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The Impact of the Baker's Yeast and Whey Catalysts to Improvement of Employing Organic Solid Waste in Vermicomposting Technology

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In this study, vermicomposting of organic solid waste with the *E. fetida* in different media materials ratios of the cow manure and rice straw with catalysts of baker's yeast and whey have been investigated. The experiments were performed with 10 treatments with three replications and a total of 30 experimental units. 50 cc whey was added to the first 15 media. 48.5cc baker's yeast (*Saccharomyces cerevisiae*) with a low pH and water along with1.5cc of diluted sodium hydroxide (1 normal at the balloon 50cc) added to each of the second 15 media. The pH receipt to 7.13, which is suitable for the growth of the *E. fetida* earthworm. The earthworms were inoculated the 3 days after the addition of catalysts. The pH, EC, Na and K of the media were measured after 15 and 30 days. The number of earthworms that had entered into substrates with the whey came out immediately. The earthworms that have not been out of media were completely destroyed after two days. After 15 days the pH and EC comparison by means of Duncan's multiple range test (P = 5%) showed significant differences between treatments, and the pH difference between 100% cow manure treatment and other treatments was significant. Significant EC differences observed in the treatment 1 compared with the other treatments. After 30 days the EC had significant differences in treatment 1 compared with the treatments 3-5. As well as there was the significant difference between the first three treatments with the treatments 4 and 5. The media of the baker's yeast increased fermentation rate, the percentage of Na and K, which increases the EC. The Higher ratios of the cow manure were effective in creating pH. The pH levels increased in the second stage; however, it was appropriate to growth and survival of *E. fetida* earthworms.

Key words*:* Catalysts, cow manure, E.fetida, rice straw, vermicomposting.

Much attention has been paid in recent years to manage different organic waste resources at low-input as well as eco-friendly basis. Vermicomposting, utilizing earthworms, is an eco-biotechnological process that transforms energy rich and complex organic substances into a stabilized humus-like product (Benitez *et al*., 2000). Vermitechnology has been proposed globally as potential tool to stabilize the natural and anthropogenic wastes, such as sewage sludge, industrial sludge, plant-derived wastes, agro-industrial solid waste, household waste, animal dung, etc (Aira *et al*., 2002). Vermicomposting is also a bio-oxidative process which engages earthworms and microorganisms (Edwards *et al*, 1988). In which detritivore earthworms interact

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intensively with microorganisms and other fauna within the decomposer community, accelerating the stabilization of organic matter and greatly modifying its physical and biochemical properties (Dominguez *et al*., 2010). The final products, vermicomposts, can be used as sources of organic matter for soil amendment, as sources of nutrients for soil fertilization or as growing media constituents for soilless cultivation (González *et al*., 2010). The biochemical decomposition of the organic matter is primarily accomplished by microbes, but earthworms are crucial drivers of the process as they may affect microbial decomposer activity by grazing directly on microorganisms (Aira *et al*., 2009; Monroy *et al*., 2009; Gómez-Brandón *et al*., 2011a), and by increasing the surface area available for microbial attack after comminution of the organic matter (Dominguez *et al*., 2010). *Eisenia fetida* is a surface-feeding or epigeic species of earthworm which has been shown to have broad international potential for conversion of organic wastes into high-value useful plant growth media (termed vermicomposts) and earthworm biomass, in windrows and a large-scale continuous-flow reactor (Edwards 1988; Edwards & Bohlen 1996). The growth patterns of *Eisenia fetida* (Savigny) in a number of different organic wastes have been investigated by various authors in laboratory studies (Neuhauser *et al*. 1980; Edwards 1988; Reinecke & Viljoen 1990a; Kodolova *et al*. 1994). Most workers studied weight increases during the first two months of active growth until the earthworms produced cocoons. The type, quality and quantities of the organic wastes in relation to the numbers of earthworms were very important in determining the rates of growth of the earthworms (Edwards 1998). Garg *et al* (2012) reported significant increase in total nitrogen, total available phosphorous, total sodium, and total potassium, while decrease in pH, total organic carbon and C:N ratio of the vermicomposting of food industry sludge's (FIS) mixed with different organic wastes employing *E. fetida*.

MATERIALS AND METHODS

Materials and earthworms

Baker's yeast (Saccharomyces cerevisiae), whey's yeast, cow manure and rice straw were the materials used for preparation of the vermicompost production media by the earthworm *E. fetida*. The treatments were prepared by mixing different amounts of cow manure and rice straw, and yeast was added into media. Number 1 relates to the whey yeast and 2 is Baker's yeast (Saccharomyces cerevisiae). The amount of cow manure (the numerator) always had the greater percentage compared with the rice straw (denominator) (Table 1).

