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RESEARCH ARTICLE

Earthworms Converting Milk Processing Industry Sludge into Biomanure

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Abstract:

Aims and Objectives:

The present study was conducted to utilize the Milk Processing Industry Sludge (MPIS) for the purpose of vermicomposting, in two sets of experiments *viz*. with earthworms (ME) and without earthworms (MW).

Methods and Materials:

Twenty young non-clitellated *Eisenia fetida* were released in each tray. The various parameters like growth, clitellum development, biomass, cocoon production and hatchlings of *E. fetida* were observed after every 15 days, during 90 days of vermicomposting.

Results:

The maximum growth and better responses were observed in ME_{25} mixtures of MPIS which was the minimum ratio of the waste to CD. The physico-chemical analysis (pH, EC, TKN, TOC, C/N ratio, TAP, TK, TNa) and heavy metals (Cr, Cu, Mn, Pb) were also done before and after vermicomposting process. There was a significant increase in TKN (23-46%), and TAP (39-47%), and a decrease in pH (6.2-6.8%), EC (24.6-37.2%), TOC (16.8-37.9%), C/N ratio (23.8-97.9%), TK (26.6-40.6%), and TNa (31.3-53%) and heavy metals (Cr 30.9-40.6%, Cu 32.7-44.6%, Mn 23.9-36.3%, and Pb 32.6-42.9%) from initial to final feed mixtures with earthworms.

Conclusion:

Thus the final vermicompost had excellent physico-chemical properties with all nutrients in plant available forms. The study further strengthens that the vermicomposting is an efficient technique in converting MPIS into nutrient rich biomanure in a short period of time *i.e*. 90 days.

Keywords: Growth, Vermiremediation, Solid industrial waste, *Eisenia fetida*, Heavy metals, Physico-chemical analysis.

1. INTRODUCTION

Modern industrialization generated a large quantity of wastes in industrial sectors such as sugar, pulp and paper, food and beverage plants, sago/starch, distilleries, milk processing plants, tanneries, slaughterhouses, poultries *etc*. India produces about 94.5 million tonnes of milk annually which is expected to be increased up to 135 million tonnes by the year 2015 [1]. Indian milk-based product processing mills is one of the major food processing mills in the country. The solid and liquid wastes generated from milk processing industry can create health and other pollution problems [1, 2]. The traditional methods of disposal such as open dumping and land filling practices of industrial wastes are not only expensive, but also environmentally unsafe [3]. The biodegradation of industrial waste prior to its use could reduce the

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pollution associated with its management [1, 4, 5]. Vermicomposting by earthworms is a bio oxidative process which is considered as one of the alternative options for converting wastes into nutrient rich vermicompost useful for plants and the soil [6, 7]. Vermicompost is also considered in agricultural practices as an alternative to chemical fertilizers [8]. Vermicompost is a rich source of plant available nutrients such as Nitrogen, Potassium, Phosphorus (NPK), sodium, magnesium and calcium [9 - 11] and can play a major role in sustainable agriculture. The final vermicompost produced from industrial wastes are generally granular in shape due to earthworm degradation and stabilization [12, 13]. Traditional composting involves biodegradation of wastes by microbes under controlled conditions. The major drawback of this process is the loss of nitrogen through volatilization of ammonia during the thermophillic stage of composting [14]. Milk processing industry pollutants are mostly of organic origin (carbohydrate, lipids, protein, suspended oils) with high concentration of biochemical oxygen demand, chemical oxygen demand, nitrate contents and suspended solids [15]. Earthworm *Eisenia fetida* can stabilize the Milk Industry Sludge (MPIS) potentially and can increase the rate of degradation of sludge greatly, which probably minimizes the putrefaction [1]. The increased rate of biodegradation of sludge is probably achieved by the maximum aeration and turnover of sludge by the earthworms [16].

The aim of the present study was to assess and compare spontaneous or natural composting (without earthworms) and vermicomposting of waste sludge from milk processing industry and to produce an end product which can be used as an organic fertilizer. The biodegradation of Milk Processing Industry Sludge (MPIS) using *E. fetida* can also be checked for the enhancement in plant nutrients (N, P, K) with the availability of phosphate and reduction of heavy metals (Cu, Pb, Mn, Cr) after completion of vermicomposting process.

