



## Vermicomposting of agro-industrial waste by-product of the sugar industry

Ayten Namlı, Hanife Akça, Muhittin Onur Akça \*

Ankara University, Faculty of Agriculture, Department of Soil Science and Plant Nutrition, Ankara, Turkey

### Abstract

The objective of the study was to investigate the survival of earthworm *Eisenia fetida* during vermicomposting of Sugar Industry wastes. These wastes are called Decanter sludge (DS) and Press filter waste soil (PKF). To achieve the objective a laboratory-based experiment was performed 12 weeks under controlled conditions. Eleven different mixtures were prepared by mixing DS, PKF and farmyard manure (FYM) in different ratios. During the incubation time, earthworms survived in treatments which included less than 50% DS or 50% PKF. The number of earthworms increased significantly in all treatments from 6 to 90 ( $P < 0.05$ ) during the experiment period. Chemical properties (pH, EC, OM, Total Nitrogen, Lime) and heavy metal contents of sugar industry vermicomposts were in accordance with the standard compost limits. Results of the present study indicated that the worms did not live in the medium containing more than 50% of the PKF and 50% of the DS. Vermicompost can be obtained from production wastes of sugar factory by applying vermicompost process on Decanter Sludge at the maximum ratio of 50% or its mix with PKF along with FYM. Use of DS and PKF as feed materials for vermicomposting can assist to turn the wastes into precious materials.

**Keywords:** Sugar waste, decanter sludge, farmyard manure, press filter waste soil, vermicompost, *Eisenia fetida*.

### Article Info

Received : 08.05.2019

Accepted : 10.06.2020

© 2020 Federation of Eurasian Soil Science Societies. All rights reserved

### Introduction

The agriculture of sugar beet in Turkey has spread around the country apart from the Mediterranean and Southeast Anatolia Regions. According to the 2017 data of the Turkish Statistical Institute, for the agriculture of sugar beet, the total plantation area is 3,392,171 hectares, production is 20,828,316 tons and the yield is 6140 tons (Anonymous, 2017). Furthermore, in some European countries, the yield reaches up to 7000-8000 kg ha<sup>-1</sup>. It is known that this difference is because of the climate and farming techniques. Of late, around the world, the recycling of waste products has become a point of interest. As is with every industry, waste products occur while treating the raw materials in the sugar industry as well. PKF and DS are among the waste products of the sugar factories. In the production process of sugar, juice treatment is done in order to both decrease the color materials to a large extent and destroy the building blocks of color materials that are expected to occur in the future; in other words, the juice treatment is made to remove the materials, apart from sugar, in the raw juice. The juice treatment is generally carried out in five stages. These are: i) First Liming, ii) Second Liming, iii) First Carbonation, iv) Second Carbonation, and v) Separation of juice from sediment by filtering and obtaining a watery juice (Ozkan, 2014). In the first carbonation, the muddy juice is precipitated in the decanter. Decanters are based on the principle of sludge particles' precipitation to the bottom because of the difference in intensity. Clear juice accumulates on the decanter, while sludge is left at the bottom. This sludge is named as decanter sludge. Press filter waste soil (PKF) is what is obtained after the carbonation process and separated from juice through filtration. When the amount of these waste

Ayten Namlı

✉ : [namli@ankara.edu.tr](mailto:namli@ankara.edu.tr)

ORCID : 0000-0003-1913-2751

Hanife Akça

✉ : [hmert@ankara.edu.tr](mailto:hmert@ankara.edu.tr)

ORCID : 0000-0001-8529-6469

\* Muhittin Onur Akça

✉ : [moakca@ankara.edu.tr](mailto:moakca@ankara.edu.tr)

ORCID : 0000-0003-4540-9371

(Corresponding author)

products in Turkey is taken into consideration, it is seen that PKF is annually 220,000 tons and DS is 125,000 tons. The sugar factory's wastes are stored in an open field in Turkey and there is a major disposal problem for them. Although fairly rich in organic nutrients, they find little use as agricultural fertilizer. The primary reason for this is the insoluble and imbalanced nature of the nutrient content in these wastes (Bhat et al., 2016). Revaluation of these waste products and decreasing the load on environmental pollution are rather important.