Experiment's method

The pre-composting process for a month before the start of the vermicomposting performed in the greenhouse of the Islamic Azad University (khorasgan). For this purpose the rice straw chopped by hand and mixed with the given ratios of cow manure. The weight ratios of the cow manure to the rice straw in the 5 treatments (T1-T2-T3-T4-T5) showed in Table 2. The samples were dumped in garbage bags and were placed in the greenhouse with temperature of 25 ° C. The samples were washed with water twice a week. Then 10 treatments with three replications of the pre-composted samples were made. To create treatments the rectangular plastic container with dimensions of 26cm length, 20cm width and 10cm height were used. The bottom of each container was built by the plastic pipes to drain the excess water media.

About 200 grams of media material (on a dry weight basis) was poured in each container. The insemination was performed by adding 3 grams of earthworm species, *Eisenia fetida*, in each container. The number of worms in terms of feeding the worms in a day was estimated (Each worm equal to its body weight during the day feeds). Adequate moisture content is one of the most important factors necessary for the working of earthworms and microorganisms in vermicomposting system. Earthworms breathe through their skin; therefore the system must have adequate moisture content. The ideal moisture range in vermicomposting process is 60-80% (Neuhauser *et al*. 1988; Edwards 1998(. On this basis, during the study the moisture content of the media was adjusted in the range of 60 to 80%. The optimum temperature range for earthworms during vermicomposting process is 12–28°C (Yadav and Garg, 2011). Accordingly, the media temperature was regulated in the range of 25°C. The pH is the important parameter which greatly influences the vermicomposting process. The acceptable pH range, suitable for earthworms and microorganisms activity, is 5.5–8.5(Kaushik and Garg, 2004).

The whey yeast was added to the first media 15. The second media 15 had the low pH due to baker's yeast (Saccharomyces cerevisiae), so sodium hydroxide 1.0 normal was diluted into balloons of the 50 cc. Then 48.5 cc water and baker's yeast with 1.5cc diluted sodium hydroxide was added to each of the media. pH reached up to 7.13, which is acceptable to the growth of worm *E. fetida*.

In this study, measurement parameters of pH, EC, Na, K during the study period 30 days was carried out every 15 days. Data were analyzed by Duncan's multiple–ranged test (p=0.05) to identify any significant difference between data sets of different parameters of different treatments.

RESULTS

Effect of the whey yeast on the media

After the transfering worms to the media, the number of worms came out of the whey-containing media. A number of earthworms that had not been out of media destroyed and decomposition and decay after two days.

Effect of the baker's yeast on the media in the first stage (after 15 days)

The comparison means of the pH in different treatments showed significant differences between treatments (Table 3). So there was a significant difference at the 0.05 level by the 100% cow manure treatment with other treatments. There was a significant difference between the treatment 1 compared with the treatments 2 and 4. The treatment 4 had significant difference with the treatments 2 and 3. The salinity percentage of the treatment showed significant differences between treatments after 15 days (Table 4). The salinity percentage in the 100% cow manure treatment created significant differences at the 0.05 level with the treatments 1, 2 and 3.

The mean comparison of the EC in different treatments showed significant differences between treatments 1 with other the treatments. The lowest mean salinity related to treatment 1.

Table 1. The yeast type and ratio of the cow manure to the rice straw in the treatments

Row	Media characteristics	Yeast type
1	80/20	1
2	70/30	1
3	60/40	1
4	50/50	1
5	100/100	1
6	80/20	2
7	70/30	2
8	60/40	2
9	50/50	2
10	100/100	2

Table 2. Weight ratios of the cow manure to rice straw in the treatments

$$T_1 = \frac{4550\text{kg}}{1142\text{kg}}$$
$$T_2 = \frac{3980\text{kg}}{1715\text{kg}}$$
$$T_3 = \frac{3415\text{kg}}{2285\text{kg}}$$
$$T_4 = \frac{2845\text{kg}}{2845\text{kg}}$$
$T_5 = 100\%$کود

Table 3. Mean comparison of the pH in the first stage (After 15 days) PH

Duncan[a]	N	Subset for alpha = 0.05			
treatment		1	2	3	4
5.00	3	7.1000			
2.00	3		7.5667		
3.00	3		7.7667	7.7667	
1.00	3			8.1333	8.1333
4.00	3				8.3667
Sig.		1.000	.319	.083	.249

The mean of the EC in the treatments 4 and 5 made significant differences with treatments 2 and 3. The treatment 5 showed the highest mean salinity in comparison with other treatments. The highest and lowest EC% observed in treatments 1 and 5 that were 4.1 and 1.4 respectively (Table 4).

