Insects associated with the composting process of solid urban waste separated at the source

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ABSTRACT. Insects associated with the composting process of solid urban waste separated at the source. Sarcosaprophagous macroinvertebrates (earthworms, termites and a number of Diptera larvae) enhance changes in the physical and chemical properties of organic matter during degradation and stabilization processes in composting, causing a decrease in the molecular weights of compounds. This activity makes these organisms excellent recyclers of organic matter. This article evaluates the succession of insects associated with the decomposition of solid urban waste separated at the source. The study was carried out in the city of Medellin, Colombia. A total of 11,732 individuals were determined, belonging to the classes Insecta and Arachnida. Species of three orders of Insecta were identified, Diptera, Coleoptera and Hymenoptera. Diptera corresponding to 98.5% of the total, was the most abundant and diverse group, with 16 families (Calliphoridae, Drosophilidae, Psychodidae, Fanniidae, Muscidae, Milichiidae, Ulidiidae, Scatopsidae, Sepsidae, Sphaeroceridae, Heleomyzidae, Stratiomyidae, Syrphidae, Phoridae, Tephritidae and Curtonotidae) followed by Coleoptera with five families (Carabidae, Staphylinidae, Ptiliidae, Hydrophilidae and Phalacaridae). Three stages were observed during the composting process, allowing species associated with each stage to be identified. Other species were also present throughout the whole process. In terms of number of species, Diptera was the most important group observed, particularly *Ornidia obesa*, considered a highly invasive species, and *Hermetia illuscens,* both reported as beneficial for decomposition of organic matter.

KEYWORDS. Compost; Diptera; diversity; urban entomology.

RESUMEN. Insectos asociados al proceso de compostaje de residuos sólidos urbanos separados en la fuente. Los macroinvertebrados saprófagos (lombrices de tierra, termitas y numerosas larvas de de dípteros) contribuyen con la generación de cambios en las propiedades físicas y químicas de la materia orgánica durante los procesos de degradación y estabilización que se llevan a cabo durante el compostaje, lo cual causa una disminución de los pesos moleculares de los compuestos. Esta actividad hace estos organismos excelentes recicladores de la materia orgánica. Este estudio estuvo orientado a evaluar la sucesión de insectos asociados a la descomposición de residuos sólidos urbanos separados en la fuente, el cual fue realizado en una compostera ubicada en el Municipio de Medellín, Colombia. Se determinaron un total de 11732 individuos, pertenecientes a la Clase Insecta y Arachnida. Se identificaron especies de 3 órdenes de insecta: Diptera, Coleoptera e Hymenoptera. Diptera correspondió al 98.5 % del total, fue el grupo mas abundante y diverso con 16 familias (Calliphoridae, Drosophilidae, Psychodidae, Fanniidae, Muscidae, Milichiidae, Ulidiidae, Scatopsidae, Sepsidae, Sphaeroceridae, Heleomyzidae, Stratiomyidae, Syrphidae, Phoridae, Tephritidae, Curtonotidae), seguido por los coleópteros con 5 familias (Carabidae, Staphylinidae, Ptiliidae, Hydrophilidae Phalacaridae). Se observaron tres fases durante el proceso de compostaje, en las cuales se pudo diferenciar las especies propias de cada y otras especies estuvieron durante todo el proceso. En términos de numero de especímenes, Diptera fue el grupo mas importante, particularmente el Syrphidae *Ornidia obesa*, como una especie altamente positivamente invasiva y el Stratiomyidae *Hermetia illuscens*, ambas reportadas como benéficas en la descomposición de la materia orgánica.

PALABRAS-CLAVE. Compostaje; Diptera; diversidad; entomología urbana.

Increasing human population, expansion of large cities and modernization processes have generated high volumes of all kinds of waste. Added to the lack of appropriate alternatives for its handling and disposal, this has caused significant pollution problems. The search for innovative alternatives for cleaner production standards with wastes being reincorporated into production systems are urgent (Pascual *et al*. 1997; Bhattacharyya *et al*. 2001; Smith & Hughes 2004). Therefore, different methods have been proposed for waste treatment, with composting being one of the preferred ones (Lee *et al*. 2004; Sharholy *et al*. 2008). This alternative, as well as providing a solution to the problem, could lead to improved agricultural production, responding to a growth in agricultural demands.

Composting is defined as the *biological oxidative decomposition of organic matter* (Stoffella & Kahn 2001) based on the catalytic activity of organisms present in the environment, responsible for the decomposition of organic matter. Under optimum conditions, and according to thermal indicators, three stages have been identified: 1) mesophilic, or moderate temperature phase; 2) thermophilic, or high temperature phase and 3) cooling or maturing phase (Kostov *et al*. 1996; Trautmann & Olynciw 2000). The duration of these phases depends on the kind of organic matter being composted as well as its efficiency, which is determined by factors such as aeration and humidity (McKinley & Vestal 1985; Strom 1985 a, b; Butler *et al*. 2001).

