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The effects of Insects on the Physicochemical Characteristics During Composting

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Abstract

Insects have a vital role in solid waste composting process. Insects are detritus feeders that enhance changing the physical and chemical properties of decomposed materials during composting processes. This behavior makes insects excellent organisms in recycling of organic matter. The present study assesses the success of insects' population in relation with the degradation of solid waste. The study was carried out in the glass house facility of the College of Science, Salahaddin University in Erbil City, Kurdistan region of Iraq, using household organic waste. During composting process, three stages of lifecycle of insects were observed and recorded. The total number of insects reached to 1268 individuals, belonging to the orders Coleoptera and Diptera, class Insects. Diptera individuals were the most abundant insects with 95.4% of the total belonged to four families (Muscidae, Calliphoridae, Ulidiidae and Milichiidae). Coleoptera individuals represented 4.6% of the total number, belonging to three families (Promecheilidae, Staphylinidae and Salpingidae). The measured physicochemical characteristics of the compost included: pH, EC, moisture, total organic carbon, total nitrogen, total phosphorous and organic matter. The pH value of the composts ranged from 7.79 to 7.97. Organic carbon content and organic matter content ranged from 20.16 to 26.99 % and 34.67 to 46.23 %, respectively. It can concluded that household waste compost is not just a waste but has the potential to be transformed into a good quality organic fertilizer through composting. Composting can convert solid organic waste into a valuable added material.

Keywords: compost, insect, decomposer, solid waste.

الحشرات المرتبطة مع الخصائص الفيزيائية والكيميائية أثناء عملية التسميد

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الخلاصة

للحشرات دور حيوي في عملية تسميد النفايات الصلبة. الحشرات تتغذى على المخلفات و بدورها (الحشرات) تساهم في تغيير الخواص الفيزيائية والكيميائية لهذه المخلفات في عمليات التحلل أثناء التسميد. هذا السلوك يجعل من الحشرات كائنات ممتازة في إعادة تدوير المواد العضوية. تقيّم الدراسة الحالية تعاقب تجمعات الحشرات فيما يتعلق بتحلل النفايات الصلبة، وقد أجريت الدراسة في البيت الزجاجي في كلية العلوم ، جامعة صلاح الدين/ أربيل ، إقليم كردستان– العراق، وذلك باستخدام النفايات المنزلية العضوية. خلال عملية التسميد ظهرت ثلاث مراحل من دورة حياة الحشرات وتم ملاحظتها. وصل العدد الإجمالي إلى 1268 فردًا،

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ينتمون إلى رتبتين هما غمدية الاجنحة وثنأية الاجنحةتعود لصنف الحشرات. كانت ثنأية الاجنحة من أكثر الحشرات وفرة حيث مثلت 95.4٪ من إجمالي عدد العائلات الأربع (Muscidae و Calliphoridae و Ulidiidae و Milichiidae). في حين مثلت غمدية الاجنحة 4.6% من إجمالي عدد العائلات الثلاث (Promecheilidae، Staphylinidae و Salpingidae).فضلا عن ذلك ، تم قياس الخصائص الفيزيائية والكيميائية للسماد والتي شملت: الرقم الهيدروجيني ، التوصيل الكهربائي، الرطوبة ، الكربون العضوي الكلي ، النيتروجين الكلي ، الفسفور الكلي والمواد العضوية. وقد وجدت قيمة الاس الهيدروجيني للسماد العضوي المعتدلة, وتراوحت بين من 7.79 إلى 7.97. اما الكربون العضوي فقد تراوحت قيمته بين 20.16 و 26.99 ٪، في حين تراوحت قيمة المادة العضوية بين 34.67 و 46.23 ٪. يمكن الاستنتاج ان سماد النفايات المنزلية ليس مجرد نفايات ولن لديه القدرة على أن يتحول الى سماد عضوي عالي الجودة من خلال التسميد. يمكن للسماد تحويل النفايات العضوية الصلبة الى مادة مضافة قيمة.

