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Successive waves of dipteran flies attracted to warfarin-intoxicated rabbit carcasses in Cairo, Egypt

Alaa Abd El-Gawad[1], Rawda M. Badawy[2], Marah M. Abd El-Bar[2*] and Mohamed A. Kenawy[2]

Abstract

Background: Forensic entomology is an increasing area of research, focuses on the violent crime, and deals with the necrophagous-feeding insects that typically decompose carcasses. The present study aimed to update the baseline data of the decay process and its associated successive waves of necrophagous flies on rabbits placed in an urban city (Cairo, Egypt) in spring season.

Results: Six rabbits divided equally into two groups were used. The first group was killed by asphyxia via hanging and marked as the control (C), while the second group was intoxicated with rodenticide warfarin (WI). The fresh, bloated, active decay, advanced decay, and skeletal stages of decomposition were observed and defined in all carcasses. Out of 30 insect families collected, 3 families were more common (Calliphoridae, Muscidae, and Sarcophagidae). Thirteen insect families were collected of which Calliphoridae, Muscidae, and Sarcophagidae were common. A total of 10,121 individuals (immature and adult stages) of 26 species were collected, of which *Chrysomya rufifacies* was the most common species on both types of carcasses (14.7%) followed by *Musca domestica*, *Chrysomya megacephala*, *Chrysomya albiceps*, *Muscina stabulans*, *Sarcophaga hertipes*, *Calliphora vicina*, *Musca sorbens*, *Lucilia cuprina*, *Sarcophaga argyrostoma*, and *Lucilia sericata* (2.0–12.4%). The other 15 species were represented by small numbers (cumulatively 2.9%). Among the collected flies, *Scathophaga litorea* (Scathophagidae) was reported for the first time as a new report in Egypt. Unexpectedly, significantly more adults and immatures were attracted to WI than to C carcasses ($P < 0.05$).

Conclusion: This study investigated the rabbit carrion dipteran necrophagous fauna as a model which may be of value for medico-legal cases.

Keywords: Forensic entomology, Entomotoxicology, Warfarin, Rabbit carcasses, Fly succession, Egypt

Background

Forensic entomology is an increasing area of research, including an entomologist's expertise comprising insect identification, life cycles, and habitats, with an enforcement of arm of law (Byrd & Castner, 2010; Guppy, 2001; Varatharajan, 2000). The Medico-legal "Medico-criminal"-forensic entomology focuses on the violent crime and deals with the necrophagous-feeding insects that normally crowd on human remains (Anderson, 1997; Dadour, Cook, & Wirth, 2001; Guppy, 2001). It relates to death investigations mainly determination of the interval time between the discovery of a body and its death and which is generally referred to as the "post-mortem interval, PMI" which is the primary purpose of forensic entomology today.

- Animal carcasses are demoralized with a plentiful complex of insects/arthropods. The main insects that colonize a body to forage, live, or reproduce are from orders Diptera (the flies), Coleoptera (beetles), the ants, and Hymenoptera (bees and wasps) (Benecke, 2001; Goff, 2000) depending on their biological favorites and on the body decomposition state. Such insects, together with bacteria, are the drivers of the decay process in the lack of vertebrate

* Correspondence: marah_elnaggar@sci.asu.edu.eg; Marah_elnaggar@yahoo.com
[2]Department of Entomology, Faculty of Science, Ain Shams University, Abbassyia, 11566 El-Khalifa El-Maamoun St, Cairo, Egypt
Full list of author information is available at the end of the article

scavengers (Coe, 1978). The five stages of body decomposition have been of prime interest for scientists over a long period of time, and each phase is accompanied by a certain grouping of insects.

- The standard classification of Sarcosaprophagous fauna allocates them into five distinctive ecological groups: necrophagous (carrion-feeder), necrophilous, omnivorous, opportunists, and accidentals (Goff, 2000). The necrophagous are those species which forage exactly on the body. Necrophagous insects (primarily Diptera and Coleoptera) come within minutes of death. The most important arthropods are necrophagous, necrophilous, and omnivorous arthropods for forensic studies, in general (Arnaldos, Garcia, Romera, Presa, & Luna, 2005).