2. MATERIAL AND METHODS

2.1. *E. fetida*, Milk Processing Industry Sludge and Cattle Dung

Young non-clitellated *E. fetida* were obtained from a stock culture reared in the vermicomposting unit of the Department of Botanical and Environmental Sciences, Guru Nanak Dev University, Amritsar, Punjab, India. MPIS was obtained from Haryana Dairy Development Cooperative Federation Ltd., Vita Milk Plant, Sirsa, Haryana. The sludge was collected at primary sedimentation stage. The collected sample was air dried for moisture removal. Cattle Dung (CD) was collected from a local dairy farm.

2.2. Experimental Design

In the present work, MPIS was mixed with CD at different ratios on dry weigh basis in two sets with earthworms (ME) and without earthworms (MW) (Table **1**). Plastic trays of volume 3,834 cc were filled with mixtures containing different percentages of MPIS/CD with and without earthworms in triplicates. The total weight of each tray was kept at 1 kg and according to the above mentioned proportions in Table **1**, mixing of waste and cattle dung was done. The trays were covered with jute mat and were kept in a shade located in the Botanical Garden of Guru Nanak Dev University, Amritsar. The mixtures were turned over manually every 24 h for 14 days in order to eliminate the toxic gases. After 14 days, 20 young non-clitellated *E. fetida* with average weight were released in trays. The moisture content was maintained to 60-70% throughout the study period by sprinkling of water. In ME sets earthworms, cocoons and hatchlings were counted manually at the interval of 15 days. At the end of the experiment (90 days), worms, cocoons and hatchlings were removed. The final product produced from all the concentrations were sieved, air dried and physico-chemical parameters were analyzed. The initial physicochemical parameters of MPIS and CD were also done (Table **2**).

Table 1. Preparations of milk processing industry sludge mixed with cattle dung.

Feed Mixture Concentrations with Earthworms Without Earthworms	Milk Processing Industry Sludge (MPIS)	Cattle Dung (CD)
ME MW	0	100
ME_{25} MW_{25}	25	75
ME_{50} MW_{50}	50	50
ME_{75} MW_{75}	75	25
ME_{100} MW_{100}	100	0

Table 2. Initial physicochemical properties of milk processing industry sludge and cattle dung.

Physico-Chemical Parameters	Milk Processing Industry Sludge (MPIS)	Cattle Dung (CD)
pH	8.34±0.03	7.86 ± 0.26
EC (mS/cm)	3.33±0.03	3.68 ± 0.04
TKN (%)	3.79±0.03	3.13±0.03
TOC (%)	49.21±0.10	41.92±1.54
C:N ratio	42.79±1.10	13.27±0.59
TAP (%)	1.88±0.05	2.81±0.07
TK (%)	1.96±0.01	0.51±0.02
TNa (%)	1.91±0.01	0.90±0.02
Cr (mg/kg)	30.87±0.12	12.07±0.37
Cu (mg/kg)	22.42 ±0.22	5.55 ±0.17
Mn (mg/kg)	85.11±0.87	40.61±0.17
Pb (mg/kg)	18.02±0.07	8.09±0.11

2.3. Physico-Chemical Analysis

Physico-chemical analysis was done to determine the availability of total nutrient content in final MPIS feed mixtures ' with and without earthworms. pH and electrical conductivity (EC) were determined in a double distilled water suspension of each concentration in the ratio of 1:10 (W/V). Total Organic Carbon (TOC) was measured after igniting the 0.5 g of sample in a muffle furnace at 550°c for 60 minutes as described by Nelson and Sommers [17]. Micro-Kjeldhal method of AOAC [18] was used for measuring total Kjeldhal nitrogen (TKN) after digestion. The method described by John [19] was used for measuring Total Available Phosphorus (TAP), Total Potassium (TK) and Total Sodium (TNa) after digesting the samples in diacid mixture ($HClO_4$:HNO_3 in 4:1 ratio). Heavy metals (Copper, Lead, Manganese and Chromium) were measured by Agilent 240 FS AA model Atomic Absorption Spectrophotometer in the digested samples.

