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Comparative study of fly species diversity and their succession on rabbit carcasses in three different habitats in Jeddah city, Kingdom of Saudi Arabia

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ABSTRACT

This study focused on associated flies with rabbit carcasses, and carried out in three different habitats; agriculture, desert and coastal, for the first time in Jeddah city, kingdom of Saudi Arabia. Four decomposition stages were observed, fresh, bloated, decay and dray. Eight species of flies belong to three families were recognized. They were; *Chrysomya albiceps* (Wiedemann, 1819), *Chrysomya megacephala* (Fabricius, 1794), *Chrysomya marginalis* (Wiedemann,1830) represented family Challiphoridae; *Sarcophaga ruficornis* (Fabricius,1794), *Sarcophaga hirtipes* (Wiedemann,1830), *Sarcophaga albiceps* (Meigen, 1826) from family Sarcophagidae, and tow species from family Muscidae; *Musca sorbens* (Wiedemann, 1830) and *Musca domestica* (Linnaeus, 1758). In general, *Chrysomya albcips* was more significant presence than all fly species in all decompositiom stages followed by *Musca sorben*. Whereas Sarcophagids flies, *Sarcophaga hirtipes* and *Sarcophaga albcips* represented the species with lowest presence. The highest mean number of flies significantly was observed in agriculture habitat followed by coastal then desert. The results proved that decomposition stages included mean numbers of flies differed significantly; they were in descending order, decay stage, fresh stage, bloated stage and dray stage.

INTRODUCTION

Forensic entomology has become synonymous with medico-legal entomology and includes the use of insects in legal and criminal investigations (Turchetto & Vanin, 2004). Basically, pathologists can estimate the time of death based on several medical parameters such as measures of livor mortis, algor mortis, rigor mortis and vitreous fluid (Henssge *et al*., 1995; Greenberg, Kunich, 2002). These traditional methods are only useful for the first few hours after death, becoming invalid after that and usually not used beyond about 72 hours. Forensic entomology is the most accurate in determining time of death (PMI) when more than a day or two have elapsed by using information of insects that visit the corpse (Kashyap &Pillai, 1989). There are two methods to determine PMI; the first using growth of fly larvae that feed upon the corpse. The flies visit animal carcasses or human corpses within minutes of death (Keh, 1985; Smith, 1986; Oliveira-Costa, 2008), they use them to obtain protein for ovarian development or as a mating site (Souza &Linhares, 1997; Carvalho *et al*., 2000). Therefore, the age of the oldest larva provides a minimum time since death (Catts & Haskell, 1990; Greenberg, 1991; Oliveira-Costa & Mello-Patiu, 2004). The second method to determine PMI is the succession of carrion arthropod species on the carrions, due to the fact that insects arrive at a corpse in a predictable manner (Payne, 1965). This method has providing both a minimum and maximum estimated of post mortem interval (Schoenlly, *et al*., 1996; Greenberg & Kunich, 2002). The first necrophagous flies arrive and oviposit on a corpse are

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typically species of the families Calliphoridae and Sarcophagidae (Watson & Carlton, 2003). The rate of corpse or carcass decomposition and arthropod succession are influenced by many factors, the more important are temperature, humidity, rainfall and abundance of insects (Tantawi *et al*., 1996). Studies on carrion arthropods had been conducted in several countries of the world to determine the species composition and succession patterns (Tabor *et al*., 2005). However, there are a little published data on the forensically important flies in Jeddah city, Kingdom of Saudi Arabia. This study aimed to document fly species associated with rabbit carcasses as human model, and its succession pattern in relation to decomposition stages of carcass, climatic conditions, and habitats.

MATERIALS AND METHODS

Study sites:

The study was carried out during the period from autumn 2015 to winter 2016in Jeddah city which is located on the west of the Kingdom of Saudi Arabia, in the middle of the eastern shore of the Red Sea. Three different habitats were chosen to conduct this study: (1) an agricultural habitat which was represented by a farm located at 50 km northwest of Jeddah city, and composed of palm trees and grasses, with dark, moist soil, and the study period in this site lasted from 28 November to 12 December 2015, (2) desert habitat existed at one km away from Dahban Highway main road, the soil was sandy with pale yellow color, at the period from 13 to 27 December 2015, (3) coast habitat located in South Obhor district at 300 m away from the Red Sea shore, no soil or plants were present in this area, and the study period lasted from 28 December 2015 to11 January 2016.

Animals and experimental cages:

To attract the insects, Domestic rabbits (*Lepus cuniculus)* weightings between 1.4 and 2.5 kg were used as models in each area. They were placed inside cages to protect from vertebrate scavengers. These cages were made of metallic material, measured 65x55x45 cm^3 with 2 cm^2 mesh to allow insects access. Inside this cage there was a small internal cage consists of 4 metal frames covered with nylon surfaces with minutes mesh to prevent insect escaping and allow ventilation. The top of tow cages were opened in its middle (9 cm diameter) for fixing a water bottle to act as a collecting chamber. One side of each tow cages had a small door (20cm x 15cm) to allow placing and taking out of the carcass. Two holes ($2cm^2$) were made on two sides of the inner cage to allow arrival of insects to the carcass, but on attempts to escape, they made their way to the collecting bottle on the top of the cage.