Certain factors such as temperature, wind, rainfall, and geographical locality affect the decay process, faunal composition, succession, and the developmental time of insects. Hence, when native climatologically data are available, the consequence of inhabiting fauna can be used to detect the PMI (Horenstein, Rosso, & Garcia, 2012).

In Egypt, few studies (Abd EL-Bar & Sawaby, 2011; Abd EL-Bar, Sawaby, EL-Hamouly, & Hamdy, 2016; EL-Kady, Essa, & Shalaby, 1994a; Tantawi, EL Kady, Greenerg, & EL-Ghaffar, 1996 & Zeariya, Hammad, Fouda, Al-Dali, & Kabadaia, 2015) have been done and dealt with the description of the decomposition process and insect (mainly blow and flesh flies) succession on rabbit carrions killed by various methods.

Warfarin is a rodenticide which initially used as an oral anticoagulant to prevent thrombosis in 1948, and it was approved in Egypt in 1954 (Holbrook et al., 2005). The present study was planned to update and document the baseline data of the decay process and its associated flies for warfarin-intoxicated rabbits placed in an urban city (Cairo, Egypt).

Materials and methods

The study site

The study was conducted during the spring (April 24–May 13 of the year 2016) at the roof of the Faculty of Science, in the campus of Ain Shams University, which is located in Abbassyia (Fig. 1), Cairo Governorate, Egypt (30° 3′ 54.03′′ N, 31° 16′ 18.16′′ E). The elevation of the study site is about 18 m above the ground level, about 48.50 m above the sea level, and covered area of about 53 m^2.

Environmental data

Since the carrion decomposition and insect activity are influenced by temperature, humidity, and rainfall, these were daily recorded at the study area. Maximum temperatures ranged from 28 to 43 °C, minimum temperatures ranged from 16 to 23 °C, and relative humidity ranged from 20 to 55%. It rained only once on the 2nd day of the experiment.

Experimental animal

The European rabbit (*Oryctolagus cuniculus* Linnaeus, 1758) was chosen as a good surrogate model to mimic the decomposition of a human cadaver. Six healthy mature domestic rabbits in weight of 1.5 kg for each and different in colors were used in this study. They divided into two groups each of three rabbits. Each of the six rabbits was used as replicate and represented a killing method (Asphyxia via hanging as a control group and Poisoning by the oral administration of the rodenticide, Warfarin as the intoxicated group). This experiment was carried out under the guidance of the Ethics Committee of the Faculty of Science, Ain Shams University.

The administration of the toxin into the rabbits

The anticoagulant "warfarin" (coumadin, 4-hydroxy-3-(3-oxo-1-phenyl butyl) coumarin; 4-hydroxy-3-(3-oxo-1-phenyl butyl)-2H-1-benzopyran-2-one) was used for the intoxication of tested rabbits. The fundamental mode of action is the inhibition of the synthesis of vitamin k-dependent clotting factors.

Each test rabbit was administrated 50 mg of warfarin per kilogram. The injection was carried out orally via a gastric tube using xylocaine according to ethical criteria and by using water during the obligate feeding to facilitate the gulp of the toxin.

Experimental design

After confirmation of killing and death occurrence, the carcasses were transferred directly to the study site and kept in wooden framed cages (50 cm^3) covered with stainless steel wire mesh (1 × 1 cm) to be guarded against scavengers. A rigid steel mesh gauge was chosen to allow insect access, prevent scavenger access, and not produce too much shade. Each carcass was placed inside a separate labeled cage. The opening of each cage was on the one side to facilitate accessing, inspecting, and taking the rabbit carcass out. Each cage was placed at approximately 1 m apart from one another to stimulate an isolated resource for insects inhabiting each carcass (Velásquez, 2008). The sand was placed under each cage to facilitate the collection of fly larvae and pupae.