From a biological point of view, decomposing organic matter is the natural habitat of microorganisms such as yeast, fungi, bacteria and macroinvertebrates, of which most are insects (Jacobs 1998; Tuomela *et al*. 2000). Numerous species participate actively in the recycling process, feeding on animal and vegetal origin wastes (Haimi 2000). Compounds generated at the different decomposition stages attract an important diversity of arthropods whose life cycles are completed within the compost, while simultaneously contributing to, and speeding up, its decomposition. These arthropods also promote the presence and development of beneficial species, such as *Hermetia illucens* (Diptera, Stratiomyidae), which is involved in controlling the development of domestic flies in this kind of substrate (Calvert *et al*. 1970; Booram *et al*. 1977; Chio & Chen 1982; Sheppard 1983; Newton *et al*. 1992, 1995).

This study aims to further knowledge of insects' role during the composting process of solid urban waste separated at source, and to provide information that will allow their utility to be determined as maturity indicators of materials generated by composting processes.

MATERIAL AND METHODS

The study took place in Belén Altavista, a rural district of Medellín, in the department of Antioquia (Colombia). The study site was located at an elevation of 1600 m with an annual average temperature of 22°C, within the premontane moist forest life zone (Holdridge 1967).

A total of 4000 kg of solid urban waste separated at source, was placed in two piles, each consisting of a system of six beds measuring 150 x 150 x 70 cm. Composting piles were built on a slightly sloping, waterproof, cement surface, in order to avoid contamination from groundwater, humidity transference from the ground to the compost and to enable an appropriate handling of leachates. Homogenization and airing of composting material was achieved through periodical turning.

To select the sampling sites was followed the methodology TMECC 02.01 proposed in *Field sampling of compost material* (TMECC 2001), sampling different sites in the bed, from surface to a 30 cm depth, homogenizing and mixing all the subsamples.

To evaluate arthropod communities present at different stages, three samples were taken per day during the first week (7:00, 12:00 and 17:00 hours), then, twice a day during the second week (11:00 and 18:00 hours) and once a day (12:00 hours) until the seventh week. Each sample consisted of 1 kg of compost taken from nine different points from each bed in order to obtain a representative sample including both immature and adult specimens. Each sample was separated into two parts, one was deposited in plastic recipients covered with muslin until adults emerged and immature stadiums were extracted from the other using a Berlese funnel. Specimens were later identified using dichotomous keys by Borror *et al*. (1989), McAlpine *et al*. (1993), Peterson (1960) and Sterh (1987).

Two statistical packages were used to analyze data: PAS, used to calculate diversity, dominance and equitability indices over the study period, and SPSS to calculate correlations between insects.

Shannon & Weaver diversity index implies that every species be represented in the sample and that these populations are heterogeneous. Maximum value is expressed by ln S, being S the number of taxons per sample, but range usually oscillates between 1,5 and 3,5. Dominance index provides an abundance measure for the most common species; the most frequently used is the Simpson index. As dominance index increases from 0 to 1, diversity and equity decreases. It is an index highly influenced by dominant species in sample. Equity index describes the abundance distribution for species and oscillates between 0 as the minimum equity to lower diversity and 1, maximum equity to higher diversity (Ramírez 2000).

To describe spatial patterns (random, uniform o grouped), one of the most typical ecological features of a species, the relationship between variance and media was analyzed with Taylor Power Law (Taylor 1984). Taylor coefficients S^2=a. m^b were calculated using linear regression for the logarithm of variance (S^2) versus logarithm of sample mean (m). Regression slope log (S^2) = log (a) + b. log (m) is considered an aggregation index, so b = 1 indicates a random pattern, b < 1 is a uniform pattern and b > 1 indicates a grouped pattern.

RESULTS

A total of 11,732 individuals were collected throughout the study. Individuals within Insecta belonged to three orders: Diptera (N=11,561), corresponding to 98.5 % of the total; Coleoptera (N= 81) and Hymenoptera (N=20). One species of Arachnida was also collected. Diptera represented the most abundant and diverse group with 16 families (Calliphoridae, Drosophilidae, Psychodidae, Fannidae, Muscidae, Milichiidae, Ulidiidae, Scatopsidae, Sepsidae, Sphaeroceridae, Heleomyzidae, Stratiomyidae, Syrphidae, Phoridae, Tephritidae and Curtonotidae) followed by Coleoptera with five families (Carabidae, Staphylinidae, Ptilidae, Hydrophilidae and Phalacaridae) (Table I).

Diptera families recorded

Syrphidae. The highest number of individuals was collected from this family throughout the entire study period (N=5700), but especially during weeks 4, 6 and 7 when a relative abundance of 100% was registered (Tables I and IV). This family was represented only by *Ornidia obesa* (Fabricius, 1775), present from the first day, and representing 89.09% of the total number of individuals collected on day 20 (Table II).

Milichiidae._This was the second most abundant species (N= 1565), with percentages of 100% during weeks 4, 5 and 6 (tables 1 and 4). It was represented only by the genus *Desmometopa* sp, which was found during the entire study period. Highest abundance was observed on days 0 and 15, with presence during the entire period (Fig. 1, Table II).