The Duncan analysis showed no significant difference between treatments at 0.05 levels in relation to the sodium and potassium elements in the first stage of the experiment. The figure 1 shows the mean Na and K in the first stage. According to this diagram, the minimum and maximum Na observed in the treatments 3 and 5 at a rate of 2.8 and 2.9 respectively. The maximum K, equal to 0.64, related to the treatment 3 and its minimum, equal to 0.54, allocated to treatment 5.

The effect of baker's yeast on the media in the second stage (after 30 days)

The mean PH with Duncan at 50/0 level showed no significant difference between treatments in the second stage. Figure 2 shows the mean PH of the treatments after 30 days. The treatment 2 with mean PH equal to 8.4 and treatment 5 with the mean PH 8.1 showed highest and lowest acidity. In these two treatments, mean of the PH increased compared with the first stage. However, in the second stage the mean PH decreased of the 8.3 to 8.1 in treatment 4 compared with the first stage.

Table 4. Mean comparison of the EC in the first stage (After 15 days)

EC Duncan[a]	N	Subset for alpha = 0.05			
treatment		1	2	3	4
1.00d	3	1.4667			
2.00c	3		2.6000		
3.00	3		3.1000		
4.00	3		3.3000	3.3000	
5.00	3			4.1333	
Sig.		1.000	.155	.084	

Table 5. EC mean comparison in the second stage (after 30 days)

EC Duncan[a]	N	Subset for alpha = 0.05			
treatment		1	2	3	4
1.00	3	2.5000d			
2.00	3	2.8333cd	2.8333		
4.00	3		3.5667bc	3.5667	
3.00	3			4.2000ab	4.2000
5.00	3				4.8667a
Sig.		.340	.052	.086	.073

Table 6. The mean comparison of Na in the second stage (after 30 days)

Na Duncan[a]	N	Subset for alpha = 0.05	
treatment		1	2
2.00	3	7.9333	
1.00	3	8.2667	
3.00	3	8.4667	
4.00	3		9.3333
5.00	3		10.0333
Sig.		.154	.060

In the second stage EC created significant differences between the treatments (Table 5). So that treatment 1 showed significant difference with treatments 3, 4 and 5. The highest and lowest EC% dedicated to treatments 1 and 5 by 4.8 and 2.5 respectively.

The mean comparison of Na in the second stage revealed the significant differences between the first three treatments with treatments 4 and 5 (Table 6). The highest and the lowest of the mean Na related to treatments 5 and 2 by 10

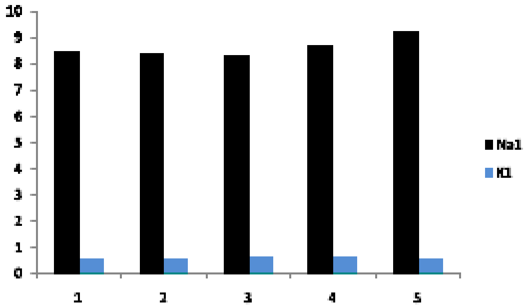

Fig. 1. The diagram of Na and K means of the treatment in the first stage (after 15 days)

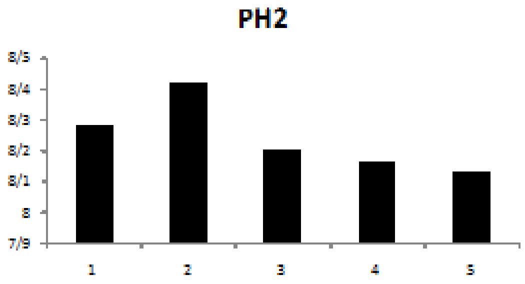

Fig. 2. The diagram of PH means of the treatments in the second stage (after 30 days)

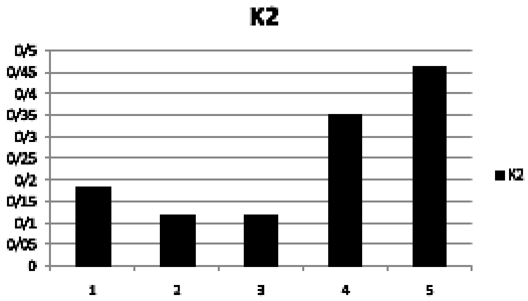

Fig. 3. The diagram of K means of the treatments in the second stage (after 30 days)

and 7.9, respectively.

