]. Among the external factors, the most important factor is the biogeoclimatic zone including habitat, vegetation, soil type and weather conditions (temperature, wind, atmospheric humidity, sunshine intensity) of the place where the body remains (Anderson 2001, Campobasso *et al*., 2001) [3, 2]. The location of the body on a shady or sunny site and its accessibility to insects or scavengers (domestic or wild) (Anderson 2001, Campobasso *et al*., 2001) [3, 2] can influence cadaverous decomposition rate. In Côte d'Ivoire, the work done by Koffi *et al*. (2017) [4] in the Guinean zone, have shown a significant loss of cadaveric body mass, mainly due to the activity of necrophagous insects. But no work relating to the influence of the type of environment in which the body is exposed to the activity of the insects involved in the decomposition process has ever been realized. The aim of this work was to highlight the influence of the place of exposure, on the activity of necrophagous insects involved in the decomposition process of exposed cadavers, in the open environment.

2. Material and methods
2.1 Study site
The work was carried out in Korhogo, a town located in the northern region (Sub-sudanese zone) of Côte d'Ivoire, from December 1, 2017 to March 31, 2018. This locality is characterized by savannah vegetation and gallery forest. Two sites, shady and sunny, were chosen respectively at the Peleforo Gon Coulibaly University's Botanic Garden (9°26 'N

- 5°38' W, altitude 380 m) and at Lataha (9°33 'N - 5°34' W; altitude 377 m), a village in Korhogo region. The shady site was characterized by the presence of trees and shrubs. As for the sunny site, it was characterized by shrub savannah vegetation with fields of cashew trees nearby. As the bird flight, the two sites are distant from each other by 15 km (Fig. 1).

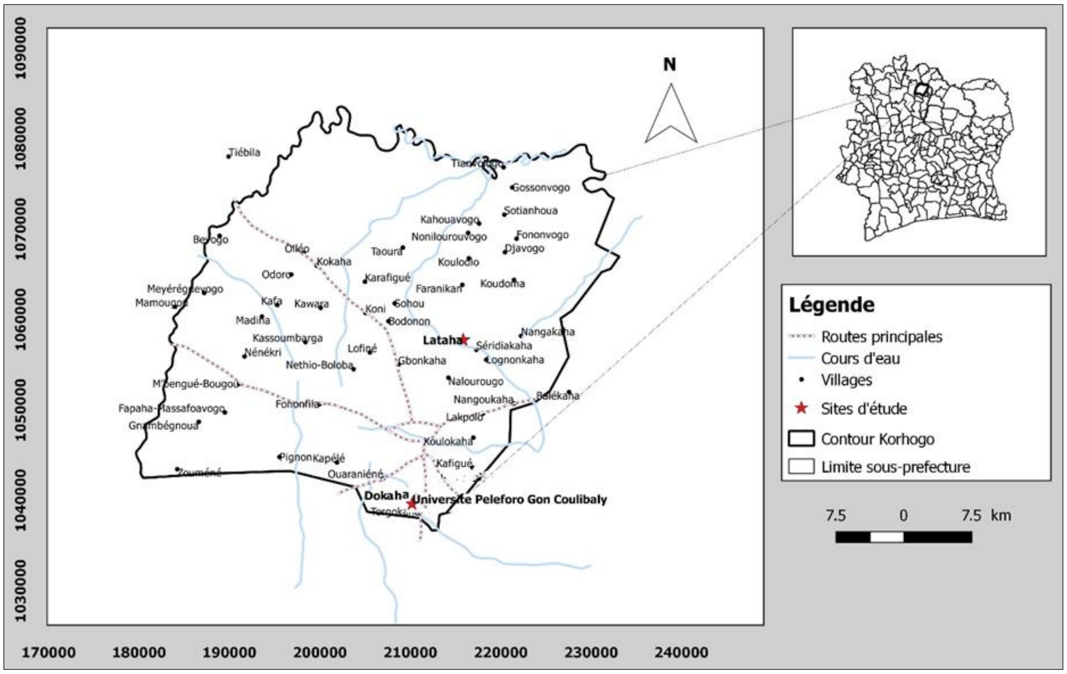

Fig 1: Study Sites

2.2 Meteorological data

The temperature and relative humidity data were obtained using thermo-hygrometer recorder IHM-172 SI. The exposure of the cadavers was carried out under ambient conditions during the dry season (December 1, 2017 to March 31, 2018). On each site the thermo-hygrometer and the rain gauge were used. The thermo-hygrometer automatically recorded temperature and relative humidity.