Muscidae. This family was represented by *Stomoxys*

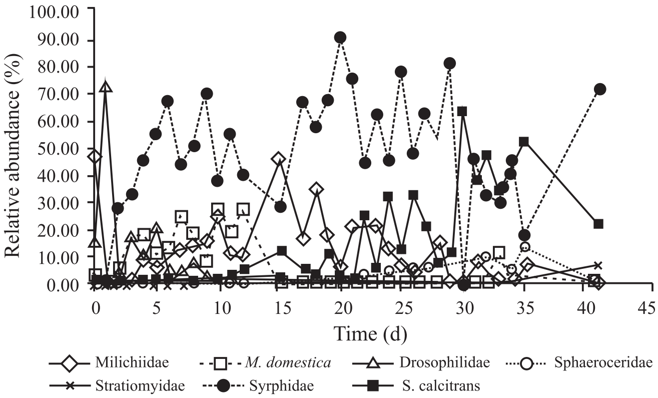

Fig. 1. Relative abundance for families having presence during the entire composting process.

calcitrans (Linnaeus, 1758) (12.02 %), *Musca domestica* (Linnaeus, 1758) (10.88%) and *Ophyra aenescens* (Wiedemann, 1830) (0.14%). *S. calcitrans* (N= 1410) showed an increase from day 20 (Figure 1, Table II), with highest relative abundance during weeks 4, 5 and 6 (Tables I and IV). Highest abundance of *M. domestica* (N = 1276) was recorded during the second week of the composting process (27.27 %), but the species was not recorded in the last week (Tables I, II and IV). *O. aenescens*, was poorly represented with only 17 individuals; this species was just observed during week 3. (Tables I, II and IV).

Drosophilidae. This family was represented by the genus *Drosophila* (N = 470), it was found throughout the study period being particularly abundant during weeks 1, 2 and 6 (Tables 1 and 4); the highest percentage (71.43%) was observed on the first day (Figure 1, Table II).

Fanniidae. This family was represented solely by *Fannia canicularis* (Linnaeus, 1761) (N = 348), it was present during the first 5 weeks of the study, with a subtle increase in relative abundance during the first and fifth week, and with a total absence during weeks 6 and 7 (Tables I and IV). The highest percentage was recorded on day 12, with 9.82% (Table II).

Sphaeroceridae. While poorly represented (N = 227), this family was recorded throughout the whole composting process, showing highest abundance during weeks 5 and 6 (Tables I and IV), with the highest percentage of individuals on day 30 (Table II).

Stratiomyidae. The only species within this family, with a total representation of 1.93% (Table I), was *Hermetia illucens* (Linnaeus, 1758), observed throughout the whole study period, but particularly from weeks 3 to 7 (Table IV). The highest increase was recorded on day 28 (Table II).

Families with numbers of individuals between 40 and 100 were: Tephritidae, Scatopsidae, Ulidiidae and Phoridae, all of which were present during the first two weeks but totally absent during weeks 6 and 7 (Tables I, IV).

Less than 40 individuals of the following families were recorded: Sepsidae, Psychodidae and Heleomyzidae; the first two were present during weeks 1 and 2. Heleomyzidae was present during weeks 2 and 5 (Tables I, IV).

The orders Coleoptera and Hymenoptera were observed in low numbers, with Staphylinidae the most abundant within Coleoptera (N = 41) and Formicidae in Hymenoptera (N = 14); less than 5 individuals were recorded from other families.

Ecological indicators. In general, low values of the Shannon-Wiener diversity index were recorded, with a slight decreasing trend in time (Fig. 2). The highest value was recorded during week 1, specifically on day 3 (H'=1.754), with an evident decrease in diversity in week 7 (H' = 0.80). With respect to diversity within families, this index was only calculated for Muscidae, with the following species *S. calcitrans*, *M. domestica* and *O. aenescens* given that only one species per family was recorded for all other families.

The highest dominance value was recorded on day 20 (D = 0.8973), coinciding with the lowest diversity value (H' = 0.45495), attributed to a high relative *O. obesa* presence (Table II).

Although a large total number of organisms was recorded, they were distributed equally in each sample, shown by the equity index fluctuating between 0.3272 (day 20) and 0.7618 (day 3). From day 21 until the end of the process, index values remained constant, corroborating the stability of the system (Figure 2).

There was always a relationship, meaning this, always that the average increased, the variance increased as well, for all of the species. This can be proved by applying a simple regression analysis of which the positive slope demonstrates such relation.

Independently of the simple regression analysis model applied it was observed that the coefficient for every species was positive: Drosophilidae (r = 0.8427), Fanniidae (0.9958), Milichiidae (0.9869), *M. domestica* (r= 0.9857), *S. calcitrans* (r = 0.9887), Scatopsidae (r= 0.9969), Sphaeroceridae (r= 0.9484), Stratiomyidae (r= 0.9617), Syrphidae (r = 0.4767), Ulidiidae (r= 0.9598).