For the treatment of these waste products, vermicomposting is used as a better method in order to deal with this existing problem. Vermicomposting is a removal technique for solid wastes as an environment-friendly and cost-effective technique to turn these waste products by worms into a valuable material for land grading. Kumar et al. (2012) left different agricultural-industrial wastes, which had been left for pre-decomposition, to composting for 12 weeks by using *Eudrilus eugeniae* in a pilot study for vermicomposting. As a result of the study, they determined that the decanter sludge can be used in vermicomposting and benefited to separate and increase the quality of vermicomposting. Dotaniya et al. (2016) stated that the chemical, physical and biological features of soil are developed and the product quality and fertility are increased by implementing the by-products of sugar industry like decanter sludge and residue; furthermore, these products can decrease the use of chemical fertilizers. In their study, Umar and Sharif (2013) studied the high-added value fertilizer potential of the sugar industry and the transformation of these products into vermicompost. They stated that the released vermicompost products are more valuable and their chemical characteristics such as heavy metal contents were within the limits of the usable values and that these products can be used as organic fertilizers in agricultural areas. Sepperumal and Selvanayagam (2015) reported the bagasse wastes at various dosages to composting for 8 weeks, and then to vermicomposting with the worms species such as *Perionyx excavatus*, *Eisenia fetida* for 8 weeks. As the result of their study, they stated that the vermicomposting process can be a different alternative choice for the recycle of the sugar industry's waste into a beneficial product, which can be used in agriculture.

The objective of this study was to estimate the potential of converting the sugar industrial waste DS (Decanter sludge) and PKF (Press filter waste) into vermicompost and to state the suitable ratio of wastes and FYM (farmyard manure) required for proper growth of earthworms.

## Material and Methods

### Materials Description

The earthworms and farmyard manure (FYM) used in this experiment were obtained from a private company, after all the Decanter Sludge (DS) and Press filter waste soil (PKF) came from a sugar plant in the city of Konya, Turkey. After the waste materials are dried and sieved, total elemental analysis is performed on the XRF to reveal the contents of the feed materials. The analysis results were given in Table 1.

Table 1. Initial physicochemical parameters of the feed materials

Materials	OM, %	pH	EC, dS m <sup>-1</sup>	CaCO <sub>3</sub> , %	N, %	CaO, %	P <sub>2</sub> O <sub>5</sub> , %	K <sub>2</sub> O, %
DS	15.27	7.39	0.33	16.42	1.05	10.38	0.15	1.51
PKF	10.36	8.61	1.67	56.78	0.62	54.16	0.41	0.10
FYM	49.00	8.51	2.08	10.92	1.68	8.45	1.19	2.08
Materials	Fe <sub>2</sub> O <sub>3</sub> , %	Ni, mg kg <sup>-1</sup>	Cu, mg kg <sup>-1</sup>	Zn, mg kg <sup>-1</sup>	Pb, mg kg <sup>-1</sup>	Cd, mg kg <sup>-1</sup>	Cr, mg kg <sup>-1</sup>	Hg, mg kg <sup>-1</sup>
DS	4.03	59.90	23.40	62.80	20.10	<0.05	65.00	1.20
PKF	0.16	3.20	7.10	13.90	2.50	<0.05	69.50	1.20

### Experimental Set Up

DS, PKF, and FYM were mixed in different quantities to produce eleven mixtures for incubation experiment. Different combination of DS, PKF, and farmyard manure (FYM) were mixed according to the proportions mentioned below.

Treatments are T<sub>1</sub>: 25% DS+ 75% FYM; T<sub>2</sub>: 30% DS + 70% FYM; T<sub>3</sub>: 40% DS + 60% FYM; T<sub>4</sub>: 50% DS + 50% FYM; T<sub>5</sub>: 20% DS + 20% PKF + 60% FYM; T<sub>6</sub>: 25% DS + 25% PKF + 50% FYM; T<sub>7</sub>: 70% DS + 30% FYM; T<sub>8</sub>: 50% PKF Soil + 50% FYM; T<sub>9</sub>: 70% PKF + 30% FYM; T<sub>10</sub>: 100% DS; T<sub>11</sub>: 100% PKF.

The mixtures, which contained different proportions of the feed materials and which were covered with gauze, were set to optimum 65 ± 10% humidity. Six adult worms (*Eisenia fetida*) were applied to each of the mixtures and the plastic pots were operated to incubation in the dark in a climate chamber at 21°C. The incubation experiment was run in plastic pots, on a dry weight basis, of volume 2500 cc in triplicates. Two kg of feed materials was added uniformly in all the eleven treatments for the study. The moisture content of all mixtures was conserved at 65 ± 10% by distilled water. During the experiment, no additional any waste was included at any stage in any pots. When incubation experiment is over, worms were picked up of each pot and obtained vermicompost materials were air dried and kept for all analysis.