2.4. Statistical Analysis

The data was presented as mean ± SE of triplicate experiment. One-way ANOVA was used to calculate the differences among treatments. Student's paired t-test was used to evaluate differences between initial and final values of various physico-chemical parameters. Statistical data analysis was done with the help of Statistical Package for the Social Sciences (SPSS) software.

3. RESULTS AND DISCUSSIONS

3.1. Earthworm Growth and Reproduction in Waste Mixtures

The number of earthworms increased significantly ($p \leq 0.05$) in different waste mixtures (Fig. **1**). The number of earthworms increased till 90 days in all waste mixture (ME, ME_{25}, ME_{50} and ME_{75}) except ME_{100} concentration. The maximum number of earthworms (41.5) was observed in waste mixture ME_{25} on 90th day of experiment followed by (39.0) in ME, ME_{50} (37.5), ME_{75} (34) and (28.5) in ME_{100} waste mixtures. The development of clitellum was found between 30th to 45th days of the experiment in all the waste mixtures of MPIS. Few earlier studies also observed the slow growth rate in mixtures with higher proportion of milk processing industry waste [1, 2]. No mortality of *E. fetida* was observed in any concentration, the reason could be probably the non toxicity of MPIS.

The number of cocoons also showed a significant difference ($p \leq 0.05$) in different proportions of MPIS (Fig. **2**). The formation of cocoon was noticed on 45th day of the experiment in all the waste mixtures. The maximum number of cocoons was observed in ME_{25} (49.5) on 90th day of the experiment. Cocoon production was relatively less in higher proportions of waste like ME_{100} and ME_{75} when compared with the lower proportion ME_{50} and $ME_{25.}$ Initially, cocoon formation rate was lower, and with time, it was enhanced. It is clear from the present study that cocoon formation in different waste proportions was directly related to the feedstock quality. The results of cocoon formation are corroborated by the findings of other researchers who have analyzed waste quality dependent cocoon formation patterns in earthworms during the process of vermicomposting [7, 20].

The number of hatchlings was also significantly different ($p \leq 0.05$) in different proportions of MPIS (Fig. **3**). The first hatchlings were observed on 60th day of experiment in ME, ME_{25}, ME_{50}, ME_{75} and ME_{100}. The maximum number of hatchlings were observed on 90th day of experiment in ME_{25} (37.5) followed by ME (33.0), ME_{50} (28.5), ME_{75} and ME_{100} (20.5). Similar results have been reported by Vig *et al.* [21] during vermicomposting of tannery sludge mixed with cattle dung.