2.3 Methods

2.3.1 Experimental apparatus

The experimental setup consisted of two types of cages (Ge and Gt), spring balance, pulley, rope, net and gallows. The cage Gt or control device had a shape of right block of dimension Length = 1.5 m, width = 0.80 m and height = 0.70 m. This iron device, was entirely covered with a very fine mesh stainless mesh gate (0.20 mm of side) preventing any insect from accessing the corpse. The cage Ge had the same dimensions as that of the corpse witness but it was covered with a stainless mesh grid (3 cm of side). This device gave access to all groups of insects associated with corpses. These two cages protected exposed corpses against various scavengers (Fig. 2) (Koffi *et al*., 2017) [4].

Fig 2: Different cages for the protection of the pig corpses A: Cage Gt on the sunny site; B: Cage Ge on the sunny site; C: Cage Gt on the shady site; D: Ge Cage on the shady site; a: Fine mesh grid (0.2 mm), b: Large mesh grid (3 cm).

2.3.2 Harvesting and identification of necrophagous insects
The necrophagous insects involved in the decomposition process, from the early hours to the skeletonization stage, were directly harvested from the pig carcasses. Flying insects were captured using a sweeper net and larvae and adult of beetle using soft grapper. Insects harvesting were also done using pitfall-traps. Larvae and pupae were also harvested on or near decomposing corpses. These harvested and breeded in the laboratory at room temperature. The imagos emerged in this breeding allow to confirm the period of the various insects trapped activity. A few larvae, nymphs and all adults of beetle harvested were kept in labeled pill containers containing alcohol 70°. As for the adults of Diptera, they were kept in khaki wrappers. The insects were harvested only from the test cadavers. Manual harvesting and trap surveys were conducted every two days between 7:00 am and 10:30 am. After emergence, the imagos obtained were put to death using ether and then distributed by family. They were identified using binocular loupe and identification keys up to the taxonomic level of the species (Wyss and Cherix, 2006, Whitworth, 2010, Szpila and Villet, 2011; Szpila, 2014 and Irish *et al.*, 2014, Rochefort *et al.*, 2015, Vairo *et al.*, 2015, Alikhan *et al.*, 2016) [5, 6, 7, 8, 9, 10, 11, 12].

2.3.3 Weighing pigs
Twelve pigs of 50 kg each one were used as bait at the rate of 6 individuals per site. The pigs were transported alive to the study sites. They were tranquilized with a sedative and then euthanized considering the ethical aspect. Inside the cages, each corpse was placed on a mesh net (2 cm) to make easy the weighings. Weekly weighings of pig carcasses were carried out every Tuesday between 7:30 am and 9:30 am. The contribution of necrophagous insects was evaluated from the initial loss of body mass observed during the decomposition process. The cumulative rate (Tc) of initial loss of body mass, for a given post mortem interval Jf, is obtained from the following formula:

$$Tc = \frac{\mathbf{Mi - Mf}}{\mathbf{Mi}} \times \mathbf{100}$$

- Tc (Jf): represents the cumulative rate of body mass loss (%) for a given post-mortem interval (IPM) Jf;
- Mi (Kg): represents the initial body weight of the pig cadaver just before slaughter,
- Mf (Jf) (Kg): represents the final mass corresponding to a given post mortem interval (IPM) Jf.

The corrected rate (Tcc) of initial body mass loss was calculated using Abbott's (1925) [13] formula:

$$Tcc\ (\%) = \frac{\mathbf{Tce - Tct}}{\mathbf{100 - Tct}} \times \mathbf{100}$$

Tcc: Corrected rate of body mass loss
Tct: Body mass lost by the control cadaver
Tce: Body mass lost by the test cadaver

2.4 Data processing
The processing of the data for the different species and the two study sites was carried out using software Statistica version 7.1. A one-way variance analysis (ANOVA) followed by the Newman Keuls test at the 5% threshold showed the homogeneity of the samples.

3. Results and discussion
3.1 Results
3.1.1 Necrophagous insects involved in the process of decomposition of cadaver exposed on sunny and shady site in the dry season
The insects collected at the two sites numbered 6872 individuals. Of these, 5972 were Diptera, representing 86.91% of all trapped insects and 900 were beetles, accounting for 13.09% of all insects collected at both sites (Fig. 3). In Diptera, a total of 3644 individuals whether 61.02% and 2328 individuals whether 38.98% respectively came from the sunny site and the shady site (Figure 4). Regarding the beetles, a total of 608 individuals, whether 67.57% were collected on the sunny site, while 292 individuals, whether 32.44%, were captured on the shady site (Fig. 5). At the Diptera, the Calliphoridae was the most abundant. It had an average of 3092.65 ± 153.69 individuals at the sunny site, representing 68.57% of all individuals in this family on both sites, while on the shady site, 1417.63 ± 63.22 individuals whether 31.43% of all individuals in this family at both sites. The ANOVA test followed by the Newman-Keuls separation test at the 5% threshold ($F = 101.5904$, ddl = 1, $P < 0.001$) indicated a significant difference in the mean numbers of specimens of this family, sites (Table 1). At the beetles, Dermestidae was the most abundant. It represents an average of 311.67 ± 51.38 individuals at the sunny site, whether 81.97% of all individuals of this family at both sites, whereas at the shaded site, 68.55 ± 4.61 individuals. That is 18.03% of all individuals in this family at both sites. The ANOVA test followed by the Newman-Keuls separation test at the 5% threshold ($F = 22.2068$, ddl = 1, $P < 0.01$) indicated a significant difference in the mean number of individuals of this family, on sites (Table 2).