The Duncan multiple range tests showed no significant difference for the element K in the second stage. Fig 3 shows the mean potassium of different treatments. The treatments 2 and 3 had the minimum potassium equal to 0.12. The maximum potassium, equal to 0.46, dedicated to the treatment 5.

DISCUSSION

The whey yeast media caused the death of *E. fetida* earthworms, so whey yeast was not suitable for vermicompost production. *Eisenia fetida* earthworms had not tolerated the growth and reproduction in this media. This earthworm as garbage-eating species superficial has high potential for organic waste management. The *E. fetida*'s inability in the media of whey yeast can be caused by a reaction to the PH. In the previous studies its reactions to salts, acid, base, moisture, temperature, light and distribution in soil in relation to pH are documented (Gates, I978). Kaplan *et al* (1980) showed that all worms died within a week at pH values < 5 or > 9.

The media impact of baker's yeast in the first stage showed that treatment with PH in 100% cow manure is significantly different from other treatments. PH optimization for *E. fetida* earthworms is normal or near normal. Despite all the treatments created acceptable PH for growth and survival of *E. fetida* earthworm. The highest PH was equal to 3/8 that related to the treatment 4. The treatments were made with identical ratio of cow manure and rice straw. Therefore, higher ratios the cow manure was a factor influencing in the optimal PH.

The PH of treatments with media of baker's yeast did not cause significant differences with each other after 30 days. The maximum PH, equal to 8.4, related to the treatment 2. The minimum PH allocated to the treatment 5, equal to 8.1. At this stage, the mean PH increased in all treatments and the highest increase related 100% cow manure treatment. However, optimum pH is neutral or near neutral. During vermicomposting the pH values of the feed substrate undergoes considerable changes. An initial phase characterized by a low pH is often observed during vermicomposting of feed substrate. This is due to the formation of carbon dioxide and volatile fatty acids in initial. With the subsequent evolution of CO_2 and utilization of volatile fatty acids, the pH begins to rise as the process progresses (Kaushik and Garg 2004).

The mean EC indicated significant differences between the treatments in the both periods of experiment. The lowest and highest EC created by the treatment 5 after 15 and 30 days. The treatments' EC had increased in the second stage, the highest increases observed in treatment 1. Anbalagan *et al.* (2012) showed increasing *in EC by* vermicompost of the cow dung treatment.

Yadav and Garg (2011) stated that increasing in EC may be due to increasing level of soluble salts in available forms due to mineralization of the feed mixtures by earthworms and micro-organisms. The content of inorganic salts is also a crucial parameter with regards to the survival of earthworms (Domínguez and Edwards, 2010a, b), and levels lower than 0.5% are considered acceptable for vermicomposting systems (Edwards, 1988).

The differences of the mean sodium and potassium elements were not significant in the first stage. Comparing sodium's mean using Duncan test indicated significant difference between the first three treatments compared with the treatments 4 and 5 in the second stage. The maximum sodium was 9.2 in the first stage; it reached the peak of 10.2 in the second stage. Secondly, the amount of sodium of the treatments 3, 4 and 5 was increased. The mean of sodium of treatment 1 and 2 was 8.5 and 8.3 at the first stage which decreased to 7.9 and 8.2 in the second stage.

There was no significant difference between the treatments for K in both stages. The maximum and minimum K in the first stage related to the treatments 3 and 5, equal to 0.64 and 0.53 respectively. The maximum K in the second stage related to the treatment 5, equal to 0.46. The minimum K related to the treatments 2 and 3, equal to 0.12. The amount of potassium of all treatments reduced in the second stage.

Prakash Pandit and Maheshwari (2012) vermicomposting sugarcane waste by using *Eisenia fetida*, they showed the potassium and sodium content were increased (1.35 to 3.7 and 2.30 to 3.34 %) at the end of study.