Correlation matrix. The highest correlations were found between Psychodidae and Sepsidae (0.717; $P << 0.005$); Sphaeroceridae and *S. calcitrans* (Muscidae) (0.759; $P <<$

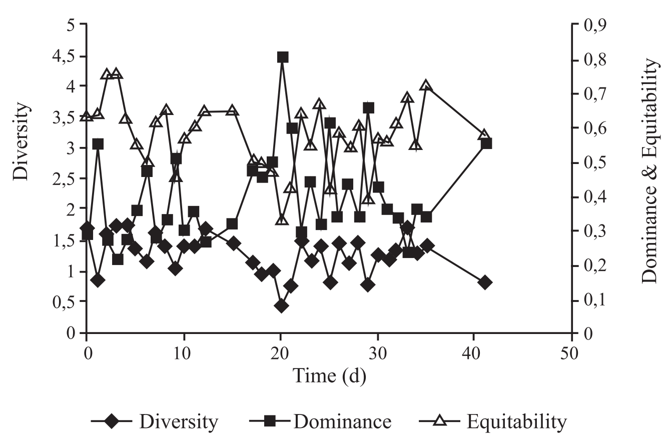

Fig. 2. Ecological indices during composting processes.

Table I. Insects found in solid urban waste compost. N, individuals; RA, relative abundance; L, larvae.

Order	Family	Subfamily	Genus	Species	N	RA
Diptera	Syrphidae	Eristalinae	*Ornidia*	*O. obesa*	5,700	48.58
	Milichiidae	Madizinae	*Desmometopa*	*Desmometopa* sp.	1,565	13.34
	Muscidae	Stomoxyinae	*Stomoxys*	*S. calcitrans*	1,410	12.02
	Muscidae	Muscinae	*Musca*	*M. domestica*	1,276	10.88
	Drosophilidae		*Drosophila*	*Drosophila* sp.	470	4.01
	Fanniidae		*Fannia*	*F. canicularis*	348	2.97
	Sphaeroceridae	Limosininae	*Coproica*	*Coproica* sp.	227	1.93
	Stratiomyidae	Hermetiinae	*Hermetia*	*H. illucens*	226	1.93
	Tephritidae				95	0.81
	Scatopsidae	Scatopsinae	*Coboldia*	*C. fuscipes*	68	0.58
	Ulidiidae	Ulidiinae	*Physiphora*	*Physiphora* sp.	67	0.57
	Phoridae	Metopininae	*Chonocephalus*	*Chonocephalus* sp.	41	0.35
	Sepsidae	Sepsinae	*Themira*	*Themira* sp.	24	0.20
	Muscidae	Azeliinae	*Ophyra*	*O. aenescens*	17	0.14
	Heleomyzidae				15	0.13
	Psychodidae (L)				6	0.05
	Calliphoridae (L1)				3	0.03
	Curtonotidae		*Curtonotum*	*Curtonotum* sp.	3	0.03
Coleoptera	Staphylinidae				41	0.35
	Hydrophilidae				5	0.04
	Ptiliidae				2	0.02
	Carabidae				1	0.01
	Phalacridae		*Stilbus*	*S. apilaclis*	1	0.01
Hymenoptera	Formicidae	Formicinae	*Paratrechina*	*Paratrechina* sp.	14	0.12
		Dolichoderinae	*Dorymyrmex*	*Dorymyrmex* sp.	4	0.03
		Ecitoninae	*Neivamirmex*	*Neivamirmex* sp.	1	0.01
	Scelionidae				1	0.01

0.005); and Phoridae and Calliphoridae (0.743; P <<0.005).

The lowest correlations with a significant P value were found between Scatopsidae - Drosophilidae (0.682; P = 0.000); Phoridae - Drosophilidae (0.651; P = 0.000), *M. domestica* (Muscidae) - Fanniidae (0.90; P = 0.000); Phoridae - Syrphidae (0.561; P= 0.001), Milichiidae - Calliphoridae (0.498; P = 0.03); Heleomyzidae - Psychodidae (0.449; P = 0.008); Sphaeroceridae - Syrphidae (-0.496; P = 0.003); Drosophilidae - Syrphidae (-0.474; P = 0.005) and *S. calcitrans* (Muscidae) - Syrphidae (-0.344; P = 0.046). A highly significant correlation was found between the latter two after week 3.

Spatial distribution. Spatial distribution showed grouped pattern of insects, especially for those which weren't present during all the composting stages. In the case of *O. obesa* species, the follow equation was obtained: Log variance = 2.55715 + 0.568466*Log average, with a slope minor to 1, expressing an uniform pattern. The other species showed a slope mayor to 1, showing a grouped pattern, in the following order: Ulidiidae (b: 3.55514, r: 0.961), Fanniidae (b: 2.5942, r: 0.9618), Scatopsidae (2.25439, r: 0.967), Milichiidae (b:2.0577, r: 0.9688), Drosophilidae (b: 1.93867, r: 0.9321), Stratiomyidae (b: 1.93593, r: 0.961), Sphaeroceridae (b: 1.82796, r: 0.948), Muscidae (*M. domestica*) (b: 1.67191, r: 0.9657), Muscidae (*S. calcitrans*) (b: 1.63327, r: 0.98). Some authors attribute cluster pattern, especially in small size species, is due to eclosion of larvae from egg masses, which coincides with most of the studied species. Random patter in observed in big size larvae, as *O. obesa*.