Introduction

The rapid growth of industrialization and urbanization is continuously resulting in magnification of waste generation. Inappropriate waste management processes such as incineration and land fillings caused significant environmental issues [1], due to the presence of pathogens and the leaching of excessive nitrogen, phosphorus and other elements, which may contaminate soil and water [2]. Management of solid waste is the second most important problem, after water quality, in the developing countries [3]. Therefore, different methods have been developed for solid waste treatment, with composting being one of the preferred ones [4]. This viable alternative method is able to provide a solution to the problem. One advantage of this process is the production of bio-fertilizers, where organic manure could lead to improved agricultural production, responding to the growth in agricultural demands. Other advantages include the relatively lower air and water pollution, low operational cost and the comparatively higher income generation [5][6].

Composting is the process of converting the waste into useful product such as humus or manure which can be further used for plant nutrition and disease management. It involves the amalgamation of various physical, chemical and biological parameters. Biological parameters involve both the micro and macro organisms that take part at different stages and play a pivotal role in degradation of the waste, converting it into a useful end product [1]. It is a biologically controlled process that uses natural aerobic processes to increase the rate of biological decomposition of organic materials. This process is carried out by successive microbial populations that break down organic materials into carbon dioxide, water, minerals and stabilized organic matter. Additionally, Dipterans and other insects are important in nature due to the fact that they degrade organic matter and convert it into biomass. Then carbon dioxide and water are released into the atmosphere, while the minerals and organic matter are converted by catalytic activity of organisms into a potentially reusable soil-like material called compost [7]. In comparison with other invertebrates, insect populations are potentially more active for biodegradation of organic matter due to the fact that insects develop in relatively short periods. Larvae of many species of the Diptera’s order are especially interesting as they are able to develop in a wide diversity of media, have a high reproductive capacity and a relatively short life cycle [8].

The aim of this study is to evaluate the insects’ role during the composting process of urban solid waste, and to provide information about the relationship between insects and physicochemical parameters during composting process.

Materials and methods

1. Sample collection and analysis

The study was conducted during summer months of 2018. The processing of waste was performed in the glass houses of the College of Science and degradable wastes (non-cooked, free fat waste) were used for composting. A total of 100 kg of solid urban waste separated according to the source was placed in one pile. Composting piles were built on a slightly sloping and waterproof wood 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 [9].

The experiment was performed in 30 days after which the whole waste was converted into manure. Samples were withdrawn and collected at regular intervals (10 days). Samples were taken in different parts of the bed and from the surface to a 30 cm depth. The Parameters viz. moisture content, electrical conductivity, pH, TOC, TP and TN content were investigated during the study. The samples were withdrawn after mixing the whole substrate. Fresh samples were used for determining moisture content by oven. Electrical conductivity and pH were analyzed in a 1:5 water soluble extract by conductivity meter and pH meter, respectively. TOC was measured by Walkely Black method. Total organic nitrogen in the compost samples was determined by Micro- Kjeldhal method. Total phosphorus was determined using ammonium molybdate with the $SnCl_2$ method [10].

However, to evaluate insect populations present at different stages during composting, samples of insects were taken in the 7th, 11th, 15th, 19th, 24th and 30th days during composting. Each sample consisted of 1kg of compost taken from five different points from the bed in order to obtain a representative sample including both immature and adult specimens [5].

Each sample was separated into two parts; one was deposited in a plastic can and covered with muslin until adults emerged, and the other was transported to the laboratory to collect immature insect stadium. Collected specimens were identified using several recommended keys [11-14].

2. Statistical analysis

The data was analysed statistically by using SPSS packages at significance level of $P< 0.05$. Two statistical packages were used to analyze data: Two- way ANOVA used to calculate physicochemical parameters, and correlation was performed between insects with physicochemical parameters [15].

