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THE PHYSICO-CHEMICAL CHARACTERISTICS AND MICROBIAL INFLUENCE ON TAPIOCA SOLID WASTE VERMICOMPOSTING

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ABSTRACT

Vermicomposting is the most economical and sustainable option for organic waste management. Tapioca solid waste (TSW) is one of the major biodegradable wastes containing high amounts of organic matter. Utilization of earthworms to breakdown organic wastes is gaining importance in solid waste management in different parts of the world. *Trichoderma viridae*, a cellulase producing fungi and *Bacillus polymyxa* a free living nitrogen fixing bacteria enrich the nutrient content of final compost. The present study has investigated the suitable ratio of tapioca solid waste (TSW) and cow dung (CD) to obtain high quality vermicompost and also to assess the combined effects of poly culture worms and microbes on tapioca solid waste vermicomposting by analyzing the physico-chemical properties of the final compost on the 75th day. The increased levels of nutrients suggest that the suitable ratio of TSW and CD treatment mixture was 1:1, 2:1 and 3:1. The per cent increase in N, P, K, Ca, Mg, Fe and other trace elements were significantly high in the 3:1 ratio sample, which proved to be the most effective treatment mixture. Similarly, there was an increase in the macro and micronutrients (N, P, K, Ca, Mg, Fe, Zn, and Mo) and decrease in Na, Cu and S contents in media treated with a combination of earthworms with microorganisms. Thus, our study showed that the combined use of *T. viridae* and *B. polymyxa* with polyculture worms was the best method for tapioca solid waste composting.

Keywords: Biodegradation, Organic matter, Polyculture worms, *Trichoderma viridae*, *Bacillus polymyxa*

INTRODUCTION

Tapioca or Cassava is a major cash crop in South India. There are about a thousand tapioca factories in South India, processing tapioca tubers into starch and sago. The residue left out from this operation is called tapioca solid waste

(TSW) and is generated at the rate of 15-20% per ton of tapioca tubers processed. The accumulation of this waste near the tapioca industrial area leads to foul odours due to microbial action. It causes the growth of undesirable microflora in the soil, creates fly menace and water pollution. Tapioca waste requires extensive biological treatment to reduce its pollution.

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potential and this involves a heavy capital which is beyond the capabilities of numerous small scale tapioca industries (Banu *et al.*, 2008, Christy and Ramalingam, 2005). Vermicomposting offers solutions to biodegradable waste as well as provides nutrient rich biofertilizer. Earlier studies on cassava peel have proved it to be a potentially valuable resource material for vermicomposting (Mba, 1996). Tapioca solid waste acts as a potential food for worms due to high content of organic matter (OM).

Plant organic wastes such as sugarcane bagasse, coffee pulp, coconut waste and betel nut residue, banana stems, saw dust, bamboo leaf litter, vegetable waste and so on are used for vermicomposting. Proper utilization of various wastes can improve soil physical condition and environmental quality as well as provide nutrients to the plants (Mishra *et al.*, 1989). Vermicomposting is a low cost technology and a viable alternative for the processing or treatment of organic wastes (Hand *et al.*, 1988). The earthworms fragment the organic waste substrates, stimulate microbial activity and increase the rate of mineralization and rapid conversion of the wastes into humus-like substances with a finer structure known as vermicompost. Earthworms feed on organic matter and utilize only trace amounts for their growth and survival and excrete large amounts of the consumed material in a partially digested form as vermicasts. The process involves physical, mechanical and biochemical activities. The physical and mechanical processes include mixing and grinding, whereas, biochemical processes include microbial decomposition in the intestine of the earthworms. Earthworms can consume all kinds of organic wastes, two to five times their body weights and after using 5-10 per cent of the feed stock for their growth, they excrete mucus coated undigested matter as nutrient rich vermicasts (Nedgwa *et al.*, 1999).