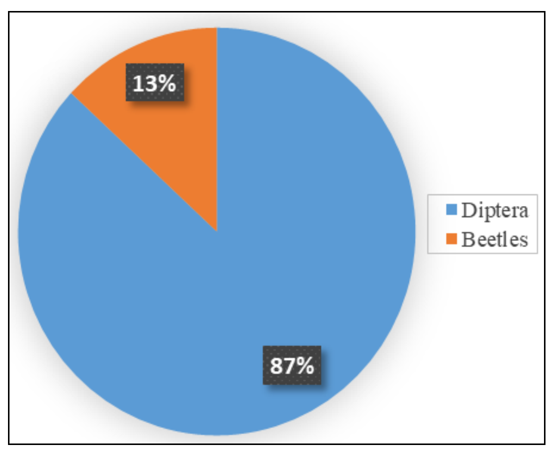

Fig 3: Abundance of insect orders collected at both sites

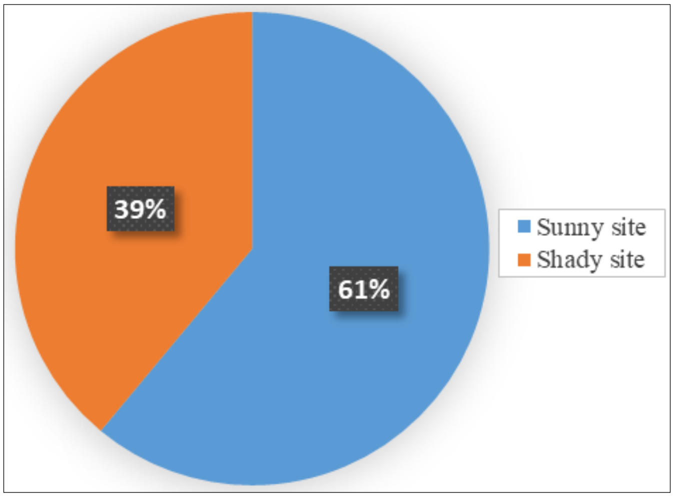

Fig 4: Abundance of Diptera at sunny and shady site

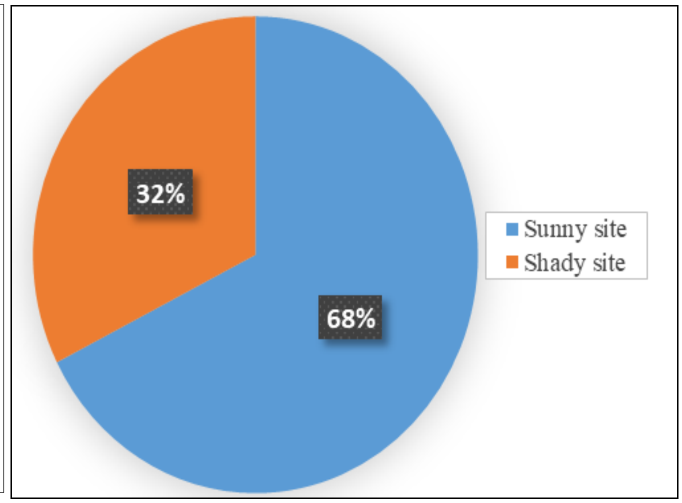

Fig 5: Abundance of beetles on sunny and shady site

Table 1: Relative abundance of necrophagous Dipteran's families harvested on pig carcasses at both sites

	Sunny site		Shady site	
Families	Average number	Ar (%)	Average number	Ar (%)
Calliphoridae	3092.65 ± 153.69^a	68.57	1417.63 ± 63.22^b	31.43
Muscidae	333.66 ± 19.05^a	40.14	497.66 ± 57.73^a	59.86
Sarcophagidae	431.98 ± 17.89^a	68.46	198.99 ± 56.58^b	31.54

NB: The figures followed by the same letter on one line are not significantly different according to the Newman Keuls test at the 5% threshold.