Results and discussion

The results showed that the pH value of household composts was in neutrality level that ranged between 7.79 and 7.97. As the decomposition process progresses, nitrogen will bind with carbon to make an organic compound. No more escape of excess nitrogen might be the reason for the decrease of pH after it had risen [16]. EC of initial composting mixture increased to 17.77 mS/cm on day 10, and then gradually decrease until the end of the composting process (Table-1). The increases in EC value in the beginning could be caused by the release of mineral salts such as phosphates and ammonium ions through the decomposition of organic substances [17]. As the composting process developed, a decrease in the EC was detected. This could be probably due to volatilization of ammonia and the precipitation of mineral salts in the later phase of composting [18]. Utilization of nutrients by the larvae could also be a probable reason for the decrease in EC in later phases of composting.

Moisture content is a measure of the sum of moisture present in a compost sample and is indicated as a percentage of fresh weight. Moisture content of the composting mix is an important environmental parameter as moisture supplies a medium for the transport of dissolved nutrients needed for the metabolic and physiological action of microorganisms [19]. Throughout the present study, the moisture content of compost samples ranged from 9.81 to 28.42 %. Initially the moisture content was high but it was decreased after decomposition of organic matter. The reduction in the moisture content percentage through the thermophilic phase of composting was reported to be caused by high evaporating rates [20]. A significant decline of organic carbon (20.16%) was observed in day 30 as compared to its initial value (26.88%). Decrease of the organic carbon was significantly affected by composting. From the beginning, the percentage of organic carbon decreased, which reflects the decomposition of waste by microbial population [21]. Part of the carbon in the decomposing residues was reported to evolve as CO_2 while the other part assimilates by the microbial biomass [22-24]. Fares and colleagues described the carbon loss for initial total carbon throughout the composting process [25].

Total phosphorous ranged between 0.25-0.99% during composting, and previous studies noticed slowly increase of phosphorous through composting process [19]. The water solubility of phosphorus decreases with humification so that phosphorus solubility during the decomposition was subjected to further immobilization. The phosphorous content during this study was identical to that detected by Elango, er al. study [19]. Nitrogen level gradually increased during the composting process from 1.5 to 4%. Increased nitrogen content through the maturation phase could be possibly caused by strong degradation of labile organic carbon compounds which decrease the weight of composting materials [26]. The organic matter content of the studied compost ranged from 34.67 to 46.23 %. The organic matter declined during different stages of composting to the maturation stage because of the increase in the decomposition of organic substances (Table-1).

Table 1-Physico-chemical characteristics of study compost

Parameters	Days		
	10	20	30
pH	7.79	7.95	7.97
EC (mS/cm)	17.77	13.87	9.87
Moisture%	28.42	12.91	9.81
TOC%	26.99	21.84	20.16
T.Phosphorous%	0.37	0.99	0.25
Total kjeldahlNitrogen%	1.5	1.96	4
Organic Matter %	46.23	37.56	34.67

Throughout the study, a total of 1268 individuals were collected from the process of composting. Individuals within class insecta belonged to two orders; Diptera (95.4%) with an individual's number of 1210 and Coleoptera (4.6%) with an individuals number of 58. Diptera represented the most abundant and diverse group with 4 families (Muscidae, Calliphoridae, Ulidiidae and Milichiidae), while the order Coleoptera was represented by three families (Promecheilidae, Staphylinidae and Salpingidae (Table-2).

Table 2-Insect population found during solid waste composting.

Order	Family	Genus and species	7th day	11th day	15th day	19th day	24th day	30th day
Coleoptera 4.6%	Promecheilidae	*Parahelops* sp. (L)			10	2		33
	Staphylinidae	*Omalium* sp. (A)			2	2		1
	Salpingidae	*Elacatiskraatzi*(L)		2		3	1	2
Diptera 95.4%	Muscidae	*Muscadomestica*(L, P&A)	137	143	140	45	355	359
	Calliphoridae	*Chrysomyabezzianna*(L)				13		3
	Ulidiidae	*Physiphora sp.* (A)				3		
	Milichiidae	*Phyllomyza*sp. (A)						12

L: larvae A: adult

From the results, it is obvious that the process of decomposing solid waste provided suitable substrate for feeding, egg laying and the development of individuals. During the composition process, three different stages were recorded; easily biodegradable substrates, formation of humus-like substances, and organic matter stabilization.