Increasing the amount of sodium and potassium may be due to the metabolic activity of microorganisms presented in earthworms gut. Solubilization of inorganic sodium and potassium in organic wastes by microorganisms through acid production was claimed by Premuzic *et al.*, (1998). Suthar (2007) suggested that earthworm processed waste material contains high concentration of exchangeable Na & K, due to enhancing microbial activity during the vermicomposting process, which consequently enhance the rate of mineraliztion. Orozco *et al.* (1996) have reported lower potassium content in coffee pulp waste after vermicomposting. This might be due to leaching of potassium by excess water that drained through the feeds. Delgado *et al.* (1995) reported higher potassium content in the sewage sludge vermicomposts. Benitez *et al.* (1999) have reported that the leachate collected during vermicomposting process had higher potassium concentration. Sangwan *et al.* (2010a) also reported an increase in potassium in vermicomposts after bioconversion of sugar industry waste. These differences in the observations can be attributed to the differences in the chemical nature of the inorganic wastes used in vermicomposting system.

CONCLUSION

Based on these results, if an appropriate number of the *E. fetida* earthworms are entered in to the media with different ratios of organic waste, including cow manure and straw rice, by providing optimal conditions, the vermicompost with high quality will be produced. Using of the whey yeast create unsuitable conditions for the survival of *E. fetida* earthworms. This leads to immediate worms' coming out of the media and destroying remaining worms in media after two days. The rate of fermentation, sodium and potassium increased in the media baker's yeast. PH of the yeast bread media was acceptable for growth and reproduction of *Eisenia fetida* earthworms after 30 days. Increasing EC at the end of the test resulted by the rising concentrations of mineral nutrients, mainly sodium and potassium.

REFERENCES

1. Aira, M., Monroy, F., Dominguez, J., Mato, S., 2002. How earthworm density affects microbial biomass and activity in pig manure. Eur. J. Soil Boi. 38, 7–10.
2. Aira, M., Monroy, F., Domínguez, J.,2009. Changes in Bacterial Numbers and Microbial Activity of Pig Slurry during Gut Transit of Epigeic and Anecic. Earthworms. *Journal of Hazardous Materials*, vol. 162, No. 2-3, pp. 1404-1407, ISSN 0304-3894.
3. Anbalagan1,M., Manivannan, S., Arul Prakasm, B.,2012. Biomanagement of *Parthenium hysterophorus* (Asteraceae) using an earthworm, *Eisenia fetida* (Savigny) for recycling the nutrients. Advances in Applied Science Research, 3 (5):3025-3031
4. Balagan,M., An1, Manivannan, S., Arul Prakasm., B.,2012. Biomanagement of

Parthenium hysterophorus (Asteraceae) using an earthworm, *Eisenia fetida* (Savigny) for recycling the nutrients. Advances in Applied Science Research, 3 (5): 3025-3031.

5. Benitez E, Nogales R, Elvira C, Masciandaro G, Ceccanti B(1999) Enzyme activities as indicators of the stabilization of sewage sludge composting with Eisenia foetida. Bioresour Technol 67:297–303.
6. Benitez, E., Nogales, R., Masciandro, G., Ceccanti, B., 2000. Isolation by isoelectric focusing of humic–urease complexes from earthworm(*Eisenia fetida*) processed sewage sludges. Biol. Fert. Soils 31, 489–493.
7. Delgado M, Bigeriego M, Walter I, Calbo R (1995) Use of California red worm in sewage sludge transformation. Turrialba 45:33–41.
8. Dominguez, J., Edwards, C.A., 1997. Effect of stocking rates and moisture content on the growth and maturation of Eisenia andrei (Oligochaeta) in pig manure. Soil Biol Biochem 29(3/4),743–746.
9. Domínguez, J., Edwards, C.A., 2010a. Relationships between composting and vermicomposting. In: Edwards, C.A., Arancon, N.Q., Sherman, R.L. (Eds.), Vermiculture Tecnology: Earthworms, Organic Waste and Environmental Management. CRC Press, Boca Raton, Florida, pp. 1–14.
10. Domínguez, J., Edwards, C.A., 2010b. Biology and ecology of earthworm species used

a. for vermicomposting. In: Edwards, C.A., Arancon, N.Q., Sherman, R.L. (Eds.), Vermiculture Tecnology: Earthworms, Organic Waste and Environmental Management. CRC Press, Boca Raton, Florida, pp. 25–37.