Sampling Protocol:

The rabbits were killed by cutting trachea without decapitation (according to principles of Islam) and immediately weighed and placed in the cages. In each site, 10 cages were distributed in tow lines which were located 10 m apart, each line includes 5 carcasses which away 2 m from each other. A sticky trap washandled half a meter from each caged carcass and about 1 meter from the ground. The study site was visited daily to determine stages of decomposition. At the end of each decomposition stage the collection bottle with the sticky traps were removed and transferred to the laboratory for examinations. Taxonomical keys were used to identify the species of adult insects according to James (1947), Whitworth (2006; 2010) and Marshall *et al.*(2011). The numbers of species were counted and representative samples were preserved in 70% ethanol. Daily weather data of temperature and relative humidity were obtained using digital thermohygrometer.The rainfall rate was obtained from faculty of meteorology environment and arid land agriculture of King Abdulaziz University.

Statistical analysis:

Method of factorial experiments analysis was used in this study which achieved in randomized complete block design with three replicates for three factors. These factors were fly species which represented by eight levels, decomposition stages included four levels (fresh, bloated, decay and dry stages) and habitats with three levels (agriculture, desert and coast). The statistical analysis included using "F test", and its results summarized in "ANOVA (analysis of variance) table", and then "Dancun's test" was used to compare means of significant factors, according to Snedicor (1958).

Results:

In this study rabbit carcasses were used to collect fly species in three different habitats; agriculture, desert and coastal which had been differed in their geographical locations and climatic conditions. Temperatures, relative humidity and rainfall rate in the period study were shown in table (1). Four stages of carcass decomposition were observed; fresh, bloated, decay and dry stages. The fresh stage began from the moment of death until the beginning of the Bulge. The bloated stage immediately followed the fresh stage and lasted until the demise of bloating by exiting gases from the body as a result of the feeding larvae on the carcass. The decay stage was identified when the carcass deflated until most of the flesh from the carcass was consumed by larvae.

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The dry stage was indicated when no maggots remain on the carcass and lasted until carrion fauna were no longer found associated with the remains and only dried skin, fur, cartilage and bones were left.

Table 1: Climatic conditions in the different habitats during the period of study

Habitat	Stage	Temperature (^{0}C)			R.H.% Mean	Rainfall (mm)
		Max.	Min.	Mean		
Agriculture	Fresh	34.2+1.41	25.20+0.00	29.2+0.42	63+5.66	0.00
	Bloated	32.04+0.85	25.4+0.00	28.55+0.212	66.00+4.243	0.00
	Decay	28.67+1.15	23.0+1.0	25.93+0.55	56.67+3.44	1.5+1.5
	Dray	29.40+1.19	22.2+2.01	25.63+0.71	39.75+19.05	0.00
For all duration		32.39+1.65	24.11+2.25	26.89+1.66	55.55+16.84	0.41+0.97
Desert	Fresh	25.9+0.71	18.30+0.42	22.5+0.28	51+4.24	0.00
	Bloated	29.40+0.849	18.10+1.838	24.00+1.414	39.00+2.828	0.00
	Decay	27.25+0.60	21.98+0.73	24.28+0.68	49.00+2.16	0.00
	Dray	26.88+0.88	19.92+2.08	23.66+0.74	49.40+5.77	0.00
For all duration		27.28+1.30	20.28+1.94	23.80.0.91	48.42+5.47	00.0
Coast	Fresh	32+0.28	23.2+1.13	27.45+0.78	55.5+2.12	00.0
	Bloated	26.80+0.283	19.60+2.263	23.45+1.485	62.5+7.778	2.00+2.828
	Decay	26.03+0.80	18.37+1.10	22.17+0.40	47.67+6.51	0.00
	Dray	28.80+0.91	20.55+0.53	24.50+0.88	53.5+6.61	0.00
For all duration		28.19+2.39	20.19+2.06	24.09+2.08	53.20+77.42	0.40+1.26

Results of the recent study cleared that eight species of Diptera belong to three families were collected from the carcasses. They were *Chrysomya albiceps* (Wiedemann,1819), *Chrysomya megacephala* (Fabricius,1794), *Chrysomya marginalis* (Wiedemann,1830) which belong to family Challiphoridae; *Sarcophaga ruficornis* (Fabricius,1794), *Sarcophaga hirtipes*(Wiedemann,1830), *Sarcophaga albiceps* (Meigen, 1826) represented family Sarcophagidae, *Musca sorbens* (Wiedemann, 1830) and *Musca domestica* (Linnaeus, 1758) from family Muscidae.