Collection and processing of Diptera specimens

Insect samples of all stages were daily collected from dissimilar areas of the rabbit body and from the sand. Catching devices included spoons for larval masses and sweeping nets for flying adults (about five repetitive trials for sweeping adults at each visit). The collected

Fig. 1 Map showing the location of the study site at Abbassyia, Cairo

adults and larvae were separately kept in labeled plastic vials (labeled by date and carcass case) and transported to the laboratory for counting and identification.

In the laboratory, the collected larvae were kept alive and reared in a jar (0.5 L) (25 larvae per jar) provided with a little damp tissue paper and pieces of rabbit tissues (about 20 gm) for the larvae feeding until adult emergence for a confirmed identification. Netting was held over the top of the jar and fastened with a rubber band to prevent escaping of emerged adults. Identification was carried out according to the keys of Morgulis and Freidberg (2014), Rochefort, Giroux, Savage, and Wheeler (2015), Marshall, Whitworth, and Roscoe (2011), and Falk (2016).

Statistical analysis

Means and standard deviations (SDs) were calculated for all examined attributes and compared with the one-way ANOVA (analysis of variance). In case of 3 variances, when F showed significantly inequality of the means, they were further exposed to pairwise comparison based on Turkey's HSD (honestly significant difference) test.

Fig. 2 Decomposition stages: fresh stage (**a**), bloated stage (**b**), active decay (**c**), advanced decay (**d**), and skeletal stage (**e**)

The SPSS software (Version II) for Windows (SPSS Inc., Chicago, IL, USA) was used for statistical analysis.

Results

Decomposition stages and duration

Five stages of decomposition were detected: fresh, bloated, active decay, advanced decay, and dry or skeletonization (Fig. 2).

Except for the fresh stage which showed similar durations (2 days) for C and WI (Fig. 3), the other decomposition processes were insignificantly faster in WI than in C ($P > 0.05$). Generally, the black rabbit whether C or WI decomposed faster by 2 days for each of bloated, active decay, and advanced decay stages) than the white or black and white rabbits. Similarly, the dry stage of black rabbits started in a shorter period (11 and 9 days for C and WI, respectively) than those of the other rabbits. The overall period elapsed from the beginning of the fresh stage to the beginning of the dry stage was insignificantly shorter ($F = 0.32$, df = 1.4, $P > 0.05$) for WI carcasses (mean ± SD = 12.67 ± 4.61 days) than that of C carcasses (mean ± SD = 14.67 ± 4.51 days).

Succession pattern of dipteran adults and immatures

The intervals for the first and last appearance of adults and immatures on different carcasses were recorded (Table 1) and revealed that adults appeared first at day 2 (fresh stage) on control carcasses and continued till the beginning of the dry stage (from days 12–19). On intoxicated carcasses, they appeared during fresh and bloated stage (from day 2 to day 3) and continued till dry stage (from days 9–16). Immatures appeared during bloated stage (from day 3) and continued till dry stage on control (from days 12–19) and intoxicated carcasses (from days 10–16). In general, adults existed from day 2 and immatures from day 3 till day 19 on control carcasses and till day 16 on intoxicated carcasses.

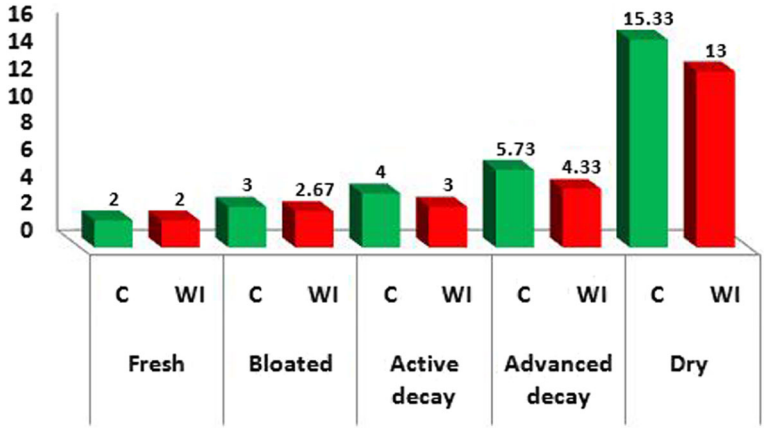

Fig. 3 Mean duration (days) of the different decomposition stages in days for control (**C**) and warfarin-intoxicated (WI) carcasses