## Physicochemical parameters and nutrient contents

The physico-chemical characteristic analysis was conducted on a dry weight basis. Each treatment was analyzed in triplicate. The parameters of pH and EC were stated in a distilled water suspension of each concentration in the rate of 1:10 using Consort C3010 multi-parameter analyzer. Total organic carbon (TOC) was determined according to Nelson and Sommers (1982), Total nitrogen (TN) was measured by Bremner and Mulvaney (1982). Total carbonate content determined by using the Scheibler calcimeter (Jackson, 1962). The amount of total Fe, Cu, Zn, Ni, Cd, Cr, Pb in digested samples were determined by the ICP-OES (Perkin Elmer DV 2100) by Kamitani and Kaneko (2007).

## Statistical analysis

“ANOVA” was used to figure out the significant differences among different factors. All treatment means were compared with the (LSD) at a 5% level of potentiality. All statistical analyses were performed using Windows Minitab software program (version 17.0).

## Results and Discussion

Twenty-four hours after worms were added, worms could not survive to include more than 50% DS or PKF treatments (T7-T11). Similar results were obtained in three repeated applications and it was decided that the worms did not live in the medium containing more than 50% of the PKF and 50% of the DS. For this reason, treatments between T7-T11 were removed from the experimental program. In the incubation experiment, the worms adapted to the environmental condition of T1- T6 treatments. For this reason, the incubation experiment was continued in these mixtures.

### Number and weight of earthworms (*Eisenia fetida*)

Best suitable mixture for the highest survival of worms was determined by observing growth rate, weight, and mortality. All treatments were performed for 12 weeks and there were survival problems in some treatments during the incubation period. Earthworms survived in treatments which included less than 50% DS or PKF. Nevertheless, FYM was mixed with the PKF in half, while the worms did not live in practice, the worms lived in practice where the FYM was mixed with the DS halfway. According to this result, DS is more suitable for earthworms as environment than PKF. The number of worms increased significantly in all treatments from 6 to 90 ( $P < 0.05$ ). Worms indicated different behavior in the way of growth in varied treatments. A number of earthworms were found in the treatments T5 (87) and T6 (90) which were significantly higher ( $P < 0.05$ ) from all other treatments (Table 2). The average weight of earthworms was found in the treatments T5 (37,70) and T6 (39,81) which were significantly higher ( $P < 0.05$ ) from all other treatments. According to Sangwan et al. (2010), 100% cow dung is the best place for *Eisenia fetida* grown. As indicated by Edwards and Fletcher (1988), the volatile gases, such as CO<sub>2</sub>, NO<sub>2</sub> could influence the living of earthworms.

Table 2. Number and weight of worms at the end of the incubation experiment

Applications	Number of Worms	Weight of Worms (g)
T <sub>1</sub>	62b	30.49b
T <sub>2</sub>	77ab	35.09ab
T <sub>3</sub>	71b	29.95b
T <sub>4</sub>	78ab	34.07ab
T <sub>5</sub>	87a	37.70a
T <sub>6</sub>	90a	39.81a
LSD<0.05	13.36	5.68

### Physico-chemical parameters and nutrient contents of the feed mixtures in different treatments

The results of the analyses of TOC, TN, C/N ratio, pH, EC, lime, total Cd, Pb, Cr, Zn, Cu, Fe, Ni in the vermicompost samples for T1-T6 treatments, derived at the end of incubation, are stated in Tables 3.

The highest TOC and TN were found in the mixture of T1 (25% DS + 75% FM), and the lowest was found the mixture of T6 (25% DS + 25% PKF + 50% FYM). The number of FYM decreases was reduced organic carbon percentage of vermicompost samples. Loss of organic carbon might be because of microbial respiration and decomposition of natural organic matter (Kaushik and Garg, 2003). According to Prakash and Karmegam (2010), changes in microbial populations are closely associated with vermicompost materials. Plaza et al. (2005) reported that the increase of total N mostly referred to decomposition of C-rich materials and, likely the situation of bacteria (N-fixing). One of the reports on vermicomposting (Umar and Sharif, 2013) reported in a different result. It is showed that organic carbon loss may be in charge of nitrogen enhancement and earthworms also impact on nitrogen cycle changes in manure. In general, the amount of organic C decreases

during vermicomposting, while the total N coverage increases (Kızılkaya and Hepşen, 2007; Fatehi and Seayegan, 2010).