Results of statistical analysis in ANOVA table (table 2) showed that there were highly significant differences in the treatments of the experiment. Each factors; fly species, habitats and decomposition stages affected significantly on mean numbers of flies, and also interaction between them with highly significant. When Dancun's test was used to compare treatments' means (by L.S.D Bayesian test) with respect to the tow studied factors fly species and habitats (table 3) it was clear that in agriculture habitat where the mean of maximum, minimum temperatures and relative humidity were 32.390C, 24.110C and 55.55%, respectively and rainfall rate was 0.41 mm/day, *Chr. albiceps* had the highest mean number significantly (11.25), but the lowest mean numbers significantly were for *Mus. sorbens* (1.00) and *Mus. domestica* (0.99). In desert habitat with the climatic conditions 27.280C, 20.30C, 48.42% RH and no rainfall, *Mus. sorbens* recorded the highest mean number of flies significantly (3.47), but the lowest mean number of insects significantly for each *Chr. megacephala*, *Chr. marginalis*, *Sar. hirtipes* and *Sar. albiceps* (1.00). In coastal habitat, where the climatic conditions were 28.190C, 20.190C, 53.2% RH and rainfall rate was 0.4 mm/day, as in agriculture habitat *Mus. sorbens* also presented in the highest mean number of insect (7.24), but all Sarcophagids; *Sar. ruficornis*, *Sar. hirtipes* and *Sar. albiceps* recorded the lowest mean numbers (1.10). Most fly species presented with highest mean number in agriculture habitat; *Chr. albiceps* (11.25), *Chr. megacephala* (3.90), *Chr. marginalis* (3.90), *Sar. ruficornis* (2.47), *Sar. hirtipes* and *Sar. albiceps* (1.49). While the lowest mean numbers were in desert habitat for *Chr. marginalis*, *Sar. hirtipes*, *Sar. albiceps* (1.00) and in coastal habitat for *Chr. albiceps* and *Sar. ruficornis* (1.10), while, *Chr. megacephala* with low mean number in each desert and coastal habitat (1.00). In contrast, *Mus. sorbens* was in the highest mean number in coastal habitat (7.24) and *Mus. domestica* in desert habitat (2.25), but both were in lowest numbers in agriculture habitat (1.00 and 0.99, respectively). In general, the mean numbers of fly species in descending order significantly; *Chr. albcips* (5.92), *Mus. sorbens* (3.90), *Chr. megacephala* (1.97) and *Chr. marginalis* (1.98), *Sar. ruficornis* and *Mus. domestica* (1.61), *Sar. hirtipes* and *Sar. albiceps* (1.20) (fig. 1). Overall, agriculture habitat included the biggest means number of flies significantly (3.31) followed by coastal habitat (2.17), but desert habitat posses the smallest one (1.79) (fig.2).

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Table 2:ANOVA for adult flies which were collected from rabbit carcasses during decomposition stages in different habitats

Source of Variance	Degree of Freedom	Sum of squares	Mean sum of squares	F-cal	F-table	Notes
Replicates	2	0.01	0.005818	0.407851	2.996, 4.605	NS
Treatment	95	1871.14	19.69622	1380.834	1.22, 1.325	**
Fly Species	7	690.40	98.62866	6914.516	2.01, 2.639	**
Study Habitats	2	121.09	60.54496	4244.599	2.996, 4.605	**
Decomposition stages	3	56.58	18.85948	1322.174	2.04, 3.782	**
Spices*Habitats	14	787.62	56.25885	3944.115	1.666, 2.039	**
Species*stages	21	89.74	4.273317	299.5876	1.571, 1.878	**
Habitats*stages	6	20.97	3.49549	245.0568	2.099, 2.802	**
Spices*Habitats* stages	42	104.73	2.493688	174.8239	1.394,	**
Error	190	2.71	0.014264			
Total	287	1873.85				

S^2	0.014264			**Bayesian least significant different for 0.01, 0.05 Confidence levels**	
$S^2_x$for 96	0.004755	$S_x$for128	0.073709	Bayesian L.S.D. for 96	0.28, 0.18
S^2_xfor32	0.001585	$S_x$for32	0.041396	Bayesian L.S.D. for 32	0.17, 0.11
$S^2_x$for 24	0.001189	$S_x$for24	0.035666	Bayesian L.S.D. for 24	0.15, 0.09
$S^2_x$for 12	0.000594	$S_x$for12	0.024973	Bayesian L.S.D. for 12	0.12, 0.07
$S^2_x$for 8	0.000396	$S_x$for8	0.020302	Bayesian L.S.D. for 8	0.11, 0.06
$S^2_x$for 4	0.000198	$S_x$for4	0.014273	Bayesian L.S.D. for 4	0.08, 0.05
S^2_xfor3	0.000149	Sxfor32	0.012338	Bayesian L.S.D. for 32	0.07, 0.04

NS; Not significant. *; Significant (0.05). **; Highly Significant (0.01)

Table 3: Comparison of treatments' means (by L.S.D Bayesian test) with respect to the tow studied factors fly species and habitats, and the interaction between them.