Table 1 Day ranges for the appearance of dipteran adults and immatures on control (C) and warfarin-intoxicated (WI) carcasses

Rabbit*		Day of appearance from …. to…. (No.)	
		Adults	Immatures
W	C	Days 2–19 (18)	Days 3–19 (17)
	WI	Days 3–16 (14)	Days 3–16 (14)
B+W	C	Days 3–16 (14)	Days 3–16 (14)
	WI	Days 3–14 (12)	Days 3–14 (12)
B	C	Days 3–12 (10)	Days 3–12 (10)
	WI	Days 3–10 (8)	Days 3–10 (8)
All	C	Days 2–19 (18)	Days 3–19 (17)
	WI	Days 3–16 (14)	Days 3–16 (14)

*White, *B+W* black and white, *B* black, *W* White

Daily collection of dipteran adults and immatures

Based on the total collection of adults and immatures, the mean number per rabbit was calculated and compared for control and intoxicated carcasses. The results (Table 2) indicated that significantly more adults and immatures were attracted to intoxicated carcasses (F (1.4) = 3.82 for immatures and 1.25 for adults) (P ˂ 0.05) than to control carcasses. Also, for only intoxicated carcasses, significantly more adults (P < 0.05) were attracted to black rabbit carcasses than to the other colored rabbits.

Collected dipteran adults and immature during the different decomposition stages

The collected adults and immatures during the different decomposition stages were counted and the comparable percentages were calculated and results are shown in Table 3. In general, for all carcasses (control and intoxicated) more adults and immature of (45.46 and 56.55%, respectively) were collected during the active decay. The overall collections of adults and immatures indicated that more adults (57.17% of 1674) and immatures (74.28% of 8452) were collected on intoxicated carcasses than on control ones (42.83% and 25.72% of adults and immatures, respectively).

Reported dipteran families and species

Thirteen families were collected (Table 4) of which Calliphoridae was the more common family (43.2% for C, 64.5% for WI) than Muscidae (32.3% for C, 30.0% for WI) or Sarcophagidae (22.5% for C, 5.0% or for WI). The other 10 families were represented by small numbers (cumulatively 2% for C and 0.5% for WI). Of the decomposition stages, the active decay attracted more families (all the 13 families for C and the 7 families for WI) than the other stages (0 to 3 families).

A total of 26 species of the 13 families were collected (Table 4), all were collected on control carcasses while 17 species were collected on intoxicated carcasses. The most common species were those of Muscidae, Calliphoridae, and Sarcophagidae. *Sarcophaga hertipes* was the most common species (17.6%) on C while *Chrysomya rufifacies* was the most common species (21. 8%) on WI carcasses. In general, on both types of carcasses, *Chrysomya rufifacies* was the most common species (14.7 %) followed in descending number by *Musca domestica* (12.4%), *Chrysomya megacephala* (11.5%), *Chrysomya albiceps* (11.3%), *Muscina stabulans* (10.1%), *Sarcophaga hertipes* (8.9%), *Calliphora vicina* (8.9%), *Musca sorbens* (7.8%), *Lucilia cuprina* (5.6%), *Sarcophaga argyrostoma* (4.7%), and *Lucilia sericata* (2.0%). The other 15 species were represented by small numbers (cumulatively 2.9% out of 10121 collected fly). *Scathophaga litorea* (F. Scathophagidae) (Fig. 4) was reported for the first time in Egypt.