Compost system phases. According to Zbytniewski & Buszewski (2005), three stages may be differentiated during the composting process: 1) decomposition of easily biodegradable substances, 2) formation of humus-like substances, and 3) stabilization of organic matter. These stages were also differentiated during the present study and were associated with characteristic insects at each stage of the decomposition process:

Stage 1: Weeks 1 – 3. The presence of Phoridae and *O. aenescens* stand out as possible indicators of this stage. During

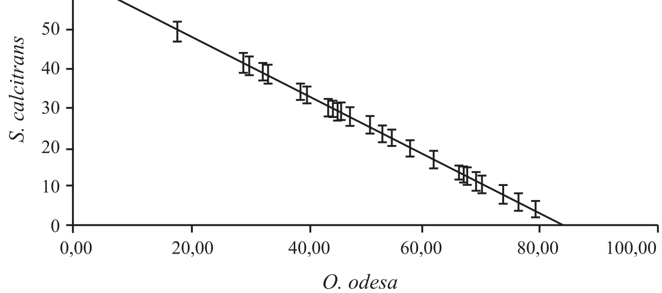

Fig. 3. Relationship between *S. calcitrans* and *O. obesa* during composting process.

Table II. Relative percentage of insect succession by family for Diptera.

Day	Syrphidae	Milichiidae	Muscidae *M. domestica*	Muscidae *O. aenescens*	Muscidae *S. calcitrans*	Drosophilidae	Fanniidae	Sphaeroceridae	Stratiomyidae	Tephritidae	Scatopsidae	Ulidiidae	Phoridae	Sepsidae	Heleomyzidae	Psychodidae	Calliphoridae	Curtonotidae
0	0.72	47.10	3.62	0.00	2.90	15.22	0.72	0.00	0.72	3.62	0.72	1.45	18.84	0.00	0.00	0.00	1.45	0.00
1	0.00	0.00	0.00	0.00	0.00	71.43	0.00	0.00	0.00	0.00	4.76	0.00	14.29	0.00	0.00	0.00	0.00	0.00
2	29.41	0.00	5.88	0.00	0.00	2.94	8.82	2.94	0.00	0.00	0.00	2.94	5.88	0.00	0.00	0.00	0.00	0.00
3	33.25	0.53	16.62	0.00	0.00	18.21	5.80	2.37	2.11	18.47	2.37	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4	45.97	9.06	18.12	0.00	0.67	10.74	5.03	0.34	0.34	1.34	1.68	1.01	0.34	4.03	0.00	0.67	0.34	0.00
5	54.37	6.41	11.37	0.00	1.17	20.85	3.50	0.00	0.29	0.29	0.29	0.00	0.87	0.00	0.00	0.00	0.00	0.15
6	66.58	9.97	13.21	0.00	2.02	4.58	1.48	0.94	0.40	0.00	0.00	0.00	0.00	0.27	0.00	0.00	0.00	0.00
7	43.73	12.71	25.08	0.00	1.32	3.47	2.15	6.60	0.00	0.00	0.17	1.65	0.17	0.17	1.98	0.50	0.00	0.00
8	50.70	13.95	19.07	0.00	0.47	7.44	6.05	0.00	0.47	0.00	1.40	0.47	0.00	0.00	0.00	0.00	0.00	0.00
9	69.46	15.41	8.38	0.00	1.08	1.62	0.00	1.89	0.81	0.00	0.54	0.54	0.00	0.27	0.00	0.00	0.00	0.00
10	38.57	25.65	27.19	0.00	1.72	0.54	3.52	0.00	0.63	0.09	0.00	1.17	0.00	0.00	0.00	0.00	0.00	0.09
11	54.52	10.54	19.25	0.00	2.04	0.86	8.49	0.00	1.94	0.43	1.83	0.00	0.00	0.00	0.00	0.00	0.00	0.00
12	40.00	9.82	27.27	0.00	4.91	0.36	9.82	0.00	2.00	0.18	3.27	0.73	0.00	1.09	0.00	0.00	0.00	0.00
15	28.99	46.01	1.86	0.00	11.44	0.00	6.38	2.39	2.13	0.00	0.00	0.53	0.00	0.00	0.00	0.00	0.00	0.00
17	66.57	16.57	0.28	4.78	4.78	0.00	1.97	0.00	4.21	0.00	0.28	0.28	0.00	0.00	0.00	0.00	0.00	0.00
18	57.98	34.63	0.00	0.00	3.11	0.00	0.78	0.00	2.72	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
19	67.30	17.78	0.00	0.00	11.43	0.00	1.27	0.00	0.63	0.00	0.00	0.00	0.63	0.00	0.00	0.00	0.00	0.00
20	89.09	5.45	0.00	0.00	1.82	3.64	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
21	74.21	20.75	0.00	0.00	0.63	0.00	1.26	0.00	2.52	0.00	0.63	0.00	0.00	0.00	0.00	0.00	0.00	0.00
22	44.16	20.13	0.65	0.00	24.68	0.00	2.60	2.60	0.65	0.00	1.95	1.30	0.00	0.00	0.00	0.00	0.00	0.00
23	62.10	21.77	0.00	0.00	4.84	0.00	1.61	1.08	6.72	0.00	0.00	1.08	0.00	0.00	0.00	0.00	0.00	0.00
24	44.89	12.44	0.00	0.00	31.56	0.00	0.89	4.00	1.33	0.00	0.00	2.67	0.00	0.00	0.00	0.00	0.00	0.00
25	76.89	6.13	0.00	0.00	12.26	0.00	0.94	0.47	2.83	0.00	0.47	0.00	0.00	0.00	0.00	0.00	0.00	0.00
26	47.52	3.72	0.41	0.00	32.23	0.00	3.72	5.37	0.83	0.00	0.00	0.41	0.00	0.83	0.00	0.00	0.00	0.00
27	61.86	5.77	0.00	0.00	21.47	0.32	0.00	0.00	7.69	0.00	0.32	2.24	0.00	0.00	0.00	0.00	0.00	0.00
28	53.13	15.54	10.28	0.00	7.77	0.25	0.50	0.00	9.27	2.01	0.00	0.50	0.00	0.00	0.00	0.00	0.00	0.25
29	79.80	3.45	0.00	0.00	10.84	0.00	0.99	0.49	3.94	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
30	2.80	8.39	0.00	0.00	62.24	0.00	2.10	17.48	2.10	0.00	0.00	0.70	0.00	0.00	0.70	0.00	0.00	0.00
31	45.51	8.08	0.00	0.00	37.72	5.99	0.00	0.60	0.00	0.00	0.00	0.30	0.00	0.00	0.00	0.00	0.00	0.00
32	32.37	4.91	0.00	0.00	46.82	4.05	0.58	9.25	0.00	0.00	0.00	0.29	0.00	0.00	0.00	0.29	0.00	0.00
33	29.93	1.79	11.29	0.00	33.87	5.38	0.36	1.43	1.97	0.00	0.00	0.36	0.00	0.00	0.00	0.00	0.00	0.00
34	44.73	2.11	0.00	0.00	39.66	2.95	0.42	4.64	2.95	0.00	0.84	0.00	0.00	0.00	0.84	0.00	0.00	0.00
35	17.55	6.27	2.51	0.00	52.66	6.58	0.00	13.48	0.94	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
41	70.73	0.00	0.00	0.00	21.95	0.00	0.00	0.00	6.10	0.00	0.00	1.22	0.00	0.00	0.00	0.00	0.00	0.00