Family Miscidae of the order Diptera had the highest number of the collected individuals throughout the entire study period with individual number of 1197, especially during the 24th and 30th day. This family was represented only by *Muscadomestica* in the form of larval, pupal and adult stages. While the family Calliphoridae was represented by 16 individuals of *Chrysomya bezzianna*, all of them were in the larval stage. These families have already been shown to be associated with the composting processes [27], food sources availability and, in many cases, favourable environmental conditions [28] [29].

The third most abundant family was Milichiidae and the only species identified in this family was the adult *Phyllomyza* sp. (12 individuals). Larvae of this family are saprophagous or coprophagous and this behaviour performs a recycling function in this substrate [30]. Finally, the less abundant taxa (n=3) belonged to the family Ulidiidae with adult *Physiphora sp.*

However, the lowest number of individuals belonged to the order Coleoptera with 58 individuals from three different families. The family Promecheilidae was the most abundant with individual number of 45 of the larval stage represented by one species, *Parahelops* sp. Salpingidae was the second abundant family of their order, represented by 8 larvae of *Elacatiskraatzi*, whereas the less abundant family was Staphylinidae, represented by only 5 species of adult *Omalium* sp.

According to the correlation matrix illustrated in Table-3, the highest positive correlations were found between the percentage of total nitrogen and each of *Parahelops* sp. and *Phyllomyza* sp. (0.88 and 0.86, respectively), pH and *Parahelops* sp. (0.81) and the percentage of phosphorous and *Omalium* sp. (0.76). However, the highest negative correlations were found between most of the physicochemical parameters and the collected species of insect. The lowest correlations were found between EC, the percentage of total organic carbon, the percentage of organic matter and *Parahelops* sp. (- 0.99, - 0.90 and - 0.9, respectively).

Table 3-Correlation between physicochemical parameters and insect taxa

Taxa	Parameter	pH	EC (mS/cm)	Moisture %	TOC %	Phosphorous %	Total kjeldahlnitrogen %	OM %
***Parahelops* sp. (L)**		0.81	-0.99	-0.86	-0.90	-0.18	0.88	-0.90
***Omalium* sp. (A)**		0.53	-0.28	-0.57	-0.51	0.76	-0.17	-0.51
***Elacatiskraatzi*(L)**		0.31	0.01	-0.31	-0.24	0.39	-0.34	-0.24
***Muscadomestica*(L, P&A)**		0.64	-0.29	-0.62	-0.55	0.61	-0.04	-0.55
***Chrysomyabezzianna* (L)**		0.59	-0.21	-0.55	-0.48	0.57	-0.07	-0.48
***Physiphora*sp. (A)**		0.41	0.01	-0.34	-0.26	0.42	-0.26	-0.26
***hyllomyza*sp. (A)**		0.56	-0.87	-0.63	-0.69	-0.42	0.86	-0.69

Conclusions

In the present study, compost showed good physical and chemical properties with neutral pH and low electrical conductivity, due to the increasing decomposition and high organic matter content. The taxa of insects are widely distributed during the composting process. The most dominated genera belonged to orders Diptera, with few numbers of Coleoptera. Strong positive correlations were observed between the percentage of total nitrogen and each of *Parahelops* sp. and *Phyllomyza*sp; pH and *Parahelops* sp.; and the percentage of phosphorous and *Omalium* sp. Meanwhile, the highest negative correlations were found between most of the physicochemical parameters and collected species of insect. The lowest correlations were between EC, the percentage of total organic carbon, the percentage of organic matter and *Parahelops* sp.

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