Discussion

Many studies had been conducted in several parts of the world to detect dipteran species composition on carrions. Most species propagate in decaying materials and dung; other certain species colonize carrions (necrophagous) and play a great role in the decomposition of human/animal matters so they are of forensic importance. This study investigated the rabbit carrion dipteran fauna as a model which may be of worth for medico-legal cases. The decomposition phases of the human body are roughly the same as in non-humans; however, caution is essential in the use of schedules generated by non-human although the good model is used (Catts & Goff, 1992).

Insects reach on a carcass in an expected sequence which is influenced by the decomposition stages. Data of

Table 2 Means ± SDs of daily and total collections of dipteran adults and immatures on control and warfarin-intoxicated carcasses

Rabbit	Adults		Immatures	
	Control	Intoxicated	Control	Intoxicated
White	15.72 ± 10.86	31.86 ± 20.29	71.94 ± 50.35A	237.93 ± 328.00
Black &White	13.80 ± 6.72	17.92 ± 16.68	23.21 ± 14.33B	95.58 ± 109.94
Black	21.09 ± 15.60	37.00 ± 18.97	62.60 ± 82.35A	224.38 ± 127.81
F (df),	1.42 (2,41)	2.94 (2,31)	3.54 (2, 38)	1.39 (2, 31)
Total per rabbit	239.00 ± 40.26	319.00 ± 117.20	724.67 ± 457.06	2091 ± 1121.68

Table 3 Percentages (%) of collected of dipteran adults and immatures during different decomposition stages of rabbit carcasses

No.	Adults			Immatures		
	C (717)	WI (957)	C+ WI (1674)	C (2174)	WI (6278)	C+ WI (8452)
Fresh	0.84	0	0.36	0	0	0
Bloated	25.75	27.9	27.84	39.42	16.20	22.17
Active decay	44.91	45.78	45.46	36.11	63.64	56.55
Advanced decay	25.38	22.99	24.01	22.36	17.01	18.39
Dry	1.95	3.24	2.68	2.12	3.15	2.89

C control carcasses, *WI* warfarin-intoxicated carcasses

the present study pointed out that carcass decays very rapidly (11–19 days and 9–16 days for control and warfarin-intoxicated carcasses, respectively) due to the relatively higher weather temperatures, this means that decomposition rate of carcass is directly proportional to temperature in agreement with the previous observations of Özdemir and Sert (2008), Zeariya et al. (2015), and Abd El-Bar et al. (2016).

Surprisingly, all warfarin-intoxicated carcasses decayed faster than the control ones. This may be due to that the toxin did not mask the odor of the carcasses which is the main attractant factor for invading insects (Abd

Table 4 Checklist of dipteran families and species of control (C) and warfarin-intoxicated (WI) rabbit carcasses