Table 2: Relative abundance of necrophagous beetle's families harvested on pig carcasses at both sites

	Sunny site		Shady site	
Families	Average number	Ar (%)	Average number	Ar (%)
Histeridae	224.67 ± 52.92^a	74.23	78.00 ± 9.02^b	25.77
Cleridae	66.67 ± 5.77^a	45.98	78.33 ± 5.77^a	54.02
Dermestidae	311.67 ± 51.38^a	81.97	68.55 ± 4.61^b	18.03
Tenebrionidae	5.00 ± 1.15^a	88.18	0.67 ± 0.57^b	11.82

NB: The figures followed by the same letter on one line are not significantly different according to the Newman Keuls test at the 5% threshold.

3.1.1.1 Necrophagous Diptera

In this study, only species listed with their larvae on cadavers were considered as species that actually contributed to the cadaverous decomposition process. Diptera were divided into three families, namely Calliphoridae, Muscidae and Sarcophagidae. However, species (*Piophila casei* and *Hermetia illucens*) belonging respectively to the families Piophilidae and Stratiomyidae were harvested with the traps, but none of their larvae were found on the carcasses during the whole period of the decomposition of corpses exposed to the open air. The species of the Calliphoridae found on cadavers at the two study sites were eight: *Chrysomya megacephala*, *Chrysomya marginalis*, *Chrysomya albiceps*, *Chrysomya putoria*, *Lucilia sericata*, *Calliphora vomitoria*, *Lucilia caesar* and *Protophormia terraenovae*. On the sunny site, the most abundant species in Calliphoridae was *C. albiceps* with an average number of 1671.00 ± 48.05 individuals representing 66.37% of all individuals of this species at both sites. On the shady site, it showed 846.66 ± 58.01 individuals whether 33.63% of all individuals of this species at both sites. The ANOVA test followed by the Newman-Keuls separation test at the 5% threshold ($F = 119.745$, ddl = 1, $P < 0.001$) indicated a significant difference in the mean numbers of *C. albiceps* individuals at both sites (Table 3). The least abundant was *C. vomitoria* with an average number of 28.33 ± 2.84 individuals, whether 72.03% of all individuals of this species at both sites. On the shady site, this species presented 11.00 ± 2.08 individuals whether 27.97% of all individuals of this species at both sites. The ANOVA test followed by the Newman-Keuls separation test at the 5% threshold ($F = 24.1428$, ddl = 1, $P < 0.01$) indicated a significant difference in the average numbers of *C. vomitoria* individuals. at the sites (Table 3). *Musca domestica* was the only species of the Muscidae family. On the sunny site, it showed an average of 333.66 ± 56.33 individuals, whether 4.14% of all individuals of this specie at both sites, while on the shady site, it presented a mean of 497.66 ± 39.07, whether 59.86% of all individuals of this specie at both sites. The ANOVA test followed by the Newman-Keuls separation test at the 5% threshold (F = 5.7219, ddl = 1, P > 0.05) did not indicate any significant difference between the mean numbers of individuals of *M. domestica*, at both sites (Table 3). As for the Sarcophagidae family, it has presented four (4) species: *Sarcophaga carnaria*, *Sarcophaga africa*, *Sarcophaga haemorrhoidalis* and *Wohlfahrtia nuba*. *Sarcophaga carnaria* was the most abundant specie of this family. The individuals of this specie were more numerous on the sunny site with an average of 295.66 ± 27.36 individuals whether 66.69% of all the individuals of the species on both sites. On the shady site, it had an average of 147.66 ± 18.55, whether 33.31% of all individuals of this species at both sites. The ANOVA test followed by the Newman-Keuls separation test at the 5% threshold (F = 20.0484, ddl = 1, P < 0.05) indicated a significant difference between the mean numbers of individuals of *Sarcophaga carnaria,* on both sites (Table 3). *Wohlfahrtia nuba* was the least abundant specie among the Sarcophagidae family. It was found only on the sunny site with an average of 17.00 ± 2.0 individuals whether 100%. The ANOVA test followed by the Newman-Keuls separation test at the 5% threshold (F = 66.6923, dd1 = 1, P < 0.001) indicated a significant difference between the mean numbers of this specie on both sites (Table 3). *Sarcophaga haemorrhoidalis* was also harvested only from the sunny site. It had an average strength of 32.66 ± 2.40 whether 100%. The ANOVA test followed by the Newman-Keuls separation test at the 5% threshold (F = 184.692, dd1 = 1, P < 0.001) indicated a significant difference between the mean numbers of this specie on both sites (Table 3).