this stage, all recorded families were observed, indicating a higher diversity, represented mainly by Syrphidae, Milichiidae, *S. calcitrans* (Muscidae), Drosophilidae, *M. domestica* (Muscidae), Fanniidae, Stratiomyidae and Scatopsidae (Fig. 4).

Stage 2: Weeks 4 – 5. Families showing important increases were Milichiidae, Fanniidae, *S. calcitrans* (Muscidae), Stratiomyidae, Sphaeroceridae, Uliiddidae, Psychodidae and Heleomyzidae. The latter two, as well as Curtonotidae, are important yet not exclusive at this stage.

Stage 3: Weeks 6 – 7. A low diversity is characteristic of this stage, with absence of most of the families: Fanniidae, Scatopsidae, Tephritidae, Uliididae, Sepsidae, Phoridae, Calliphoridae, Curtonotidae, Psychodidae, *O. aenescens* (Muscidae) and Heleomyzidae (Figure 4). Remaining families are stable throughout this stage, without important changes.

Although temperature has been associated with different stages of the composting process, this study found that while environmental temperature remained constant, compost temperature decreased, without notable differentiation between stages (Fig. 5).

DISCUSSION

Eighteen species of Diptera were recorded during the decomposition process of solid urban waste separated at source in which both larvae and adults were collected, demonstrating that this kind of substrate is apt for feeding, egg laying and the development of individuals.

Three different stages were recorded during the decomposition process: 1) easily biodegradable substrates, 2) formation of humus-like substances and 3) stabilization of organic matter.

Of the families collected during this study, Calliphoridae, Muscidae, Fanniidae and Syrphidae have already been associated with composting processes (Laos *et al*. 2004). Presence and permanence is considered to depend on the availability of food sources and in some cases, on favorable environmental conditions (Sharanowski *et al*. 2008; Montoya *et al*. 2009).

Among the species recorded, *Desmometopa* sp. (Milichiidae) showed the highest relative abundance, reaching a maximum on day 0 (47.10 %), implying that it is a pioneer in this kind of waste. Larvae of this family are saprophagous or coprophagous (Sabrosky 1987) and this behavior performs a recycling function in this substrate. Another pioneer species with similar behavior was *Drosophila* sp., associated with decomposing fruit (Wheeler 1987).