Family	C %	WI %	Species	C		WI		Mean %
				No.	%	No.	%	
Muscidae	32.2	30.0	*Musca domestica* (Linnaeus, 1758)	394	13.5	807	11.2	12.4
			Musca sorbens (Wiedemann, 1830)	146	5.0	756	10.5	7.8
			Muscina stabulans (Fallén, 1817)	358	12.3	562	7.8	10.1
			Stomoxys calcitrans (Linnaeus, 1758)	4	0.1	0	0	0.1
			Synthesiomyia nudiseta (Van Der Wulp, 1883)	33	1.1	37	0.5	0.8
			Helina lasiophthalma (Macquart, 1835)	4	0.1	0	0	0.1
Calliphoridae	43.2	64.5	*Calliphora vicina* (Robineau-Desvoidy, 1830)	398	13.7	294	4.1	8.9
			Chrysomya albiceps (Wiedemann, 1819)	312	10.7	861	11.9	11.3
			Chrysomya megacephala (Fabricius, 1794)	103	3.5	1395	19.4	11.5
			Chrysomya rufifacies (Macquart, 1842)	221	7.6	1569	21. 8	14.7
			Lucilia sericata (Meigen, 1826)	80	2.8	78	1.1	2.0
			Lucilia cuprina (Wiedemann, 1830)	143	4.9	455	6.3	5.6
Sarcophagidae	22.5	5.0	*Wohlfahrtia nuba* (Wiedemann, 1830)	6	0.2	10	0.1	0.2
			Sarcophaga hertipes (Wiedemann, 1830)	513	17.6	16	0.2	8.9
			Sarcophaga argyrostoma (Robineau-Desvoidy, 1830)	135	4.6	337	4. 7	4.7
Piophilidae	0.1	0.1	*Piophila casei* (Linnaeus, 1758)	3	0.1	10	0.1	0.1
Psychodidae	0.2	0.1	*Tinearia alternata* (Say, 1824)	6	0.2	5	0.1	0.2
Sphaeroceridae	0.3	0	*Coproica vagans* (Haliday, 1833)	9	0.3	0	0	0.2
Hippoboscidae	0.1	0	*Hippobosca equina* (Linnaeus, 1758)	2	0.1	0	0	0.1
Fannidae	0.4	0.2	*Fannia canicularis* (Linnaeus, 1761)	11	0.4	14	0.2	0.3
Drosophilidae	0.2	0.1	*Drosophila repleta* (Wollaston, 1858)	7	0.2	5	0.1	0.2
Syrphidae	0.2	0	*Eumerus amoenus* (Loew, 1848)	4	0.1	0	0	0.1
			Eupeodes corollae (Fabricius, 1794)	2	0.1	0	0	0.1
Phoridae	0.3	0	*Megaselia scalaris* (Loew, 1866)	9	0.3	0	0	0.2
Scathophagidae	0.1	0	*Scathophaga litorea* (Fallén, 1819)	3	0.1	0	0	0.1
Ulidiidae	0.1	0	*Physiphora alceae* (Preyssler, 1791)	4	0.1	0	0	0.1
Totals				2910		7211		

C control carcasses, *WI* warfarin-intoxicated carcasses

Fig. 4 Adult *Scathophaga litorea*: a new report in Cairo, Egypt

El-Bar & Sawaby, 2011; Voss, Forbes, & D, 2008). In contrast, EL-Kady, Essa, and Shalaby (1994b) reported that neither decomposition occurred nor arthropods were captured from the arsenic oxide poisoned rabbits.

Five stages of decomposition were noticed, namely fresh, bloated, active decay, advanced decay, and skeletonization similar to the observations of previous workers (EL-Ghaffar, Goff, & Shalaby, 2008; Voss et al., 2008; Bunch, 2009; Abd EL-Bar & Sawaby, 2011; Kyerematen, Boating, Haruna, & Eziah, 2013; Polat & Kökdener, 2014; Zeariya et al., 2015; Abd El-Bar et al., 2016; Hore, Parui, Saha, & Banerjee, 2017 & Aly, Osman, Galal, & Ali, 2017). However, Mckinnereny (1978), Tantawi et al. (1996), Galal, Abd-EL-Hameed, Attia, and Uonis (2009), Ekanem and Dike (2010), Mabika, Masendu, and Mawera (2014), and Albushabaa and Almousawy (2016) observed only four stages (fresh, bloated, active decay, and dry). Others as Payne (1965) divided the decay process into six stages.

Generally, it was observed that the decomposition process started from the time of oviposition of dipterous flies mainly in the body orifices including mouth, nose, eyes, and ears and ended till the animal remnants were fully dry and no live or active insects were detected in any of the cages which are in agreement with the observation of Tantawi et al. (1996), El-Ghaffar et al. (2008), Zeariya et al. (2015), Abd El-Bar et al. (2016), and Hore et al. (2017).

In forensic entomology, necrophagous insects are valuable for determination of the PMI, post mortem transfer, and presence of toxins. In the present study, blowflies were the first insect colonizers. The dipteran assemblage in early stages of decay was conservative, like the findings of Al-mesbah, Moffatt, El-azazy, and Majeed (2012) who studied rabbit decomposition in Kuwait and found that *Chrysomya albiceps* consistently present early in succession. This species is aggressive and may feed also on other larvae, which can explain its dominance over the other calliphorid larvae. Similarly, in the present study, on the calliphorid species, *Chrysomya albiceps* was the early colonizers of the carrion, while Zuha, Huong- Wen, Disney, and Omar (2017) reported that *Sarcophaga* spp. are the earliest species to colonize the carrion.