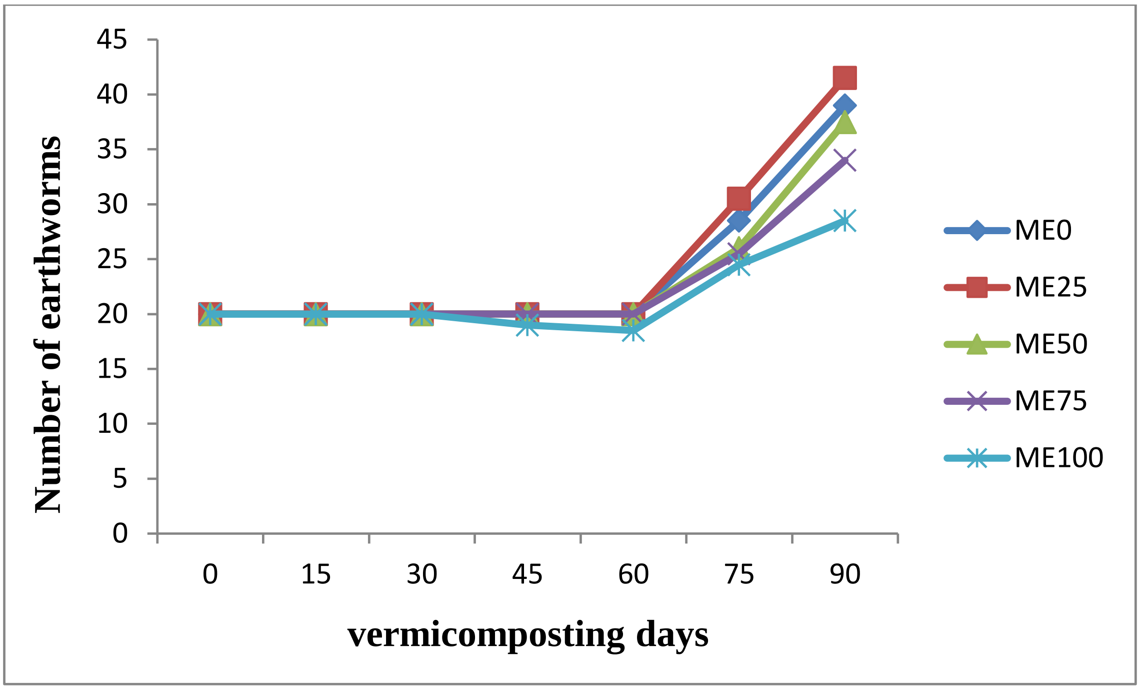

Fig. (1). Number of earthworms in different waste mixtures of milk processing industry sludge and cattle dung.

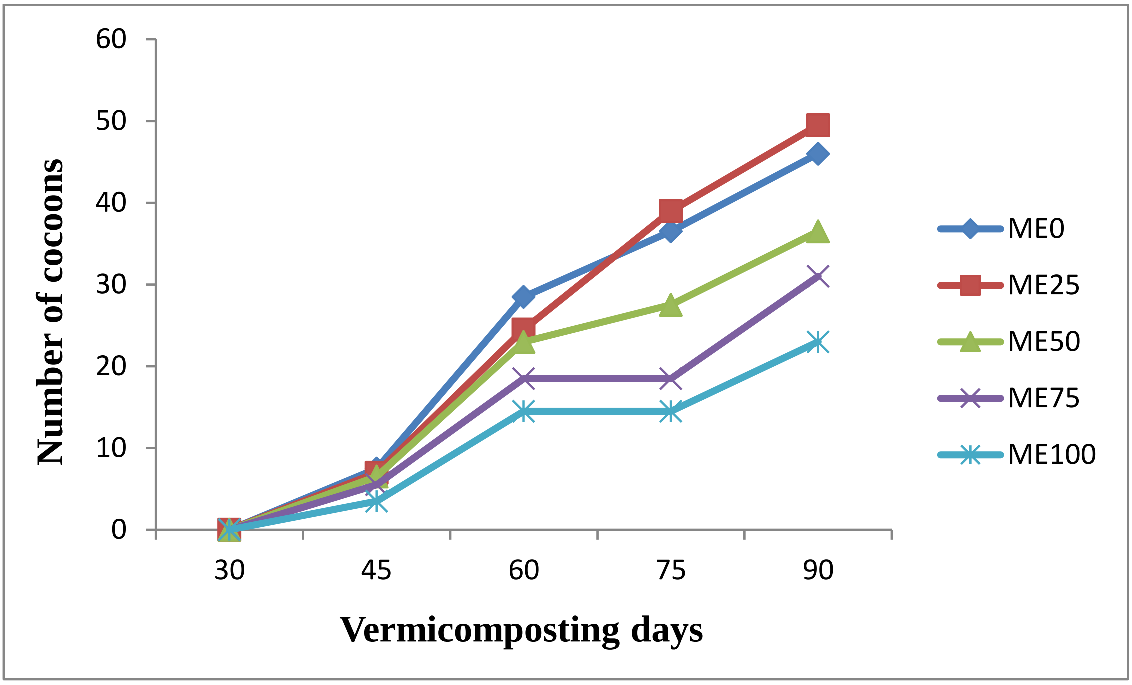

Fig. (2). Number of cocoons in different waste mixtures of milk processing industry sludge and cattle dung.