Habitats	Fly species								Habitats' means
	Chr. albiceps	*Chr. megacephala*	*Chr. marginalis*	*Sar. ruficornis*	*Sar. hirtipes*	*Sar. albiceps*	*Mus. sorbens*	*Mus. domestica*	
Agriculture	11.25±2.13 Aa	3.90±1.31 Ab	3.90±1.31 Ab	2.47±0.65 Ac	1.49±0.55 Ad	1.49±0.55 Ad	1.00±0.09 Ce	0.99±0.08 Ce	3.31±3.37 A
Desert	3.33±1.30 Bb	1.00±0.09 Be	1.00±0.09 Ce	1.25±0.46 Bd	1.00±0.09 Ce	1.00±0.09 Ce	3.47±2.63 Ba	2.25±1.72 Ac	1.79±1.55 C
Coastal	3.18±1.16 Cb	1.00±0.09 Bf	1.035±0.15 Bd	1.10±0.20 Ce	1.10±0.21 Be	1.10±0.21 Be	7.24±1.43 Aa	1.56±0.79 Bc	2.17±2.16 B
Species' means	5.92±4.1 a	1.97±1.57 c	1.98±1.56 c	1.61±0.77d	1.20±0.40 e	1.20±0.4 e	3.90±3.1 b	1.60±1.1 d	2.42

Small letters for the horizontal comparisonsCapital letters for the vertical comparisons.
(L.S.D. Bayesian) for 24 Means =00.09 (L.S.D. Bayesian) for 8 Means=0.06
(L.S.D. Bayesian) for 3 Means=0.04

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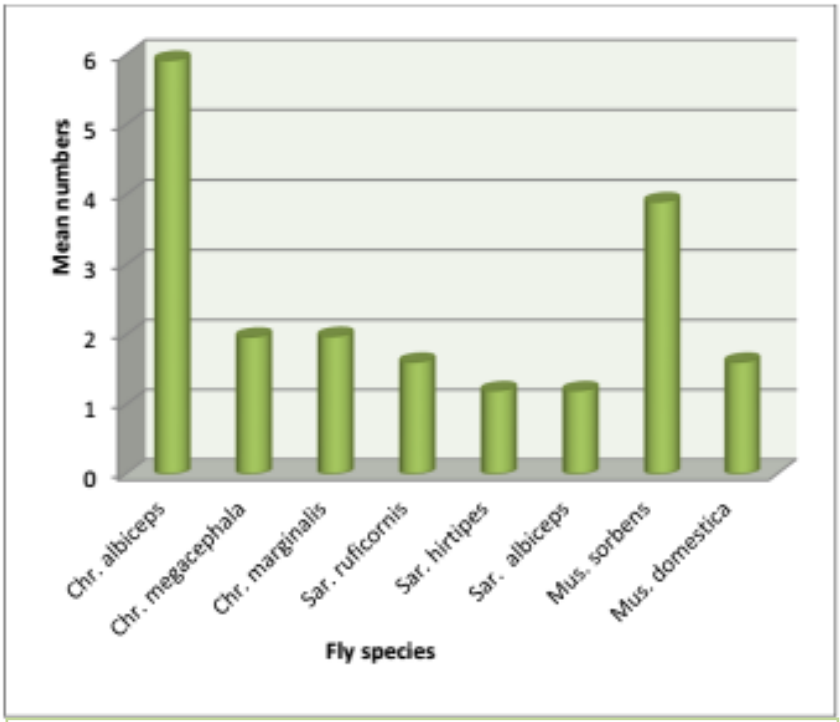

Fig. 1: Mean numbers of different fly species through all habitats

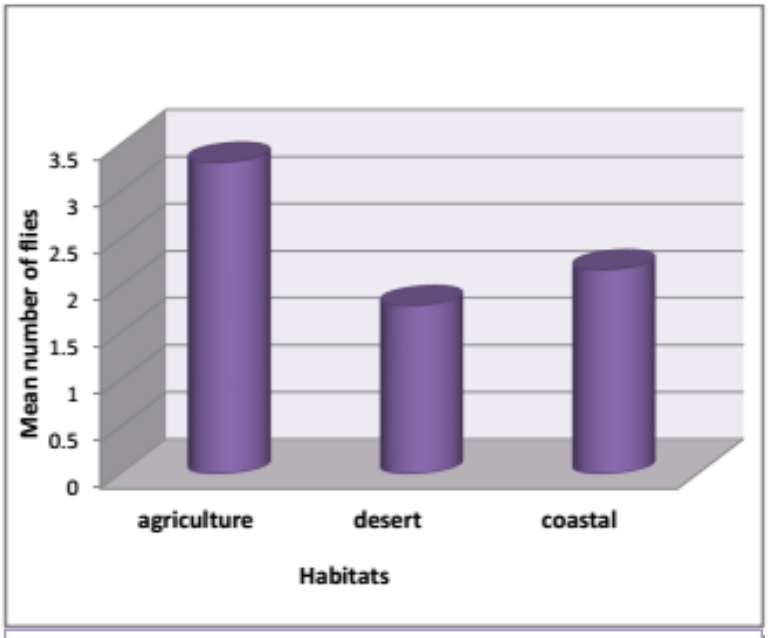

Fig. 2: Mean numbers of all flies among different habitats

When comparing means of fly numbers by L.S.D Bayesian test (table 4, fig. 3) and according to the factors of fly species and decomposition stages, it was clear that in all decomposition stages; fresh, bloated, decay and dray stages *Chr. albiceps* had the highest mean number significantly (6.96, 5.51, 7.11 and 4.10, respectively) followed by *Mus. sorbens* (2.72, 3.22, 5.86 and 3.81). But the lowest mean numbers in fresh stage for *Sar. hirtipes*, *Sar. albiceps* (1.24) with *Mus. domestica* (1.46). As well as in bloated stage *Sar. hirtipes*, *Sar. albiceps* (1.14) and *Mus. domestica* (1.00), and dray stage for all these three species (1.00). While, in decay stage all Sarcophagids were in the lowest mean numbers *Sar. ruficornis* (1.33), *Sar. hirtipes* and *Sar. albiceps* (1.14). In general, mean numbers of all fly species differed significantly among the four decomposition stages. Decay stage had the highest mean number (3.07) followed by fresh stage (2.50) then bloated stage (2.30), whereas the lowest mean was in dray stage (1.83) (fig. 4).