Out of the collected dipterous flies, *Piophila casei* was identified and considered to be one of the most potential indicators of the advanced stage of decay: thus, it has been documented as a key forensic fly used in the determination of PMI in homicide and suicide criminal cases. Adults of this species are known to attract to proteinaceous materials such as meat, fish, and cheese; are the chief pests of the food industry; and are the cause of myiasis. This family is frequently cited for its conventional presence on corpses.

In our study, many factors might have induced the absolute number of insect taxa found during this study. It was observed for the first time that the color of rabbit fur can affect the number of the attracted insects as more adults were attracted to black rabbit carcasses than to other colored carcasses. However, such case needs further investigations.

In this study, calliphorid flies appeared on the carcasses at the fresh, bloated, and active decay stages of decomposition, whereas some individuals were previously observed during advanced and skeletonization stages (El-Ghaffar et al., 2008; Oliveira-Costa, Lamego, Couri, & Mello-Patiu, 2013 & Zeariya et al., 2015), while Abouzied (2014) observed calliphorid flies during the fresh and bloated stages only. A total of 1017 individuals of Sarcophagids representing 3 species (*Wohlfarhtia nuba*, *Sarcophaga hertipes*, and *Sarcophaga argyrostoma*) were collected from this study. Neither Hegazi, Shaaban, and Sabry (1991) nor Tantawi et al. (1996) found carrion breeding sarcophagids in whichever of the studied season in Alexandria, although they found unidentified *Sarcophaga* sp., while *Wohlfahrtia* sp. was absent in spring and present in summer (Tantawi et al., 1996).

Our results indicated that the dipteran species mostly occurred during the active decay of decomposition, while Galal et al. (2009) and Abouzied (2014) observed that members of Muscidae were restricted only to the bloated stage. Wolff, Uribe, Ortiz, and Duque (2001) and Al-Mesbah et al. (2012) collected muscids during all stages of decomposition. Of these, *Musca domestica* appeared at the bloated stage and advanced decay stages

similar to Abajue, Ewuim, and Akunne (2013) and Abd El-Bar et al. (2016) observations. In our study, nine individuals of *Megaselia scalaris* of family Phoridae were identified. Although there is a forensic importance of this family, the previous studies in Egypt did not record any of its members except by Tantawi et al. (1996), Zeariya et al. (2015), and Aly et al. (2017).

Abd El-Bar et al. (2016) reported Physiophora alceae of family Ulidiidae which is similar to our findings of four individuals of such species. A few species belonging to Drosophilidae and Psychodidae were collected. All are of minor importance as forensic indicators. Similarly, Psychodidae was recorded by Tantawi et al. (1996) and Eberhardt and Elliot (2008). Al-Mesbah et al. (2012) observed Drosophilidae and Ephyridae as insects of forensic interests. Moreover, Kyerematen et al. (2013) and Calzolari, Defilippo, Zani, Colombo, and Dottori (2014) collected members of Dolichopodidae and Psychodidae. Other dipterous flies of Hippoboscidae were collected in the present study.