Three species of earthworms have been consistently used for commercial composting due to their high tolerance of environmental variations. *Eisenia fetida*, popularly known as European worm or tiger worm is ubiquitous and many organic wastes become colonized naturally by this species. They have a wide temperature tolerance and can live in organic wastes within a wide range of moisture content (Lakshmipraba *et al.*, 2007). *Perionyx excavatus* is very common in several parts of India. This species is highly adaptable and can tolerate varying degrees of moisture. This is a large earthworm, native of Africa commonly known as African night-crawler that grows rapidly and is quietly prolific. The worm *Perionyx excavatus* inhabits litter heaps or any other degrading organic matter such as cow dung on soil surface (Priyashankarchaudhuri, 2005). *Lampito mauritii* is greyish white in colour and shiny, thicker and longer, nearly 16 cms compared to *Perionyx excavatus* and present in the upper layers of the soil and feed on organic waste and leaf litter. *Lampito mauritii* effectively create a drilosphere apart from helping in compost production (Parthasarathi and Ranganathan, 2000).

Inoculation of suitable cellulolytic and lignolytic strains of microorganisms have been reported to hasten the rate of composting which in turn leads to the enrichment of nutrients in the final product (Tiwari *et al.*, 1989). *Trichoderma viridae*, a cellulase producing fungi considered as an effective

inoculant for composting (Manna *et al.*, 2003). Inoculation of free living nitrogen fixing bacteria *Bacillus polymyxa* during composting increases the nitrogen content of the stabilized product (Kaushik *et al.*, 2004). The nitrogen fixing ability of bacteria depends on the organic wastes used. All the microbes present in organic waste are not killed during passage through earthworm gut (Hendrikson, 1990). The quality of the composts depends on several factors viz. type of substrate, aeration, humidity, temperature and earthworm species used during composting (Pramanik *et al.*, 2007).

Hence, the present study investigated the suitable proportion of substrate (TSW) and co-substrate (CD) as well as the effect of microbes on vermicompost by analyzing the physico-chemical properties of the final compost.

MATERIALS AND METHODS

Tapioca solid waste (TSW) was collected from Yogesh Sago Factory, H. Pudupatti, Dharmapuri district, Tamil Nadu, South India, shadow dried and powdered to reduce the particle size. Cow dung (CD) was also collected and shadow dried. Each experimental cistern contained 5kg of feed mixture with varying proportions of TSW and CD viz 1:1, 2:1, 3:1, 4:1, 5:1, 6:1. Each experimental ratio consisted of four media. Medium-1 served as control (C). Medium-2 served as worms (W), where a mixture of three types of earthworms was introduced and maintained as 10 worms/Kg of the feed mix. Medium-3 served as worms and microbes (W+M), 10 worms/kg and two types of microbes (*Trichoderma viridae*, *Bacillus polymyxa*) 50 ml of fresh culture /kg of feed mix was introduced. Medium-4 served as only microbes (M) both types of microbes was introduced 50 ml of fresh culture/kg of the feed mix. The feed mixture was allowed to partially decompose for 20 days before treatment. For each treatment medium three replicates were maintained. After 75 days the composts were collected, air dried, sieved and used for physico-chemical analysis.

The pH was measured in 1:10 (W/V) vermicompost water suspension using water analyzer 371 (systronic). Electrical conductivity was determined in 1:10 (W/V) vermicompost water suspension using water and soil analysis kit (Model 191E). Total organic carbon and organic matter of the vermicompost was estimated by using the standard dichromate oxidation methods (Nelson and Sommers, 1982). Total nitrogen, phosphorous, and potassium were determined by microkjeldhal, spectrophotometric and flame photometric methods respectively. The concentration of sodium, calcium, iron, magnesium, zinc, copper, molybdenum and boron were determined by using atomic absorption spectrophotometer. (Na and Ca metals by flame photometer systronic 125 model, Fe, Mg, Cu, Zn, Mo, B flame AAS/Graphite furnace by direct aspiration of the solutions into an air acetylene or nitrous oxide acetylene flame). Sulfur was determined by gravimetric method (Blumenthal *et al.*, 1935). The starch and cellulose content of the TSW and CD was estimated colorimetrically using anthrone reagent (Hodge and Hofreiter, 1962). C:N ratio was calculated by dividing the percentage of carbon

with percentage by nitrogen.