The PKF based vermicompost had a higher electrical conductivity (EC) and CaCO<sub>3</sub> content than DS+FYM based vermicompost. The T1 application is only lower in number than the others, and in fact, T1 application and T2, T3, and T4 are statistically the same groups (P< 0.05). Kirven (1986) reports that EC values at 2-4 dS m<sup>-1</sup> for organic materials should be considered moderate, and EC at 4-6 levels should be considered high. Even if the French and Turkish standards on composted EC content are not of a limit value, none of the vermicomposts obtained in this work have exceeded the value specified by Kirven. According to Ansari and Rajpersaud (2012), there was a significant decrease in EC of the initial materials as the vermicomposting process proceeded until a lower EC was attained.

Table 3. Physical and chemical parameters in the vermicompost at the end of the experiment

Applications	T <sub>1</sub>	T <sub>2</sub>	T <sub>3</sub>	T <sub>4</sub>	T <sub>5</sub>	T <sub>6</sub>	NFU <sup>a</sup> Standard	TG <sup>b</sup> Standard	LSD<0.05
TOC, %	43.24a	42.92a	34.56b	30.96b	36.50ab	30.40b	< 15 to 25 % of total matter	<20%	6.510
TN, %	1.60a	1.39a	1.45a	1.23a	1.18a	1.14a	< 1 %*	<0.5*	0.573
P <sub>2</sub> O <sub>5</sub> , %	1.29	1.23	1.02	1.15	1.35	1.30	< 1 %*	-*	0.480
K <sub>2</sub> O, %	2.43a	2.50a	2.52a	2.56a	2.10ab	2.05b	< 1 %*	-*	0.542
C/N	13.51ab	15.43a	11.92b	12.59b	15.46a	13.34ab	> 8	8-22	3.180
CaCO <sub>3</sub> , %	10.73b	10.15b	10.82b	9.95b	23.08a	24.09a	-	-	6.575
pH	8.41a	8.36a	8.46a	8.51a	8.76a	8.88a	-	-	0.969
EC, dS m <sup>-1</sup>	1.19b	1.58ab	1.41b	1.26b	1.84a	1.89a	-	-	0.341
Fe, %	0.39	0.50	0.37	0.39	0.31	0.31	-	-	0.150
Cu, mg kg <sup>-1</sup>	24.60	20.40	18.10	16.10	20.60	19.80	300	450	9.20
Zn, mg kg <sup>-1</sup>	59.00	55.10	48.00	45.90	46.00	50.00	600	1100	13.06
Ni, mg kg <sup>-1</sup>	86.90a	84.40a	83.80a	87.00a	64.30b	66.40b	60	120	6.45
Pb, mg kg <sup>-1</sup>	17.72a	19.55a	12.59ab	10.92b	8.15b	7.25b	180	150	6.48
Cd, mg kg <sup>-1</sup>	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	3	3	-
Cr, mg kg <sup>-1</sup>	70.68	60.3	77.67	64.66b	72.70	75.10	120	350	8.13

The PKF based vermicompost had a higher electrical conductivity (EC) and CaCO<sub>3</sub> content than DS+FYM based vermicompost. The T1 application is only lower in number than the others, and in fact, T1 application and T2, T3, and T4 are statistically the same groups (P< 0.05). Kirven (1986) reports that EC values at 2-4 dS m<sup>-1</sup> for organic materials should be considered moderate, and EC at 4-6 levels should be considered high. Even if the French and Turkish standards on composted EC content are not of a limit value, none of the vermicomposts obtained in this work have exceeded the value specified by Kirven. According to Ansari and Rajpersaud (2012), there was a significant decrease in EC of the initial materials as the vermicomposting process proceeded until a lower EC was attained.

On the other hand, there is an increase in EC may have been due to the loss of weight of organic matter and release of different minerals such as phosphate, ammonium, and potassium as suggested by researchers (Garg et al., 2006; Kaviraj and Sharma, 2003; Khwairakpam and Bhargava, 2009; Hait and Tare, 2011). EC is a good demonstration of the suitability of vermicompost materials, and Kitturmath et al. (2007) have stated as press mud in agro-industrial wastes the electrical conductivity of ranged from 0.76 ds m<sup>-1</sup> to 1.15 ds m<sup>-1</sup>.