11. Domínguez, J, Aira, M., Gómez-Brandón, M., 2010.Vermicomposting: earthworms enhance the work of microbes. In: Insam H, Franke-Whittle I, Goberna M, editors. Microbes at work. Berlin: Springer, 93-114.
12. Edwards, C. A.,1988. Breakdown of animal, vegetable and industrial organic wastes by earthworms. In: Edwards, C. A., Neuhauser, E. F. (eds) Earthworms in waste and environmental management. SPB Academic Publishing, The Hague, pp. 21–31.
13. Edwards, C. A., Bohlen, P. J.,1996. Biology and Ecology of Earthworms. Chapman & Hall, London.
14. Edwards, C.A., 1998. The use of earthworms in the breakdown and management of organic waste. In: Edwards, C.A. (Ed.), Earthworm Ecology. St. Lucie Press, Boca Raton, pp. 327–354.
15. Garg, V.K., Suthar, S., Yadav, A.,2012. Management of food industry waste employing vermicomposting technology. Bioresource Technology 126, 437–443.
16. González, M., Gómez, E., Comese, R., Quesada, M., Conti, M., 2010. Influence of organic amendments on soil quality potential indicators in an urban horticultural system. Bioresour. Technol. 101, 8897–8901.
17. Gómez-Brandón, M.; Aira, M.; Lores, M., Domínguez, J., 2011a. Epigeic Earthworms Exert a Bottleneck Effect on Microbial Communities through Gut Associated Processes. *Plos One*, vol. 6, No. 9, pp.1-9, ISSN 1932-6203.
18. Kaushik, P., Garg., V.K., 2004. Dynamics of biological and chemical parameters during vermicomposting of solid textile mill sludge mixed with cow dung and agricultural residues. Bioresour Technol 94,203–209
19. Kodolova, O. P., Striganova, B. R., Sidorova, T. N.,1994.Comparative study of the reproductive potential in local populations of the manure worm *Eisenia fetida* (Savigny, 1926) (Oligochaeta, Lumbricidae). Ecology (special edition), 449–456.
20. Kaushik, P., Garg, V.K.,2004. Dynamics of biological and chemical parameters during vermicomposting of solid textile mill sludge mixed with cow dung and agricultural residues. Bioresour Technol 94,203–209
21. Monroy, F.,Aira, M., Domínguez, J.,2009. Reduction of Total Coliform Numbers during Vermicomposting is Caused by Short-term Direct Effects of Earthworms on Microorganisms and Depends on the Dose of Application of Pig Slurry. *Science of the Total Environment*, vol. 407, No. 20, pp. 5411-5416, ISSN 0048-9697.
22. Neuhauser, E. F., Kaplan, D. L., Malecki, M. R., Hartenstein, R.,1980. Material supporting weight gain by the earthworm *Eisenia fetida* in waste conversion systems. Agricultural Wastes 2, 43–60.
23. Neuhauser, E.F., Loehr, R.C., Malecki, M.R .,1988. The potential of earthworms for managing sewage sludge. In: Edwards CA, Neuhauser EF (eds) Earthworms in waste and environmental management. SPB Academic Publishing, The Hague, pp 9–20.
24. Orozco,F.H., Cegarra, J.,Trujillo, L.M, Roig A.,1996. Vermicomposting of coffee pulp using the earthworm Eisenia foetida: effects on C and N contents and the availability of nutrients. Biol Fertil Soils 22,162–166
25. Prakash Pandit, N, Maheshwari, S.K.,2012. Optimization of vermicomposting technique for sugarcane waste management by using *Eisenia fetida*. *International Journal of Biosciences* (IJB),

ISSN: 2220-6655. Vol. 2, No. 10(1), p. 143-155.

26. Premuzic,Z., Bargiela, M.,. Garcia, A., Rendina, A., Iorio, A.,1998. Calcium, Iron, Potassium, Phosphorous and vitamin C content of organic and hydroponic tomatoes, Hort Sci. 33, 255-257.
27. Reinecke, A. J., Viljoen, S. A.,1990b. The influence of worm density on growth and cocoon production of the compost worm *Eisenia fetida* (Oligochaeta). Revue d'Ecologie et de Biologie du Sol 27, 221–230.
28. Suthar, S.,Singh, S., 2008. Comparison of some novel polyculture and traditional monoculture vermicomposting reactors to decompose organic wastes. *Ecol Eng*. **33**, 210-219.
29. Sangwan, P., Kaushik, C.P.,Garg, V.K. Vermicomposting of sugar industry waste (pressmud) mixed with cow dung employing an epigeic earthworm *Eisenia foetida*. *Waste Mgmt Res* 2010a; **28**,71–75
30. Yadav, A, Garg .V. K. Industrial wastes and sludges management by vermicomposting. *Rev Environ Sci Biotechnol*. 2011; **10**,243–276
31. Yadav,A., Garg, V.K., *Bioresour., Technol*. 2011; **102**, 2872-2880.