RESULTS AND DISCUSSION

STATISTICAL ANALYSIS

The whole experimental data was collected and expressed as mean \pm SD. They were analyzed statistically with the computer software SPSS. Statistical comparisons were performed by one-way analysis of variance (ANOVA), followed by Duncan's Multiple Range Test (DMRT). The results were considered statistically significant if the *p* values were 0.05 or less.

The physico-chemical characteristics of the TSW and CD are presented in Table 1. The TSW contains high amount of OM (95.92%), organic carbon (OC) (54.34%), cellulose (22.5%), starch (11.3%), sodium (0.80%) and sulfur (0.90%). The concentration of nitrogen, phosphorus and potassium were however low. The earthworm survived in high content of sugar and nitrogen (Satchell, 1967). Since TSW lack sufficient amount of major nutrients to support the growth of earthworms and microorganisms, it was decided to supplement it with cow dung. Since CD contains high levels of N,

TABLE 1
Physico-chemical characteristics of undecomposed TSW and CD

	TSW	CD
pH	6.4+0.16	5.8+0.03
EC(ds m-1)	2.8+0.39	3.3+0.21
OM%	95.92+0.10	66.36+0.80
OC%	54.34+0.54	36.67+0.04
N%	0.83±0.10	1.23±0.20
P%	0.39±0.012	0.50±0.010
K%	0.20±0.02	0.71±0.024
Na%	0.80±0.02	0.45±0.02
Ca%	0.70±0.04	6.2±0.09
Fe%	0.002±0.0003	2.43±0.09
Mg%	0.21±0.03	0.5±0.01
Cu%	0.002±0.0001	0.30±0.03
Zn%	0.0060±0.0003	0.09±0.003
Mo%	0.0054±0.0004	0.080±0.001
S%	0.11±0.004	0.08±0.001
B%	0.02±0.003	0.03±0.002
C:N	65:1	29:1
Starch%	11.3±0.30	0.05±0.001
Cellulose %	22.5±0.23	2.5±0.11

TSW: Tapioca solid waste, CD: Cow dung

P, K, Ca, Fe and other trace elements. The earthworms prefer higher quantity of NPK and calcium (Cooke Luxton, 1980).

The physico-chemical characteristics of each experimental medium in the TSW and CD feed mixture 1:1 to 6:1 ratios are presented in Tables 2-7. The physico-chemical analysis of the vermicompost indicated that the pH increased over control in all treatment media. A major increase towards neutrality (7.04) was observed in the 3:1 ratio W+M treated medium, and this increase was about 12.5%. The pH around neutrality provides valuable information about the decomposition stage of organic matter during the humification process. The pH close to neutrality also indicates that there was biological stabilization of the product. The decomposition of organic matter leads to the formation of (NH_4^+) ions and humic substance. These two components have exactly opposite effects on the pH. Presence of carboxylic and phenolic groups in humic acid caused lowering of pH, while ammonium ions increased the pH of the system. The combined effect of these

two oppositely charged ions actually regulates the pH of vermicompost leading to a shift of pH towards neutrality (Komilis and Ham, 2006).

The electrical conductivity (EC) was significantly increased in all treatment media. A maximum increase (45%) was observed in the 3:1 ratio W+M treated medium. The increase in EC might have been due to the loss of organic matter weight and release of different mineral salts in available forms such as phosphate, potassium and ammonium (Kaviraj *et al.*, 2003). A gradual increase in EC was observed with increase in decomposition time (Wong *et al.*, 1997).

A high degree of OM reduction was observed in all W+M treated media (70%, 74.14%, and 72.43% in 1:1, 2:1, 3:1 ratios respectively). The percent reduction over control was more in the 3:1 ratio (14.3%) followed by the 2:1 ratio (12.3%) and the 1:1 ratio (11.3%). A gradual reduction with the stabilization of OC was observed. The organic matter in soil and vermicompost acted as a buffer for many deficiency

TABLE 2
Physico-chemical characteristics of vermicomposted TSW:CD (1:1 ratio)