Ornidia obesa is reported to be of great importance to the composting process due to its presence throughout every stage. This species has been associated with decomposition of organic matter, mainly coffee pulp, being considered beneficial in recycling of organic matter (Lardé 1989; 1990). Its correlation with species such as *Chonochepalus* sp., *Coproica* sp., *Drosophila* sp. and *S. calcitrans* suggests than *O. obesa* participates in the decrease of the former species.

Occasional presence and low abundance of Calliphoridae, Heleomyzidae and Psychodidae, as well as *Curtonotum* sp. (Curtonotidae), *O. aenescens* (Muscidae) and *Themira* sp. (Sepsidae), indicate that they have little effect on the composting process. This contrasts with the occasional presence but high abundance of Tephritidae, *Chonocephalus* sp. (Phoridae) and *Drosophila* sp. (Drosophilidae) at the beginning of the process, coinciding with stages of increased decomposition of organic matter (Sharanowski *et al*. 2008).

Sepsidae is present only during the first two weeks, reappearing again at week 4, with a relatively low presence (Table IV). According to other studies, this family is more closely related to decomposition of organic matter of animal origin. Thus it is of higher interest to studies of forensic entomology rather than decomposition of solid urban waste (Sharanowski *et al*. 2008; Wang *et al*. 2008; Martinez *et al*. 2007).

The family Fanniidae was found almost throughout the whole composting process, with a maximum relative abundance of 9.82 % at day 12. Larva can generate gastric myiasis, urinary myiasis and ear myiasis among others (Yang *et al*. 2005; Arsalane *et al*. 2001; Perez & Mouffok 1999). Both this family and *M. domestica* (Muscidae) are important in animal health (Chakrabarti *et al*. 2007).

A high relative abundance of *S. calcitrans* during the whole composting process is especially noteworthy, due to

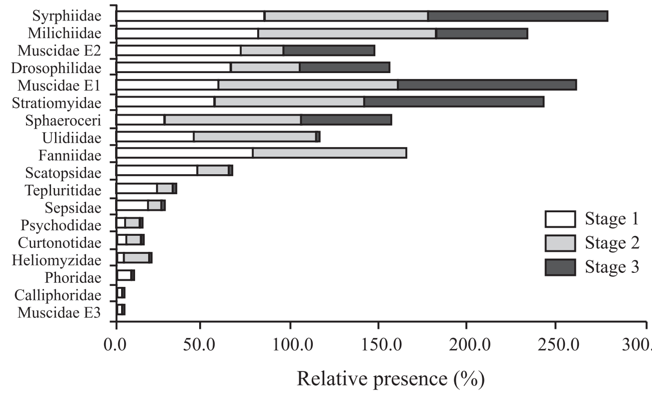

Fig. 4. Relative presence of Diptera larvae during composting process stages. (E1: *S. calcitrans*, E2: *M. domestica*, E3: *O. aenescens*).

Table III. Diptera larvae succession matrix during composting process (presence – absence by sampling day). d, day.

Taxa	Time (d)																																		
	0	1	2	3	4	5	6	7	8	9	10	11	12	15	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	41
1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
3	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	1	1	1	1	1	0
4	0	0	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	0	1	1	1	1	1	1	0	1	1	1	0	1	1	1	0	0
5	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0
6	1	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0
7	1	0	1	1	1	1	1	1	1	0	1	1	1	1	1	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	1	0	1	0
8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
10	0	0	0	0	1	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
12	1	1	0	1	1	1	0	1	1	1	0	1	1	0	1	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0
13	0	0	0	0	1	0	1	1	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
14	0	0	1	1	1	0	1	1	0	1	0	0	0	1	0	0	0	0	0	0	1	1	1	1	0	0	1	1	1	1	1	1	1	0
15	1	0	0	1	0	1	1	0	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	0	0	1	1	1	1
16	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1
17	1	0	0	1	1	1	0	0	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
18	1	0	1	0	1	0	0	1	1	1	1	0	1	2	1	0	0	0	0	1	1	1	0	1	1	1	0	1	1	1	0	0	0	1

1. Calliphoridae, 2. Curtonotidae, 3. Drosophilidae, 4. Fanniidae, 5. Heleomyzidae, 6. Milichiidae, 7. *M. domestica*, 8. *O. aenescens*, 9. *S. calcitrans*, 10. Phoridae, 11. Psychodidae, 12. Scatopsidae, 13. Sepsidae, 14. Sphaeroceridae, 15. Stratiomyidae, 16. Syrphidae, 17. Tephritidae, 18. Ulidiidae.

Table IV. Relative presence (%) of Diptera during each week of the composting process.