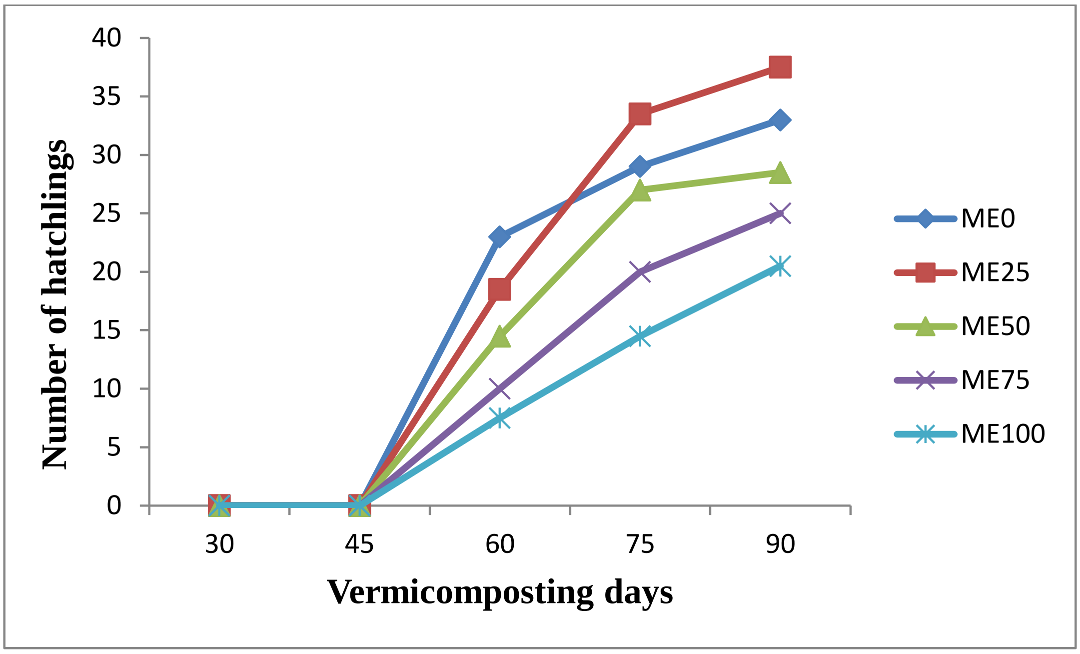

Fig. (3). Number of hatchlings in different waste mixtures of milk processing industry sludge and cattle dung.

3.2. Physico Chemical Analysis

The physicochemical parameters of different proportions of MPIS and CD with and without earthworms are given in Table **3**. There was a significant reduction in pH of final vermicompost as compared to initial feed mixtures with earthworms. The maximum decrease in pH was in ME_{25} (7.6%) waste mixture and minimum in ME_{50} (6.2%) feed mixture. The percent decrease in pH was in order of $ME_{25} > ME > ME_{100} > ME_{75} > ME_{50}$. The reduction in pH of final vermicompost has also been confirmed by other authors [10, 22, 23]. The pH decrease could be due to the production of metabolic compounds of aerobic digestions (CO_2, ammonia, NO_3^- and organic acids) during vermicomposting process [24]. Suthar *et al.* [2] also confirmed a significant reduction in pH during vermicomposting of milk processing plant sludge. Das *et al.* [25] also observed that the alkaline pH of organic waste is shifted towards the neutral pH during vermiremediation of organic wastes. This might be due to the combined action of microbial metabolism and release of organic acids during vermistabilization. The pH reduction was again related to the quality of the initial sludge mixture as it was approaching towards a neutral pH from an alkaline state.

Electrical Conductivity (EC) declined significantly (<0.05) over initial in the end product of vermicompost. The maximum decrease in EC was in also ME_{25} (37.2%) waste mixture and minimum 24.6% in ME_{75} feed mixture. The percent decrease in EC was in order of $ME_{25} > ME > ME_{100} > ME_{50} > ME_{75}$. Waste mixtures without earthworms also showed some decline in the EC, the maximum decrease in EC was in MW_{25} (8.1%) and minimum in MW_{100} (1.9%). Singh *et al.* [26] also observed that the reduction in EC may be due to the production of soluble metabolites during vermicomposting. Varma *et al.* [27] also reported reduction in the Electrical Conductivity (EC) during vermiconversion of waste carbide sludge and agricultural waste. The EC reduction may be due to the addition of waste carbide sludge to agricultural wastes and uptake of the minerals by earthworms. Reduction in ionic concentration will produce better compost at the end.