Table 3: Relative Abundance of necrophagous Diptera species harvested from a pig cadaver Exposed to the sunny and shady site

		Sunny site		Shady site	
Families	**Species**	**Average number**	**Ar (%)**	**Average number**	**Ar (%)**
Calliphoridae	*Chrysomya megacephala*	501.00 ± 34.70^{a}	89.52	58.66 ± 2.73^{b}	10.48
	Chrysomya marginalis	250.33 ± 8.98^{a}	87.53	35.66 ± 3.48^{b}	12.47
	Chrysomya albiceps	1671.00 ± 48.05^{a}	66.37	846.66 ± 58.01^{b}	33.63
	Chrysomya putoria	134.33 ± 6.17^{a}	54.61	111.66 ± 1.20^{b}	45.39
	Lucilia sericata	131.66 ± 16.47^{a}	77.91	37.33 ± 2.40^{b}	22.09
	Calliphora vomitoria	28.33 ± 2,84^{a}	72.03	11.00 ± 2.08^{b}	27.97
	Lucilia ceasar	233.00 ± 45,57^{a}	74.6	79.33 ± 9.84^{b}	25.4
	Protophormia terrhanovae	143.00 ± 10.69^{b}	37.6	237.33 ± 32.21^{a}	62.4
Muscidae	*Musca domestica*	333.66 ± 56.33^{a}	40.14	497.66 ± 39.07^{a}	59.86
Sarcophagidae	*Sarcophaga carnaria*	295.66 ± 27.35^{a}	66.69	147.66 ± 18.55^{b}	33.31
	Sarcophaga africa	86.66 ± 2.18^{a}	62.8	51.33 ± 3.18^{b}	37.2
	Wohlfahrtia nuba	17.00 ± 2.08^{a}	100	0.00 ± 0.00^{b}	0
	Sarcophaga haerrhomoidalis	32.66 ± 2.40^{a}	100	0.00 ± 0.00^{b}	0

NB: The figures followed by the same letter on one line are not significantly different according to the Newman Keuls test at the 5% threshold.

3.1.1.2 Necrophagous beetles

On both sites (sunny and shady), harvested Coleoptera were divided into 4 families, namely, those of Histeridae, Cleridae, Dermestidae and Tenebrionidae. Six (6) and seven (7) species, distributed among these 4 families, were harvested respectively on the shady site and on the sunny site. *Margarinotus brunneus* was the most abundant species among Histeridae species. It was more abundant on the sunny site with an average of 155.66 ± 35.41 individuals whether 78.09% of all individuals of this species at both sites. On the shady site, it had an average size of 43.66 ± 4.70 individuals, whether 21.91% of all individuals of this species at both sites. The ANOVA test followed by the Newman-Keuls separation test at the 5% threshold (F = 9.8315, ddl = 1, P < 0.05) indicated a significant difference between the mean numbers of this specie on both sites (Table 4). The least abundant specie among Histeridae was *H. quadrinotatus*. It was found only on the sunny site with an average of 0.66 ± 0.66 individuals, whether 100% of all individuals of this specie at both sites. The ANOVA test followed by the Newman-Keuls separation test at the 5% threshold (F = 1.00, ddl = 1, P > 0.05) did not indicate any significant difference in mean numbers of this specie on both sites (Table 4). The families of Cleridae, Dermestidae and Tenebrionidae were each represented by a single species. On the sunny site, the Cleridae family was presented by *N. rufipes* with an average of 66.66 ± 14.07 individuals whether 45.98% of all individuals of this specie at both sites. On the shady site, it showed an average of 78.33 ± 7.68, whether 54.02% of all individuals of this specie at both sites. The ANOVA test followed by the Newman-Keuls separation test at the 5% threshold (F = 0.5291, dl = 1, P > 0.05) did not indicate any significant difference in mean numbers of this specie on both sites (Table 4). *Dermestes maculatus*, a specie of the Dermestidae family, had an average of 311.66 ± 43.55 individuals at the sunny site, representing 68.55% of all individuals of this specie at both sites. On the shady site, it had an average of 143.00 ± 31.77 individuals whether 31.45%

of all individuals of this specie at both sites. The ANOVA test followed by the Newman-Keuls separation test at the 5% threshold (F = 9.7891, dl = 1, P <0.05) indicated a significant difference in mean numbers of this species in both species. sites (Table 4).

Tenebrio molitor, a specie belonging to the family of Tenebrionidae, has an average number of 5.00 ± 1.15 individuals whether 88.24% of all individuals of this specie at both sites. On the shady site, an average of 0.66 ± 0.66 individuals, whether 11.76% of all individuals of this specie harvested at both sites. The ANOVA test followed by the Newman-Keuls separation test at the 5% threshold (F = 10.5625, ddl = 1, P < 0.05) indicated a significant difference in average numbers of this specie on both sites (Table 4).