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Table 4: Comparison of treatments' means (by L.S.D Bayesian test) with respect to the tow studied factors fly species and decomposition stages, and the interaction between them.

Stages	Fly species								Stages` means
	Chr. albiceps	*Chr. megacephala*	*Chr. marginalis*	*Sar. ruficornis*	*Sar. hirtipes*	*Sar. albiceps*	*Mus. sorbens*	*Mus. domestica*	
Fresh	6.96±4.55 Ba	2.20±1.80 Ac	2.24±1.77 Ac	1.86±0.99 Bd	1.24±0.37 Af	1.24±0.37 Af	2.72±2.58 Db	1.46±0.45 Be	2.50±2.67 B
Bloated	5.51±3.77 Ca	2.19±1.79 Ac	2.19±1.79 Ac	2.00±0.87 Ad	1.14±0.22 Ae	1.14±0.22 Ae	3.22±2.02 Cb	1.00±0.09 Cf	2.30±2.021 C
Decay	7.11±4.78 Aa	2.23±1.85 Ad	2.23±1.85 Ad	1.33±0.51 Ce	1.41±0.62 Ae	1.41±0.62 Ae	5.86±3.69 Ab	2.94±1.74 Ac	3.07±3.11 A
Dry	4.10±3.11 Da	1.24±0.37 Bc	1.24±0.37 Bc	1.24±0.37 Cc	1.00±0.12 Bd	1.00±0.12 Bd	3.81±3.33 Bb	1.00±0.08 Cd	1.83±1.98 D
Species' means	5.92±4.12 a	1.97±1.57 c	1.98±1.56 c	1.61±0.77 d	1.20±0.40 e	1.20±0.4 e	3.90±3.1 b	1.60±1.18 d	2.42

Small letters for the horizontal comparisons. (L.S.D. Bayesian) for 8 Means=0.06 Capital letters for the vertical comparisons. (L.S.D. Bayesian) for 4 Means=0.05 (L.S.D. Bayesian) for 32 Means =0.11.