The heavy metal contents of the vermicompost are below the standard values specified in the Turkish Organic Manure Regulation and also French NFU 44051 Standard, and its productivity parameters are of equal quality to those of earthworm manure available in the market (Table 3). The heavy metal content of the organic material used in the vermicomposting significantly influences the compost content. Gupta and Garg (2008) have stated that if vermicompost obtained from sewage sludge, there is an increase in heavy metal concentration. In this study, although the vermicomposts obtained from sugar factory wastes contain heavy metals below the limit values, the heavy metal contents must be followed whilst the compost is obtained from such wastes. Therefore in vermicompost materials, thus the metal contamination in vermicompost is a severe problem, it should not apply directly to agricultural areas.

## Conclusion

In this study, it was researched whether vermicompost could be done from DS and PKF which are sugar factory wastes. Eleven orders of DS with PKF and FYM were vermicomposted using a type of earthworm (*Eisenia fetida*) and the living conditions of worms in vermicompost materials were stated in varied feed mixtures. All treatments have a C/N ratio which fulfills the French regulation NFU 44051 standard and the

Turkish Government standard. According to the French Standard, all the treatments vermicompost nearly fulfill the Standard limit value for heavy metals. There is only one heavy metal (Ni) which very close to the limit value of French standards (60 mg kg<sup>-1</sup> for Ni). But all vermicompost's Ni contents are well below the limit values in the Turkish standard (120 mg kg<sup>-1</sup> for Ni). The CaCO<sub>3</sub> content was higher in treatment T5 (20% DS + 20% PKF + 60% FYM) and treatment T6 (25% DS + 25% PKF + 50% FYM) treatments than that in the T1-T4 treatments because of PKF. PKF has higher CaCO<sub>3</sub> as compared to DS and FYM (Table 1). The composts in T1-T4 treatments have a good agronomic quality and a low contaminant and CaCO<sub>3</sub>, which make them suitable for all agricultural lands and crops. It was possible to obtain the vermicompost by mixing the DS alone or as a 50% mixture with PKF (at most 50%) with the burned FYM as the other half, adding the *Eisenia fetida* into the mixture, composting the mixture for about 12 weeks in the dark under the conditions of an average temperature of 21°C and 65±10% humidity. Our results demonstrate that earthworms survived in treatments which included less than 50% DS or PKF. This study revealed that byproducts of sugar industry can be instrumental turned into precious vermicompost with epigeic earthworms *Eisenia fetida*.

## Acknowledgements

This study was financially supported by PankoBirlik Beet Cooperatives.