Table 4: Relative abundance of necrophagous beetles' species harvested on the pig carcasses exposed in two sites

		Sunny site		Shady site	
Families	**Species**	**Average number**	**Ar (%)**	**Average number**	**Ar (%)**
Histeridae	*Margarinotus brunneus*	155.66 ± 35.41^a	78.09	43.66 ± 4.70^b	21.91
	Hister cadaverinus	30.00 ± 3.78^a	59.21	20.66 ± 1.45^a	40.79
	Pachylister inaequalis	38.33 ± 1.76^a	73.72	13.66 ± 0.88^b	26.28
	Hister quadrinotatus	0.66 ± 0.66^a	100	0.00 ± 0.00^b	0
Cleridae	*Necrobia rufipes*	66.66 ± 14.07^a	45.98	78.33 ± 7.68^a	54.02
Dermestidae	*Dermestes maculatus*	311.66 ± 43.55^a	68.55	143.00 ± 31.77^b	31.45
Tenebrionidae	*Tenebrio molitor*	5.00 ± 1.15^a	88.24	0.66 ± 0.66^b	11.76

NB: The figures followed by the same letter in one line are not significantly different according to the Newman-Keuls test at the 5% threshold.

3.1.2 Contribution of insects in the decomposition process

The monitoring and weighing of the pig carcasses exposed to the sunny air, made it possible to highlight the period of activity of the various groups of insects. Figure 8 shows the cumulative rate of initial body mass loss as a function of the post-mortem interval. Curves (a) and (b) represent the body mass loss rates of the test cadavers and the curves (c) and (d), the rates of body mass loss of the control cadavers. The curve (a) corresponds to the accessible corpse from the sunny site and the curve (b) to that of the shady site. From D1 to D7 post-mortem, the corrected cumulative mass loss rate of the test cadavers increases exponentially, from 0 to 37% for corpses of the sunny site, and from 0 to 25.32% for those on the shady site (Fig. 6).

This decomposition phase constituted the active decomposition stage with a high activity of the Diptera larvae. On the sunny site, between D7 and D56 post-mortem, the cumulative rate of mass loss of the test cadavers (mummification) increased very slowly and increased from 37 to 49.63%. In the same interval, that of the accessible corpses (desiccation) of the shady site, ranged from 25.32 to 41.02%. In the sunny and shady sites, between D56 and D112 post-mortem, the cumulative rates of mass loss of test cadavers gradually increased from 49.63 to 84.45% and from 41.02 to 68.89% respectively. In this interval, it has been possible to observe a resumption of the decomposition corresponding to the advanced decomposition. At this stage, a large number of Dermestidae larvae were observed within cadaveric dry matter. In the evolution of body mass loss, a stationary phase was observed between D112 and D119 post-mortem. On the sunny and shady sites, the mass loss rates of the test cadavers were virtually unchanged, rising from 84.45 to 85.40% and 68.89 and 70.97%, respectively (Fig. 6).

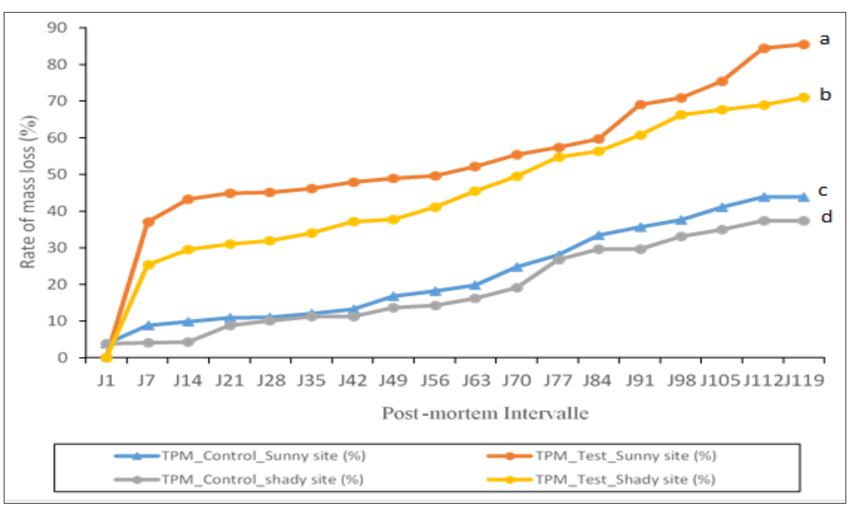

Fig 6: Evolution of corrected cumulative rates of body mass loss of pigs' cadavers on sunny and shady site

3.1.3 Process of decomposition of corpses

Table 3: involvement of insects in the decomposition process of pig carcasses at the both study sites