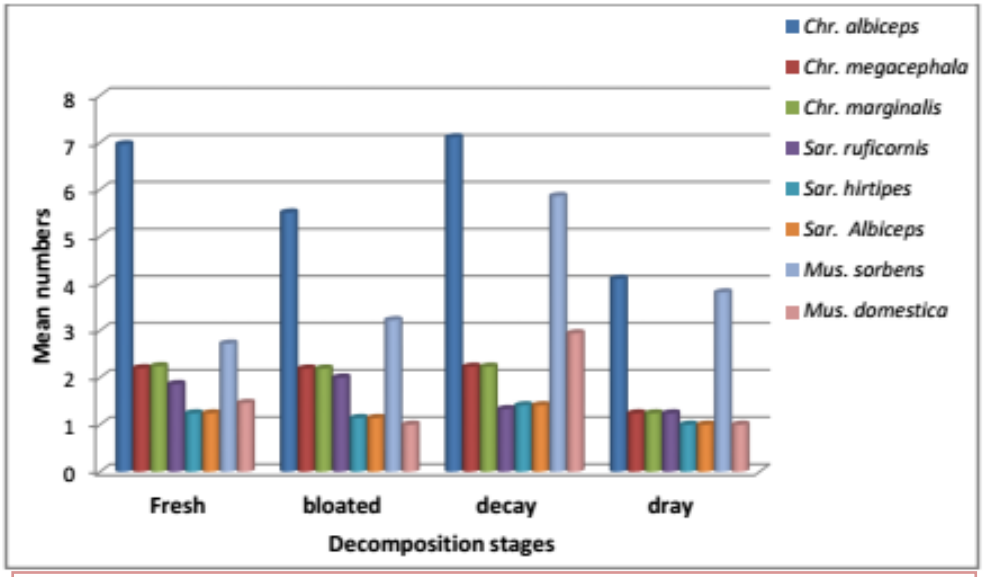

Fig. 3: Mean numbers of fly species through different decomposition stages

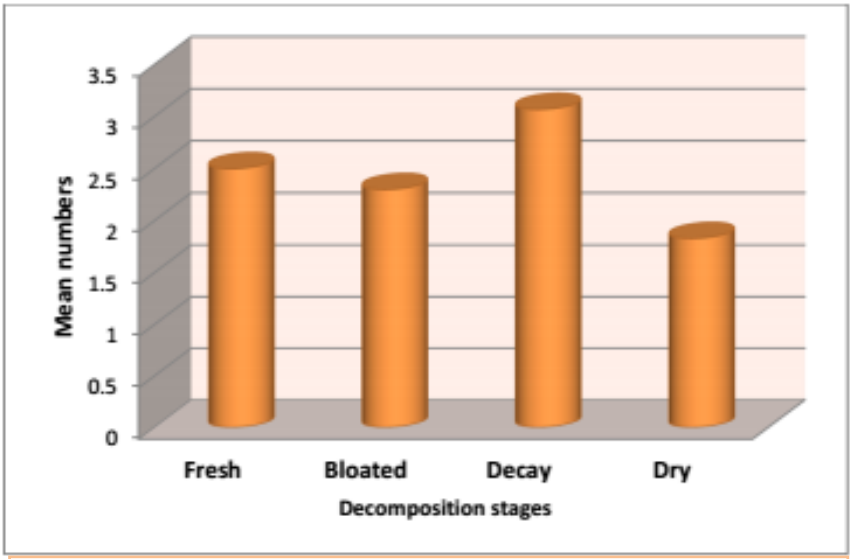

Fig. 4: Mean numbers of all flies among different decomposition stages

By comparing means of fly numbers under the influence of two factors habitats and decomposition stages (table 5), we found that, significantly, always agriculture had the biggest mean numbers of flies, followed by

coastal then desert habit in each stages fresh (3.83, 1.97, 1.67), bloated (3.34, 1.95, 1.60), decay (3.90, 2.71, 2.59) and dray (2.18, 2.02, 1.29).

With respect to the habitats, agriculture had the biggest mean numbers of flies in fresh (3.83) and decay stage (3.90) but the lowest was in dray stage (2.18). In desert habitat, the biggest mean number of flies was also in decay stage (2.59), and lowest in dray stage (1.29). For Coastal habitat, the biggest mean number of flies in decay stage (2.71), but they were equal significantly in other stages fresh (1.97), bloated (1.95) and dray (2.02).

Table 5: Comparison of treatments' means (by L.S.D Bayesian test) with respect to the tow studied factors; habitats, decomposition stages and the interaction between them.

Stages	Habitats			
	Agriculture	Desert	Coastal	Stages` means
Fresh	3.83±3.75 Aa	1.67±1.51 Bc	1.97±1.70 Bb	2.50±2.67 B
Bloated	3.34±3.17 Ba	1.60±0.85 Bc	1.95±1.59 Bb	2.30±2.021 C
Decay	3.90±3.91 Aa	2.59±2.41 Ac	2.71±2.76 Ab	3.07±3.11 A
Dry	2.18±2.37 Ca	1.29±0.52 Cc	2.02±2.41 Bb	1.83±1.98 D
Habitats' means	3.31±3.37 a	1.79±1.55 c	2.17±2.16 b	2.42

Small letters for the horizontal comparisons Capital letters for the vertical comparisons. (L.S.D. Bayesian) for 12 Means =0.07 (L.S.D. Bayesian) for 4 Means=0.05 (L.S.D. Bayesian) for 3 Means=0.04

The interaction between three factors, fly species, habitats and decomposition stages (table 6) proved that the highest mean numbers of fly species were *Chr. albiceps* in decay stage in agriculture habitat (13.38) and *Mus. sorbens* in decay stage in coastal habitat (8.94), whereas the lowest one was *Mus. sorbens* in each fresh, bloated and decay stages in agriculture habitat (1.00). In general, significantly, *Chr. albiceps* was more presence than all fly species in all stages and habitats (5.92), but, *Sar. hirtipes* and *Sar. albiceps* presence in lowest numbers (1.20). Agriculture habitat posses the highest mean number of fly species especially in fresh (3.83) and decay (3.90) stages. In contrast, desert habitat had the lowest mean number of flies especially in fresh (1.67) and bloated (1.60) stages.

Table 6: Comparison of treatments' means (by L.S.D Bayesian test) with respect to the three studied factors; fly species, habitats, decomposition stages and the interaction between them.