	C	W	W+M	M
pH	6.03±0.02a	6.50±0.04b	6.70±0.12c	6.20±0.04a
EC (ds m-1)	4.0±0.05a	5.0±0.05b	5.31±0.02c	4.1±0.004a
OM%	78.90±0.71a	72.01±0.07b	70.0±0.10c	74.0±0.02d
OC%	46.0±0.07a	41.1±0.20b	35.2±0.10c	40.70±0.12b
N%	0.98±0.01a	2.74±0.05b	3.78±0.08c	1.41±0.10d
P%	0.50±0.012a	0.55±0.02b	0.59±0.03c	0.53±0.03a
K%	0.48±0.024a	0.58±0.01b	0.63±0.001c	0.51±0.01a
Na%	0.65±0.02a	0.33±0.024b	0.29±0.03b	0.64±0.03a
Ca%	3.70±0.05a	5.43±0.05b	5.53±0.41b	4.00±0.30a
Fe%	1.33±0.12a	3.30±0.10b	4.00±0.12c	1.70±0.10d
Mg%	0.36±0.03a	0.44±0.04b	0.46±0.001c	0.40±0.02d
Cu%	0.014±0.001a	0.012±0.002b	0.011±0.001c	0.0143±0.002a
Zn%	0.045±0.004 a	0.062±0.002b	0.072±0.002c	0.048±0.001a
Mo%	0.0090±0.0001a	0.0160±0.001b	0.0200±0.003c	0.0098±0.0002a
S%	0.56±0.02a	0.48±0.01b	0.40±0.01c	0.57±0.07a
B%	0.031±0.002a	0.040±0.004b	0.052±0.001c	0.033±0.002a
C:N	47:1	15:1	09:1	29:1

TABLE 3
Physico-chemical characteristics of vermicomposted TSW: CD (2:1 ratio)

	C	W	W+M	M
pH	6.2±0.05a	6.7±0.05b	6.9±0.023c	6.4±0.07a
EC(ds cm-1)	3.60±0.02a	4.74±0.032b	5.1±0.040c	3.70±0.10d
OM%	82.30±0.21a	74.80±0.08b	72.14±0.30c	77.00±0.33d
OC%	48.00±0.20a	42.20±0.13b	37.50±0.32c	42.10±0.60b
N%	0.96±0.21a	2.70±0.032b	3.72±0.02c	1.43±0.012d
P%	0.44±0.02a	0.52±0.02b	0.58±0.02c	0.48±0.01d
K%	0.39±0.03a	0.46±0.032b	0.53±0.01c	0.42±0.02a
Na%	0.73±0.02a	0.36±0.04b	0.31±0.02b	0.76±0.02a
Ca%	3.20±0.024a	4.80±0.10b	5.03±0.10c	3.60±0.20d
Fe%	1.04±0.11a	3.00±0.012b	3.81±0.10c	1.33±0.02d
Mg%	0.31±0.01a	0.41±0.02b	0.43±0.03b	0.35±0.040a
Cu%	0.011±0.001a	0.009±0.0002b	0.008±0.0001c	0.012±0.0002d
Zn%	0.034±0.003a	0.05±0.004b	0.06±0.004c	0.038±0.001a
Mo%	0.006±0.0003a	0.012±0.001b	0.014±0.001c	0.007±0.0004a
S%	0.63±0.03a	0.53±0.012b	0.42±0.012c	0.65±0.03a
B%	0.022±0.003a	0.030±0.002b	0.039±0.002c	0.024±0.001a
C:N	50:1	16:1	10:1	29:1

cies in soil, it forms the main source of energy for both soil organisms and plants and are also useful in maintaining soil physico-chemical properties (Christy and Ramalingam, 2005).

Application of microbes with worms recorded high loss of OC in all the treatment media. Among the six ratios, the 3:1 W+M treated medium showed high reduction in organic carbon (32.4%) in which it has high proportion of TSW than 1:1 (38.2%) and 2:1 ratio (35.3%). The percentage of reduction over control was high in the 1:1 W+M treated medium (23.5%) followed by 2:1 (21.9%) and 3:1 (21.4%). This was due to the mineralization of the organic matter and higher rate of decomposition by microbes during the vermicomposting process and the loss of water soluble carbon compared to the labile carbon existing in the initial substrate (Garcia *et al.*, 1995).