## References

- Anonymous, 2016. Data of Turkish statistical institutions. Available at [Access date: 29.01.2017]: <http://www.tuik.gov.tr>
- Ansari, A.A., Rajpersaud, J., 2012 Physicochemical changes during vermicomposting of water hyacinth (*Eichhornia crassipes*) and grass clippings. ISRN Soil Science Article ID 984783.
- Bhat, S.A., Singh, J., Vig, A.P., 2016. Effect on growth of earthworm and chemical parameters during vermicomposting of pressmud sludge mixed with cattle dung mixture. *Procedia Environmental Sciences* 35: 425-434.
- Bremner, J.M., Mulvaney, C.S., 1982. Nitrogen total. In: Methods of soil analysis. Part 2 Chemical and microbiological properties. 2nd edition. Page, A.L. Miller, R. H., Keeney, D.R. (Eds.). American Society of Agronomy, No. 9, Madison, WI, USA. pp. 595-624.
- Dotaniya, M.L., Datta, S.C., 2016. Biswas, D.R., 2016. Use of sugarcane industrial by-products for improving sugarcane productivity and soil health. *International Journal of Recycling of Organic Waste in Agriculture* 5(3): 185-194
- Edwards, C.A., Fletcher, K.E., 1988. Interactions between earthworms and microorganisms in organic-matter breakdown. *Agriculture, Ecosystems & Environment* 24(1-3): 235-247.
- Fatehi, M.H., Shayegan, J., 2010. Vermicomposting of organic solid waste with the *E. Fetida* in different bedding materials. *Journal of Environmental Studies* 36(55): 37-42.
- Garg, P., Gupta, A., Satya, S., 2006. Vermicomposting of different types of waste using *Eisenia foetida*: A comparative study. *Bioresource Technology* 97(3): 391-395.
- Gupta, R., Garg, V.K., 2008. Stabilization of primary sewage sludge during vermicomposting. *Journal of Hazardous Materials* 153(3): 1023-1030.
- Hait, S., Tare, V., 2011. Optimizing vermistabilization of waste activated sludge using vermicompost as bulking material. *Waste Management* 31(3): 502-511.
- Jackson, M., 1962. Soil Chemical Analysis. PrenticeHall, Inc. Englewood Cliffs, New Jersey, USA. 498p.
- Kamitani, T., Kaneko, N., 2007. Species-specific heavy metal accumulation patterns of earthworms on a floodplain in Japan. *Ecotoxicology and Environmental Safety* 66(1): 82-91.
- Kaushik, P., Garg, V.K., 2003. Vermicomposting of mixed solid textile mill sludge and cow dung with the epigeic earthworm *Eisenia foetida*. *Bioresource Technology* 90(3): 311-316.
- Kaviraj, Sharma, S., 2003. Municipal solid waste management through vermicomposting employing exotic and local species of earthworms. *Bioresource Technology* 90(2): 169-173.
- Khwaitrakpam, M., Bhargava, R., 2009. Bioconversion of filter mud using vermicomposting employing two exotic and one local earthworm species. *Bioresource Technology* 100(23): 5846-5852.
- Kızılkaya, R., Hepşen, Ş., 2007. Microbiological Properties in earthworm cast and surrounding soil amended with various organic wastes. *Communications in Soil Science and Plant Analysis* 38(19-20): 2861-2876.
- Kirven, D.M., 1986. An industry viewpoint: horticultural testing is our language confusing. *HortScience* 21(2): 215-217.
- Kitturmath, M.S, Girradi, R.S, Basavaraj, B., 2007. Nutrient Changes During Earthworm, *Eudrilus eugeniae* (Kinberg) Mediated Vermicomposting of Agro-industrial Wastes. *Karnataka Journal of Agricultural Science* 20(3): 653-654.
- Kumar, V.V., Shanmugaparakash, M., Aravind, J., Namasivayam, S.K.R., 2012. Pilot-scale study of efficient vermicomposting of agro-industrial wastes. *Environmental Technology* 33(9): 975-981.
- Nelson, D.W., Sommers, L.E., 1982. Total carbon and organic carbon and organic matter. In: Methods of soil analysis. Part 2 Chemical and microbiological properties. 2nd edition. Page, A.L. Miller, R. H., Keeney, D.R. (Eds.). American Society of Agronomy, No. 9, Madison, WI, USA. pp. 539-579.

- Ozkan, M., 2014. Evaluation of sugar beet process in terms of occupational health and safety. Thesis for Occupational Health and Safety Expertise. Ministry of Labour and Social Security, Directorate General of Occupational Health and Safety, Ankara, Turkey. 126 p.
- Plaza, C., Senesi, N., Brunetti, G., Mondelli, D., 2005. Cocomposting of sludge from olive oil mill wastewater mixed with tree cuttings. *Compost Science & Utilization* 13(3): 217–226.
- Prakash, M., Karmegam, N., 2010. Vermistabilization of pressmud using *Perionyx ceylanensis* Mich.. *Bioresource Technology* 101(21): 8464–8468.
- Sangwan, P., Kaushik, C.P., Garg, V.K., 2010. Vermicomposting of sugar industry waste (press mud) mixed with cow dung employing an epigeic earthworm *Eisenia fetida*. *Waste Management & Research* 28(1): 71-75.
- Sepperumal, U., Selvanayagam, S., 2015. Vermiremediation of sugar industry waste using earthworms *Eudrilus eugeniae*, *Perionyx excavatus* and *Eisenia fetida*. *European Journal of Zoological Research* 4(1): 28-36.
- Suthar, S., 2008. Bioremediation of aerobically treated distillery sludge mixed with cow dung by using an epigeic earthworm *Eisenia fetida*. *The Environmentalist* 28(2): 76-84.
- Umar, Z., Sharif, F., 2013. Use of earthworms for composting of sugar industry waste. *Biologia (Pakistan)* 59: 115-123.