Family	Stadium	Weeks						
		1	2	3	4	5	6	7
Syrphidae	Adult	37.5	40	60	14.28	85.71	100	0
	Larva	81.3	90	80	100	85.71	100	100
M. domestica	Adult	25.0	30	20	14.28	14.28	0	0
(Muscidae)	Larva	81.3	80	40	14.28	28.57	100	0
Drosophilidae	Adult	12.5	10	40	0	14.28	100	0
	Larva	81.3	70	20	14.28	57.14	100	0
Milichiidae	Adult	25.0	20	40	28.57	85.71	100	0
	Larva	75.0	90	80	100	100	100	0
Fanniidae	Adult	12.5	0	0	28.57	14.28	0	0
	Larva	75.0	80	80	85.71	85.71	0	0
Scatopsidae	Adult	6.3	0	0	28.57	0	0	0
	Larva	43.8	60	20	28.57	14.28	0	0
S. calcitrans	Adult	18.75	20	40	14.28	71.42	100	100
(Muscidae)	Larva	37.5	80	80	100	100	100	100
Stratiomyidae	Adult	12.5	20	20	0	28.57	100	0
	Larva	37.5	70	80	100	71.42	100	100
Sphaeroceridae	Adult	0	0	0	14.28	0	100	0
	Larva	31.25	30	20	57.14	85.71	100	0
Tephritidae	Larva	31.25	30	0	0	14.28	0	0
Ulidiidae	Adult	0	0	0	0	14.28	0	0
	Larva	25	70	60	71.42	57.14	0	0
Sepsidae	Larva	18.75	30	0	14.28	0	0	0
Phoridae	Adult	25	0	20	0	0	0	0
	Larva	12.5	10	0	0	0	0	0
Calliphoridae	Adult	12.5	0	0	0	0	0	0
	Larva	6.25	0	0	0	0	0	0
Curtonotidae	Larva	6.25	10	0	0	14.28	0	0
Psychodidae	Larva	6.25	10	0	0	14.28	0	0
O. aenescens (Muscidae)	Larva	0	0	20	0	0	0	0
Heleomyzidae	Larva	0	10	0	0	28.57	0	0

both female and male being hematophagous (Mramba *et al*. 2007). Locally known as "stable fly", it is of public health interest, due to its irritating bite to animals and humans. In bovine livestock it causes weight loss, decrease in milk production and can lead to death in particular severe cases. This fly breeds in organic waste matter of both animal and vegetal origin, and is associated with the transmission of bovine annaplasmosis (Knapp *et al*. 1992; Miller 1992).

Despite their relatively low abundance, *Physiphora* sp. (Ulidiidae) and *C. fuscipes* (Scatopsidae) were found throughout almost the whole composting process.

A highly significant negative correlation was found between *O. obesa* and *S. calcitrans* after week 3 (Figure 3). These results are important given that the lineal regression model predicts that if *O. obesa* reaches abundances higher than 84% of the total arthropod population, *S. calcitran*s decreases. This can therefore be achieved by allowing the free propagation of *O. obesa* without introducing control methods to eradicate *S. calcitrans* from the compost.

With respect to ecological indices (diversity, abundance and equity) very constant values were obtained, implying that despite large numbers of organisms, they are distributed uniformly throughout the study period, corroborating system stability. Additionally, highest diversity was found within Muscidae, with three species (*S. calcitrans*, *M. domestica* and *O. aenescens*), given that in other families, only one species per family was recorded.

It was observed that as the composting process progresses, diversity of Diptera decreased. During the first week the presence of 17 taxa out of a total of 18 were recorded, but during the last week a significant presence of only three taxa was recorded: *O. obesa* (Syrphidae), *S. calcitrans* (Muscidae)

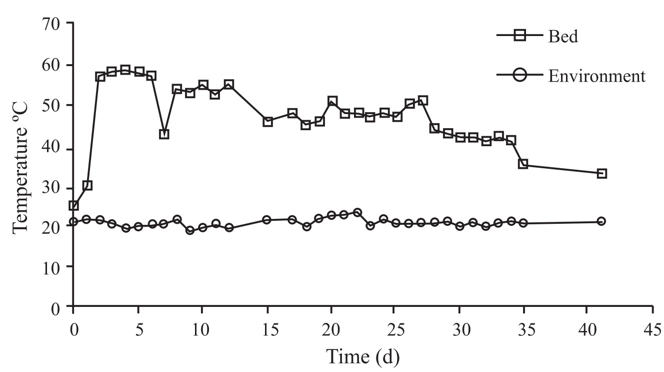

Fig. 5. Temperature against time during composting process.

and *H. illucens* (Stratiomyidae). This corresponds to results reported by several authors, according to which a decrease in diversity is attributable to depredation by other Diptera species at the larval stage, also influencing their abundance (Labud *et al*. 2003).

Presence of *H. illucens* larvae, reported in other studies as consumers of decomposing organic matter and responsible for decreases of *M. domestica,* is clear evidence of the role of *H. illucens* in controlling *M. domestica* (Furman 1959 *apud* Williams 2005).

The composting process requires parameters that can be controlled as moisture, temperature, pH, relation carbon/nitrogen and metals; which is not opposite to the action of arthropods, who has a role of recycling, allowing a clean, efficient and low-cost alternative without insecticides as in traditionally intervention, getting at the end a high quality product with minimum of contaminates effects.

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