PMI	Shady site	Sunny site	Stage of the corpse	Insects activities
J0 01/12/2017			- Fresh cadaver - No odor is felt at the corpses of both sites	Presence of some adult members: Families of Muscidae and Calliphoridae (Diptera)
J1 02/12/2017			- Beginning of swelling of the corpse in the shady site; - Maximum swelling of the corpse in the open site Perception of cadaverous odor.	Presence of adults of Calliphoridae, Muscidae and Sarcophagidae, Presence of clusters of eggs on the hidden faces of corpses
J3 03/12/2017			- Maximum swelling of the corpse in the shady site; - Rupture of the corpse abdomen in the open site followed by active decomposition	Presence of large numbers of stage 1, 2 and 3 larvae of Diptera and Coleopterans' adult of Histeridae and Cleridae on the corpse in the open site; Presence of Larvae (L1) on the shady site
J7 07/12/2017			- Active decomposition of corpses - Dehydration of corpses - Presence of cadaverous odor - Blackening of the skin of the corpses of both sites	Presence of Diptera pupae on both sites and some Diptera stage 2 and 3 larvae in the shady site; Presence of Dermestidae, Histeridae adults and their larvae
J20 20/12/2017			- Partial mummification of the corpse in the shady site; - Dry rot of the corpse in the open site; - Detachment of hair; Appearance of the bones of the skull	Absolute absence of Diptera larvae on the corpses in the two sites; Presence of Dermestidae, Cleridae, and Histeridae Adult
J50 19/01/2018			- Beginning of the advanced decomposition of the corpses in the two sites	Presence of Dermestidae, Histeridae Adult and a considerable number of Dermestidae larvae
J80 20/02/2018			- Advanced decomposition of corpses; - Degradation of dried skin; - Appearance of the bones of the head and legs	Presence of Dermestidae Adult, Presence in considerable numbers of this specie larvae
J119 31/03/2018			- Partial skeletonization of the body of the shady site and total of the corpse in the open site; - Appearance of the bones at 85.40% of the corpse of the open site and 70.97% of the corpse in the shady site	Presence in considerable numbers of Dermestidae larvae and some adult members of this family

4. Discussion

The insects collected during our work were divided into two orders: the Diptera and Coleoptera. Diptera were divided into three families and Coleoptera into four families. In the Diptera, the Calliphoridae was represented by eight (8) species: *C. marginalis, C. megacephala, C. albiceps, C. putoria, P. terranova, C. vomitoria, L. sericata* and *L. caesar*.

Muscidae was presented by one specie, *M. domestica,* while Sarcophagidae was presented by four species: *S. carnaria, S. africa, W. nuba and S. haemorrhoidalis*. Of all the Diptera harvested, *C. albiceps* was the most abundant specie at both study sites. These results are followed similar trends as those described in other research (Carvalho *et al*. 2001; Souza *et al*. 2008; Biavati *et al*. 2010; and Faria *et al*. 2013) [14, 15, 16, 17]. Moreover, at both sites, the test cadavers experienced a significant loss of body mass in the first week post mortem. This loss of body mass was more pronounced at the sunny site. But the loss of mass obtained during our works were inferior of those of Nazni *et al*. (2011) [18], who studied the action of entomological fauna on monkey cadavers placed in an open and closed environment in Malaysia and Koffi *et al*. (2017) [4] who conducted work on the loss of body mass of pig carcasses exposed in the Guinean zone of Côte d'Ivoire. The early colonization of corpses by the species of the three families of Diptera in general, and by those of Calliphoridae in particular, would be due to their powerful chemotactile reception device, allowing them to locate a cadaver at many tens of meters. A similar observation was made by Charabidze and Bourel (2007) [19] during their work on forensic entomology. These results are also consistent with those of Picimbon (2002) [20] who says that in these flies, the sensilli specific to a molecule or a family of chemical molecules, function as peripheral microsensors odor molecules of the environment. The presence of these insects on the corpses would be related to the search for food and place of lay. This argument is similar to that of Archer *et al*. (2003) [21], whom distinguished two categories of necrophagous Diptera: the first concerns individuals in search of food and the second relates to females in search of laying place, the latter being largely in the majority. The corpses exposed on the shady site were colonized much later than those exposed on the sunny site. This would be due to the vegetation cover that would hinder the diffusion of cadaverous odors over long distances. On the sunny site, from the first three days' post-mortem, beetles belonging to various families, began to appear on the corpses. On the shady site, they appeared on corpses from the 7th day post-mortem. This apparition on the corpses would be due at the fat rancidity of exposed corpses. The activity of the maggots would cause the decomposition and the total transformation of the tests corpses. Six phases of decomposition were observed, namely, fresh cadaver stages, swelling, active decomposition, dry putrefaction, advanced decomposition and skeletonization. These observations are similar to those of Payne (1965) [22], who also noted six stages of decomposition of corpses exposed to insect action, namely, fresh putrefaction, swelling, active putrefaction, advanced putrefaction, dry putrefaction and remain. However, they are different from that of Anderson and Van Laerhoven (1996), Galloway (1997) and Goff (2009) [23, 24, 25], who distinguished 5 stages of decomposition that are: the initial stage or fresh cadaver, swelling, active decomposition, advanced decomposition and skeletonization. This difference would be due to low relative humidity and no rain. After the 7th post-mortem day, the corpses of the sunny site had dried up. The desiccation of corpses is also due to the low relative humidity, the absence of rain and the high intensity of the sun on this site. This desiccation caused early death of Diptera larvae due to lack of cadaveric liquids. On the shady site, the Diptera larvae were able to complete their development cycle because they would have been protected from the sun's rays. The canopy has therefore favored their survival. The desiccation of the bodies, observed on the sunny site, was later observed on the shady site. The decomposition of the cadaverous dry matter was under the action of Dermestidae larvae which are fond of dry matter. On both sites, these larvae grew in considerable numbers on the corpses, but they were more abundant on the corpses of the sunny site. During this study, the Stratiomyidae (Diptera) and Piophilidae (Diptera) were not observed on the carcasses of both site. On the other hand, in the southern forest of Côte d'Ivoire, Koffi *et al*. (2017) [4] observed a large abundance of individuals (larvae and adults) of these two Diptera families at the advanced decomposition stage on the pig carcasses exposed in open-air. The absence of the species of these two Diptera families on cadavers of the sunny and shady sites, could be explained by the poor quality of the bait. This poor quality of the bait would be unfavorable to the good development of their larvae. This argumentation joins that of Koffi *et al*. (2018) [26] who found that the quality of the bait influenced the necrophagous Diptera population dynamics. On the sunny site, the decomposition of corpses was very fast. This could be explained by the fact that the insects were particularly numerous on this site. The fact that this site is open and subject to strong sunstroke, had to favor the abundance of the first Diptera. This argumentation followed similar trends as those described by (Charabidze *et al*. 2012) [27]. On the other hand, on the shady site, the insects were relatively few. This could be explained by the fact that the abundance of vegetation cover would limit the diffusion of cadaverous odors. In addition, the location of this shady site in a highly anthropized zone could be at the origin of the low presence of necrophagous insects.