Total kjeldhal nitrogen (TKN) was high in the 1:1 ratio W+M treated medium (3.78%), due to high proportion of cow dung. But the TKN percent increase was high in 3:1 ratio (288.4%) of W+M treated medium. Microbial inoculation in the biodegradable organic waste increased the TKN content of vermicompost. The Cow dung recorded maximum increase in nitrogen content (275%) upon microbial inoculation (Pramanik *et al.*, 2007). Increase in TKN content in the vermi-

compost on inoculation of lignolytic fungi *T. viridae* might be due to enhanced decomposition of organic matter, leading to decrease in the organic carbon content (Viel *et al.*, 1987). Thus a decrease in the C:N ratio in the vermicompost as compared to the initial organic substrate might be due to the relative increase in the TKN on loss of dry matter organic carbon as CO₂, as well as water loss by evaporation during mineralization (Viel *et al.*, 1987). The decrease in C:N ratio over time might also be attributed to increase in the earthworm population (Nedgwa and Thompson, 2000). The TKN content of vermicompost depended not only on the quality and quantity of initial organic materials but also on the extent of nitrogen fixed by free-living nitrogen fixing bacteria (Kale *et al.*, 1982).

A significant narrowing of C:N ratio occurred in W and W+M treated media of 1:1 ratio (15:1 & 9:1), 2:1 ratio (16:1 & 10:1) and 3:1 ratio (16:1 & 11:1). The C:N ratio is an important criteria of good manure. It should lie between 10 and 20. The plant cannot assimilate mineral nitrogen unless the C:N ratio is 20:1 or less (Edwards and Bohlen, 1996). In the present study, a significant reduction of OM, OC and C:N in W+M & W treatment groups of 1:1 to 3:1 ratios and results fall in line with the already reported results (Karmegam *et al.*, 2000).

TABLE 4
Physico-chemical characteristics of vermicomposted TSW:CD (3:1 ratio)

	C	W	W+M	M
pH	6.26±0.02a	6.81±0.04b	7.043±0.02c	6.5±0.02d
EC(ds m-1)	3.4±0.012a	4.55±0.020b	4.93±0.02c	3.52±0.04d
OM%	84.50±0.40a	75.50±0.50b	72.43±0.50c	78.70±1.0d
OC%	50.10±1.0a	43.50±1.0b	39.40±1.0c	43.20±0.80b
N%	0.95±0.012a	2.69±0.03b	3.69±0.03c	1.45±0.05d
P%	0.42±0.02a	0.56±0.02b	0.63±0.05c	0.50±0.01b
K%	0.36±0.01a	0.44±0.01b	0.52±0.02c	0.41±0.01b
Na%	0.74±0.01a	0.34±0.03b	0.29±0.02c	0.76±0.01a
Ca%	2.37±0.020a	4.46±0.024b	4.90±0.02c	2.70±0.10d
Fe%	0.743±0.01a	2.83±0.014b	3.92±0.02c	1.20±0.04d
Mg%	0.30±0.012a	0.43±0.024b	0.54±0.01c	0.34±0.012d
Cu%	0.0091±0.0002a	0.007±0.0004b	0.004±0.001c	0.0096±0.0002d
Zn%	0.0254±0.002a	0.044±0.001b	0.052±0.001c	0.029±0.001d
Mo%	0.006±0.0005a	0.014±0.001b	0.018±0.001c	0.007±0.0001a
S%	0.67±0.01a	0.52±0.002b	0.43±0.01c	0.70±0.005a
B%	0.017±0.001a	0.030±0.001b	0.040±0.004c	0.022±0.003a
C:N	53:1	16:1	11:1	30:1

Total phosphorous (TP) and total potassium (TK) was high in the W+M treated medium. The 3:1 ratio showed high percentage of increase in total phosphorous (50%) and total potassium (44.4%). Acid production during organic matter decomposition by the microorganisms is a major mechanism for solubility of insoluble phosphorous and potassium. Also, the percentage of large number of microflora in the gut of earthworms might play an important role in increasing P and K content in the process of vermicomposting (Kaviraj, 2003). *B. polymyxa*, being a free living N-fixing bacterium, increased the NO₃⁻ concentration in vermicompost. Higher phosphorous content in the *B. polymyxa* treated vermicompost might be explained by the higher adsorption rate of NO₃⁻ anions which replaced PO₄⁻ ions from humic colloids thereby releasing the PO₄⁻ ions in the system (Alexander, 1977).