In general, a total of 26 species of the 13 families were collected from control and intoxicated carcasses. Of the reported species, *Musca domestica*, *Musca sorbens*, *Muscina stabulans*, *Synthesiomyia nudiseta*, *Calliphora vicina*, *Chrysomya albiceps*, *Chrysomya megacephala*, *Chrysomya rufifacies*, *Lucilia sericata*, *Lucilia cuprina*, *Wohlfahrtia nuba*, *Sarcophaga hertipes*, *Sarcophaga argyrostoma*, *Piophila casei*, *Tinearia alternata*, *Fannia canicularis*, *Drosophila repleta*, and *Physiphora alceae* were previously reported in Egypt on rabbit carcasses by El-kady et al. (1994a), Aly et al. (2013), Ibrahim, Galal, Alaa Eddeen, Seufi, and Elhefnawy (2013), and Zeariya et al. (2015). Other reported species *Stomoxys calcitrans*, *Helina coniformis*, *Coproica vagans*, *Hippobosca equina*, *Eumerus amoenus*, *Eupeodes corollae*, *Scathophaga litorea*, and *Megaselia scalaris* were not reported on carrions before. Of these species, *Scathophaga litorea* (F. Scathophagidae) was found in the present study for the first time as an addition to Egyptian fauna (details of which will be published in a separate study). A similar species, *Conisternum decipiens* (Haliday, 1832) was reported in Egypt by Becker, 1903 (Sifner, 2008). Still some other species reported by other authors were missed during the present study, these are *Ophyra leucostoma* (Muscidae) (El-kady et al., 1994a); *Scaptomyza* sp. (Drosophilidae), *Diplonevra peregrine* (Phoridae), *Boettcherisca peregrine* (Sarcophagidae), *Parasarcophaga africa* (Sarcophagidae), *Parasarcophaga ruficornis* (Sarcophagidae), and *Allograpta cubana* (Syrphidae) (Shalaby, De Carvalho, & Goff, 2000); *Sarcophaga aegyptica*, *Muscina prolapsa*, and *Fannia leucostica* (El-Ghaffar et al., 2008); *Musca autumnalis* (Aly et al., 2013); *Agriella setosa* (Sarcophagidae) and *Pollenia* sp. (Calliphoridae) (Hegazi et al., 1991); *Sarcophaga carnaria* and *Wohlfartia magnefica* (Ibrahim et al., 2013); *Sarcophaga carnaria*, *Wohlfahrtia magnifica*, *Atherigona varia* (Muscidae), *Sepsis fissa* (Sepsidae), *Physiphora demandata* (Ulidiidae), and *Scatella* sp. (Ephydridae) (Aly et al., 2017).

A complementary part of our study was objected at examining the effect of warfarin on the developmental periods of dipterous larvae and the malformed pupae and adults as a delayed effect of the toxin (Abd EL-Gawad, Kenawy, Badawy, & Abd EL-bar, 2018).

Conclusion

The faunal composition on carrions can be expected for any given zone under specific circumstances. The fields of forensic entomology and entomotoxicology research are still scanty in Egypt excluding some studies. This study may add information on necrophagous fly diversity, relative abundance, and occurrence of forensic dipterans in Cairo during Spring season. Moreover, it is the first record of the dipteran flies' successive waves on warfarin-intoxicated remains. The climatic conditions are crucial factors for the progression of the decomposition of a corpse and the appearance of necrophagous insects. *Scathophaga litorea* (F. Scathophagidae) was documented as a new report in the Egyptian fauna for the first time.

Abbreviations

C: The control carcasses group (untreated); WI: The Warfarin-intoxicated carcasses group

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Authors' contributions

AA had performed the practical section, injection of animals, and collection of samples and wrote her master thesis (at which this manuscript is based on). RB had identified the samples and carried out the taxonomic part of this study. MA helped in designing the study, preparing the experiment, analyzing data, and writing the manuscript. MK had designed the study, analyzed the data, and wrote the manuscript. All authors read and approved the manuscript.

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The Research Ethics Committee (REC) at the Faculty of Science, Ain Shams University, Cairo, Egypt, has approved the experiments.

Consent for publication

Not applicable

Competing interests

The authors declare that they have no competing interests.

Author details
[1]Department of Entomology, Ain Shams University, Abbassyia, 11566 El-Khalifa El-Maamoun St, Cairo, Egypt. [2]Department of Entomology, Faculty of Science, Ain Shams University, Abbassyia, 11566 El-Khalifa El-Maamoun St, Cairo, Egypt.

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