Habitats	Stages	Species								habitats` means
		Chr. albiceps	*Chr. megacephala*	*Chr. marginalis*	*Sar. ruficornis*	*Sar. hirtipes*	*Sar. albiceps*	*Mus. sorbens*	*Mus. domestica*	
Agriculture	Fresh	12.85±0.02 Ba	4.59±0.00 Ab	4.59±0.00 Ab	3.16±0.01 Ac	1.73±0.01 Bd	1.73±.01 Bd	1.00±0.1 He	0.97±0.07 Ee	3.83±3.75 A
	Bloated	10.54±0.01 Ca	4.58±0.01 Ab	4.58±0.01 Ab	3.00±0.2 Ac	1.00±0.1 Dd	1.00±0.1 Cd	1.00±0.1 Hd	1.00±0.1 Ed	3.34±3.17 B
	Decay	13.38±0.02 Aa	4.69±0.02 Bb	4.69±0.02 Ab	2.00±0.2 Bd	2.24±0.01 Ac	2.24±0.01 Ac	1.00±0.1 He	1.00±0.1 Ee	3.90±3.91 A
	Dry	8.25±0.02 Da	1.73±0.01 Cb	1.73±0.01 Bb	1.73±0.02 Cb	1.00±0.1 Dc	1.00±0.1 Dc	1.00±0.1 Hc	1.00±0.1 Ec	2.180±2.37 E
Desert	Fresh	5.39±0.17 Ea	1.00±0.1 Dc	1.00±0.1 Cc	1.00±0.01 Dc	1.00±0.1 Dc	1.00±0.1 Dc	1.00±0.1 Hc	2.00±0.09 Cb	1.67±1.48 G
	Bloated	2.83±0.04 Ha	1.00±0.1 Dc	1.00±0.1 Cc	2.00±0.05 Bb	1.00±0.1 Dc	1.00±0.1 Dc	3.00±0.1 Fa	1.00±0.1 Ec	1.60±0.85 G
	Decay	3.03±0.07 Gc	1.00±0.1 Dd	1.00±0.1 Cd	1.00±0.1 Dd	1.00±0.1 Dd	1.00±0.1 Dd	7.65±0.05 Ca	5.00±0.25 Ab	2.59±2.41 D
	Dry	2.06±0.12 Ia	1.00±0.1 Db	1.00±0.1 Cb	1.00±0.1 Db	1.00±0.1 Db	1.00±0.1 Db	2.24±0.02 Ga	1.00±0.1 Eb	1.29±0.52 H
Coastal	Fresh	2.65±0.01 Hb	1.00±01 Dc	1.14±0.26 Cc	1.41±0.05 Cc	1.00±0.1 Dc	1.00±0.1 Dc	6.16±0.01 Da	1.41±0.01 Dc	1.97±1.70 F
	Bloated	3.16±0.04 Gb	1.00±0.1 Dd	1.00±0.1 Cd	1.00±0.1 Dd	1.41±0.2 Cc	1.41±0.11 Cc	5.66±0.13 Ea	1.00±0.1 Ed	1.95±1.59 F
	Decay	4.91±0.60 Fb	1.00±0.1 Dd	1.00±0.1 Cd	1.00±0.1 Dd	1.00±0.1 Dd	1.00±0.1 Dd	8.94±0.03 Aa	2.83±0.02 Bc	2.71±2.76 C
	Dry	2.00±0.2 Ib	1.00±0.1 Dc	1.00±0.1 Cc	1.00±0.1 Dc	1.00±0.1 Dc	1.00±0.1 Dc	8.19±0.02 Ba	1.00±0.1 Ec	2.02±2.41 F
Species' means		5.92±4.12 a	1.97±1.57 c	1.98±1.56 c	1.61±0.77 d	1.20±0.40 e	1.20±0.4 e	3.90±3.1 b	1.60±1.18 d	2.42

Small letters for the horizontal comparisons. Capital letters for the verticalcomparisons.
(L.S.D. Bayesian) for 96 Means =0.18 (L.S.D. Bayesian) for 12 Means =0.07 (L.S.D. Bayesian) for 8 Means =0.06 (L.S.D. Bayesian) for 4 Means=0.05 (L.S.D. Bayesian) for 3 Means=0.04

Discussion:

In this study rabbit carcasses were used to collect adult flies in three locations represented different habitats (agriculture, desert and coastal). Each of them characterized by its environmental components (climatic conditions, type of soil, presence or absence of living organisms either human or plants). Four stages of

carcasses decomposition were distinguished; fresh, bloated, decay and dray stages, and their characteristics were similar to those of previous studies such as Braack (1986) and Tantawi *et al*. (1996).

The recent study proved that flies from three families; Calliphoridae, Sarcophagidae and Muscidae visited rabbit carcasses. Calliphoridae was the first colonizers and was represented by three species; *Chrysomya albcips*, *Chrysomya megacephala* and *Chrysomya marginalis*. Although Sarcophagids comprised a small number of all flies collected on the carcass, this family was represented by three species; *Sarcophaga ruficornis*, *Sarcophaga hirtipes* and *Sarcophaga albcips*. Muscid was identified by only two species *Musca domestica* and *Musca sorbens*. Actually it is not surprisingly, the dipterans visitors to the carcasses were from these families, because they have been recognized together in many previous studies; like Al-Mesbah (2010) on rabbit carcass in Kuwait, Bharti & Singh (2003) in India. Other researches recorded Calliphoridae and Muscidae among carrion flies, without emergence of Sarcophagidae such as Eberhardt & Douglas (2008) in New Zealand and Segura *et al.*,(2009) in Colombia on pig carcass). Whereas, Sarcophagidae family was stated as one of the most important Diptera families in the process of carrion decomposition (Reed, 1958; Payne, 1965; Early & Goff, 1986).

Many previous experiments reported most of species which we found in our study; *Chr. megacephala* was collected on dead body in Malaysia (Nor Afandy *et al*., 2001; Noratiny *et al*., 2002), and also Azwandi & Abu Hassan (2009) recorded it with *Mus. sorbens* on monkey carcasses in oil palm plantation in Malaysia, *Chr. megacephala* was recorded in Kuwait by Al-Mesbah *et al.*(2010), *Mus. domestica* was reported by Tabor *et al.*(2004) on pig carcass in Southwest Virginia. Barbosa *et al.*(2009) recorded *Sar. ruficornis* and *Mus. domestica* on pig carcasses in Brazil. Substantial similarity of entomofauna composition in previous and current study resulted from the fact that most of the important carrion insects tolerate a broad range of habitats, few differences refer to species of little importance for the process of carrion decomposition (Matuszewski *et al.*, 2008).