The level of calcium was found to be high in the 1:1 ratio W+M treated medium (2.37%). An optimum per cent increase was found in 3:1 ratio (106.8%). The Mg content was

high in the 3:1 ratio W+M treated medium (0.54%), followed by the 1:1 ratio (0.46%) and 2:1 ratio (0.43%). Increase in Ca and Mg content was observed in vermicompost (Joshi and Kelkar, 1952, Kale and Bano, 1988). The increased level of Ca and Mg in the vermicompost may be due to the increased microbial and enzyme activity in the gut of earthworms (Panthasarathi and Ranganathan, 2000). High content of iron was found in the 1:1 ratio W+M treated medium (1.33%), but the per cent increase was high in the 3:1 ratio W+M treated medium (427.5%). This was due to the maximum activity of worms with microbes. Iron is the most abundant metal in the compost. The production of organic acids during composting and further mineralization resulted in the increased concentration of iron (Diaz *et al.*, 1993).

TABLE 5
Physico-chemical characteristics of vermicomposted TSW:CD (4:1 ratio)

	C	W	W+M	M
pH	6.32±0.02a	6.72±0.02b	6.9±0.04c	6.44±0.12n
EC(ds m-1)	3.20±0.004a	3.92±0.01b	4.2±0.012c	3.28±0.001a
OM%	88.04±0.02a	82.3±0.02b	79.05±1.0c	83.80±0.20d
OC%	52.01±0.04a	48.0±0.40b	47.2±0.60b	48.05±0.02b
N%	0.90±0.02a	2.2±0.12b	2.81±0.40c	1.2±0.12d
P%	0.41±0.02a	0.45±0.02b	0.48±0.01b	0.44±0.01a
K%	0.32±0.01a	0.38±0.012b	0.41±0.04b	0.34±0.03a
Na%	0.75±0.01a	0.45±0.02b	0.41±0.03b	0.73±0.02n
Ca%	2.09±0.02a	2.8±0.05b	3.0±0.50b	2.22±0.02a
Fe%	0.52±0.01a	1.21±0.032b	1.40±0.12c	0.65±0.03d
Mg%	0.31±0.03a	0.36±0.03b	0.38±0.01b	0.33±0.03b
Cu%	0.007±0.0002a	0.0061±0.0002b	0.0056±0.0002b	0.0071±0.0002a
Zn%	0.022±0.001a	0.030±0.001b	0.034±0.001c	0.024±0.001a
Mo%	0.005±0.0001a	0.008±0.0001b	0.012±0.001c	0.0054±0.0002a
S%	0.71±0.02a	0.63±0.04b	0.57±0.002b	0.74±0.01a
B%	0.016±0.001a	0.020±0.002b	0.026±0.001c	0.018±0.001a
C:N	57:1	22:1	17:1	40:1

A reduction in the levels of Na and S occur in all media except control and microbe treated medium. The 3:1 ratio W+M treated medium showed a high percent reduction in Na (60.8%) and S (35.8%). The results confirmed that the presence of microbes enhance the activity of worms. It also indicated the worm action was optimum in this group. In general, sulfur is an essential element for the synthesis of amino acids and vitamins. The reduction in Na and S levels may be due to their utilization for worm growth and biomass production (Ramalingam and Ranganathan, 2001).

An increase in Zn was found in all the treatment media. A maximum increase was in the 1:1 ratio W+M treated medium (0.072%); it may be due to the availability of high proportion of cow dung. The percentage increase was high in the 3:1 ratio W+M treated medium (104.7%). The levels of Mo (0.02%) and B (0.052%) were high in the 1:1 ratio W+M treated medium. An optimum percentage of increase for Mo (200%) and B (135.3%) was high in the 3:1 ratio W+M treated medium. A maximum reduction in Cu was observed in the 3:1 ratio W+M treated medium (0.0061%) with the

TABLE 6
Physico-chemical characteristics of vermicomposted TSW:CD (5:1 ratio)