5. Conclusion

The work carried out on sunny and shady sites in Korhogo. Two orders of necrophagous insects, Diptera and Coleoptera were collected. Among the Diptera, the family Calliphoridae was the most abundant in general and especially on the sunny site. In the case of Coleoptera, the Dermestidae family was the most abundant. This abundance was obtained on the sunny site. The species C. *albiceps* and *D. maculatus* were the most abundant species respectively of the Diptera and Coleoptera order. The sunny site was richer in species and in specimens than the shady site. The significant loss of body mass of the pig carcasses exposed resulted to the abundance of necrophagous insects' specimens at the sunny site. Exposed pig carcasses decomposed 1.20 times faster on the sunny site than on the shady site during the dry season in the sub-sudanese zone. This study revealed that in the dry season, when a cadaver is exposed in the open air, it is broken down into six phases which are fresh corpse stage, swelling, active decomposition, dry putrefaction, advanced decomposition and skeletonization. These different stages were observed at the cadavers of both study sites but at different post-mortem intervals. The active decomposition phase was caused by Calliphoridae (Diptera) Muscidae (Diptera) and Sarcophagidae (Diptera) larvae from the first week post-mortem. During this period, the large thermal amplitudes caused the death of several Diptera larvae, which facilitated the slowdown of the active decomposition on the sunny site. This desiccation of pig carcasses was accentuated by the low relative humidity values and the absence of precipitation at the study sites. Forty-two days after the dry rot, larvae of the Dermestidae (Coleoptera) began to consume cadaverous dry matter causing an advanced decomposition which continued until skeletonization of carcasses on the 119th post-mortem day.

In the context of an entomological expertise to date a death, during the discovery of a corpse, the most commonly used method today is that which is based on the development cycle of the necrophagous Diptera found on the corpse. Since the latter are largely involved in the recycling of organic matter into the ecosystem, post mortem interval (PMI) estimation cannot be totally separated from cadaver decay. As a result, the condition of the corpse, in relation to the loss of body mass, may well help to establish a chronology of death, especially if the victim was known by people who could portray him during his lifetime. The cadaverous state of putrefaction and the insect species collected must be correlated with the environmental conditions of the exposure site and all the factors that may influence the decomposition of the cadaver and the development of the insects, which could help the medical entomologists in the criminal entomology expertise.

6. Declaration of interests

The authors declare that they have no conflicts of interest in relation to this article.

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