Overall, *Chr. albcips* was the first fly species to arrive and more present significantly than other fly species in all stages of decomposition (fresh, bloated, decay and dray) followed by *Mus. sorbens*, but the Sarcophagids, especially *Sar. hirtipes*, *Sar. albiceps* and *Mus. domestica* in fresh, bloated and dray stages presented in lower number than all fly species, and as well as in decay stage all Sarcophagids present in the lowest mean numbers. Our findings agreement with Tabor *et al.*(2004) in Southwest Virginia, who observed Calliphorids Constitute 60% of all flies collected, but Sarcophagids comprised a small proportion (less than 5%). Denno & Cothran (1976) stated that the competition that exists between adult Calliphorids and Sarcophagids can affect the population size of Sarcophagids. Bharti & Singh (2003) recorded similar competition in some Muscidae species, where their competition with Calliphoridae and Sarcophagidae reduced the number of this muscid species. Türkiye *et al.*(2014) in Turkey reported *Chr. albiceps* as the most common Calliphorid species along the fresh, bloated, active and advanced decay stages of the carcass decomposition, but in opposite of us there was no capture of this species at dry stage. Many researchers recorded Calliphoridae from fresh stage to dray; Anderson & VanLaerhoven (1996), Wolff *et al.*(2001), Okiwelu *et al.*(2008), Velásquez (2008), Ortloff (2012).

Our results showed that, mean numbers of all fly species differed significantly among the four decomposition stages. Decay stage had the highest mean number, followed by fresh stage, then bloated stage, whereas the lowest mean was in dray stage. This finding due to the strength of odor during carcass decomposition in decay stage which attracted numerous of flies. But in dray stage most of flesh fade, and only dray skin and bones remaining, these substances were not suitable for flies to lay eggs or feeding larvae.

This study proved that, *Chr. albiceps* was the most common and prominent species because it was collected from all study habitats which differed in maximum temperature, relative humidity and rainfall; agriculture (32.39^0C, 55.6%, 0.41mm/day), desert (27.28^0C, 48.24%, no rainfall) and coast (28.19^0C, 53.2%, 0.40 mm/day). This result shows that *Chr. albiceps* bears a wide range of temperatures and humidity and resistant to weather extremes in terms of drought or rainfall. Segura *et al*. (2009) in Colombia recorded *Chr. albiceps* in the fresh stage of decomposition in agriculture area at an average temperature of 14 ^{0}C, a relative humidity of 73.25% and an annual rainfall of 790 mm/day.

The recent experiment clear that agriculture was the most favorable habitat for Calliphorid species (*Chr. megacephala* and *Chr. marginalis*) although they still less than *Chr. albcips*, may be because their larvae were pried by *Chr. albcips* larvae which was recorded previously as preditor (Greenberg,1971), that is why Sarcophagids were also fewer.

Overall, agriculture habitat was not a favorite for all Muscid species which were at least in number in this area, due to the presence of plants in the location. Whereas, desert and coastal habitats both were most favorite habitats for *Mus. sorbens*, where they present in large number than all species even *Chr. albcips*. But, Sarcophagids and *Chr. megacephala* and *Chr. marginalis* were low in numbers at this tow area.

This study is very important because documentation of insect faunal succession on carcasses will allowed to establish timelines for succession patterns in Jeddah city. In the recent study, being *Chr. albcips* was the first fly species to arrive the carcasses and has the highest number than other fly species in all study habitats, particular in fresh stage of decomposition, suggests a possible use for estimating a minimum postmortem interval in

Jeddah city, in Saudi Arabia. And it is valuable in accurately estimating a postmortem interval during the two weeks' time frame after death because it was found with highest number in all decomposition stages. This result is confirmed by what has been recorded previously about presence of *Chr. albcips* in previous years even in Jeddah (Al-Ghamdi *et al*., 2015; Al-Shareef & Al-Qurashi, 2016) or other cities in Saudi Arabia such as Al-Baha Province at southwestern region (Abouzied, 2014).

Conclusion:

This study proved that in Jeddah city, eight species of flies belong to three families were recognized. They were; *Chrysomya albiceps, Chrysomya megacephala, Chrysomya marginalis* from Challiphoridae; *Sarcophaga ruficornis, Sarcophaga hirtipes, Sarcophaga albiceps* belong to family Sarcophagidae, and two species from family Muscidae; *Musca sorbens* and *Musca domestica*. In general, *Chrysomya albcips* was more significant presence in all decomposition stages, but Sarcophagids flies, *Sarcophaga hirtipes* and *Sarcophaga albcips* represented the species with lowest presence. The highest mean number of flies significantly was found in agriculture habitat followed by coastal then desert. Decomposition stages included mean numbers of flies differed significantly; they were in descending order, decay stage, fresh stage, bloated stage and dray stage.

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