	C	W	W+M	M
pH	6.34±0.02a	6.72±0.02b	6.83±0.05b	6.40±0.08a
EC(ds m-1)	3.11±0.02a	3.80±0.2b	4.00±0.21b	3.18±0.02a
OM%	88.3±0.90a	82.3±0.01b	80.03±2.0b	86.2±0.70a
OC%	53.02±2.0a	50.3±3.0a	49.00±1.0a	50.33±3.0a
N%	0.88±0.021a	2.0±0.22b	2.30±0.30b	1.1±0.20a
P%	0.40±0.004a	0.43±0.024a	0.45±0.04a	0.42±0.20a

(cont'd)

	C	W	W+M	M
K%	0.30±0.04a	0.34±0.012b	0.39±0.02b	0.31±0.02a
Na%	0.75±0.02a	0.51±0.02b	0.43±0.02c	0.74±0.02a
Ca%	1.9±0.10a	2.6±0.30b	2.7±0.22b	2.0±0.3a
Fe%	0.44±0.01a	0.97±0.04b	1.10±0.02c	0.50±0.03a
Mg%	0.21±0.02a	0.24±0.01a	0.26±0.02a	0.22±0.03a
Cu%	0.006±0.0003a	0.0054±0.0003b	0.005±0.0004b	0.0062±0.0002a
Zn%	0.02±0.003a	0.024±0.001b	0.028±0.001b	0.021±0.002a
Mo%	0.0045±0.0002a	0.006±0.0002b	0.0088±0.0001b	0.0048±0.0002a
S%	0.73±0.02a	0.68±0.02b	0.66±0.001b	0.75±0.01a
B%	0.0154±0.001a	0.019±0.002b	0.021±0.002c	0.0172±0.0004a
C:N	58:1	25:1	21:1	45:1

TABLE 7
Physico-chemical characteristics of vermicomposted TSW:CD (6:1 ratio)

	C	W	W+M	M
pH	6.4±0.020a	6.72±0.01b	6.8±0.12b	6.5±0.1a
EC(ds m-1)	3.05±0.03a	3.62±0.024b	3.84±0.03c	3.11±0.10d
OM%	88.07±0.02a	83.05±0.03b	80.08±0.021c	87.06±0.01d
OC%	54.30±7.0a	52.40±0.50b	50.40±1.0c	52.02±0.012a
N%	0.86±0.012a	1.80±0.21b	2.05±0.40b	1.03±0.10a
P%	0.39±0.02a	0.41±0.02a	0.43±0.02a	0.41±0.02a
K%	0.28±0.02a	0.31±0.01a	0.33±0.024a	0.30±0.03a
Na%	0.76±0.02a	0.55±0.04b	0.49±0.03b	0.78±0.01a
Ca%	1.80±0.01a	2.20±0.20b	2.53±0.44c	1.90±0.10a
Fe%	0.39±0.004a	0.75±0.04b	0.90±0.03c	0.42±0.02d
Mg%	0.21±0.02a	0.23±0.03a	0.26±0.02b	0.22±0.01a
Cu%	0.006±0.0001a	0.0056±0.0002b	0.0052±0.0002b	0.0062±0.0003a
Zn%	0.018±0.001a	0.019±0.001a	0.022±0.002b	0.0185±0.002a
Mo%	0.0044±0.0002a	0.0052±0.0002b	0.0069±0.0004c	0.0046±0.0002a
S%	0.78±0.01a	0.73±0.01b	0.71±0.01b	0.79±0.01a
B%	0.016±0.002a	0.018±0.004a	0.02±0.001a	0.017±0.002a
C:N	63:1	29:1	25:1	50:1

C: Control, W: Worms, W+M: Worms and Microbes, M: Microbes

optimum percentage of decrease (56%) over control. The total micronutrient was higher in vermicompost than compost, while the trend was reverse with regard to copper (Rajesh et. al., 2003).

CONCLUSION

It can thus be concluded from the above findings the optimum ratio of TSW and CD treatment mixture was 1:1, 2:1 and 3:1, among these ratios the 3:1 ratio proved the be most

effective. Similarly, the levels of macronutrients and micronutrients were significantly high in treatment media which had both earthworms and microorganisms.

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