There was a significant decline ($p < 0.05$) in the Total Organic Carbon (TOC) of the end products of vermicomposting. Decline in TOC was maximum in ME_{25} (37.9%) and minimum in ME_{100} (20.1%) feed mixtures. The percentage of decrease in TOC was in order of $ME_{25} > FE > ME_{50} > ME_{75} > ME_{100}$. Waste mixtures without earthworms showed slight decline in TOC. Decline in TOC was maximum in MW_{50} (16.2%) and minimum in MW_{100} (8.9%) feed mixture. TOC loss was more in which earthworm mixtures as compared to the end products of without earthworms. Suthar [1] also observed a significant decrease in TOC due to combined action of earthworms and microorganisms. Similar observations have been reported by Bhat *et al.* [7, 10] during vermicomposting of sugar mill waste. Khwairakpam and Bhargava [28] observed that the cattle dung contains various fungal stains and other microbes like bacteria, protozoa, nematodes, fungi, actinomycetes, which play an important role in organic matter decomposition by providing extra-cellular enzymes in vermireactors. The organic carbon reduction in vermicomposting is the result of metabolic process in feed mixtures as well as assimilation of carbohydrates and other polysaccharides from the feed mixtures by earthworms. This reduction will also maintain a good C/N ratio for the end product to be used as manure.

Total Kjeldhal Nitrogen (TKN) content increased significantly with vermicomposting time in all waste mixtures in the presence of earthworms. The maximum increase in TKN was in ME (46.0%) and minimum in ME_{100} (23.2%). The percentage of increase in TKN was in the order of ME> ME_{25}> ME_{50}> ME_{75}> ME_{100}. Waste mixtures without earthworms also showed slight increased in TKN but not like with earthworms. The maximum increase in TKN was in MW_{100} (10.8%) and minimum in MW_{75} (7.6%). Many researchers have revealed that the earthworms add nitrogen to the final substrates in the form of mucus, nitrogenous excretory substances, growth stimulating hormones and enzymes [1, 29 - 31]. Loss in TOC might be responsible for the addition of TKN. The content of nitrogen rich substances in waste mixtures is always important for overall nitrogen enhancement of the vemicompost.

The C:N ratio decreased significantly ($p < 0.05$) with time in waste mixtures in the presence of earthworms. Decline in C:N ratio was maximum in ME_{25} (57.4%) feed mixture. The percentage of decrease in C:N ratio was in order of ME_{25} > ME> ME_{50}> ME_{75}> ME_{100}. However, waste mixtures without earthworms showed a little decrease in C:N ratio. The maximum decrease in C:N ratio was in MW_{50} (24.3%) and minimum in MW_{75} (16.10). Senesi *et al.* [32] observed that a decline of C:N ratio to less than 20 indicates an advanced degree of organic matter stabilization and maturation. Change in C:N ratio is understandable and proportional to changes in TOC and TKN. In the present experiment, the decrease in C/N ratio in the feed mixtures with earthworms is brought about by a simultaneous decline in TOC and an increase in the TKN content. Cabrera *et al.* [33] also observed that vermicomposting resulted in faster reduction of C/N ratio as compared to traditional composting.

Total Available Phosphate (TAP) increased significantly $p <0.05$) with time in all the waste mixtures in the presence of earthworms. The maximum increase in TAP was recorded in ME_{25} (47.1%) feed mixture and minimum in ME_{50} (39.0%) feed mixture with earthworms. The percentage of increase in TAP was in order of ME_{25}> ME_{100}> ME_{75}> ME> ME_{50}. On the other hand, a little increase in TAP was also observed in waste mixtures without earthworms. The maximum increased in TAP was in MW_{25} (17.6%) and minimum in MW (11.8%) feed mixtures. Pramanik *et al.* [34] observed that the acid production during organic matter decomposition by the micro-organisms is majorly responsible for solubilization of insoluble phosphorus, which results in TAP increase in feed mixtures with earthworms.

Total Potassium (TK) decreased significantly from initial in different waste mixtures of earthworms with time. Maximum percentage decrease in TK content of vermicompost with earthworms was in ME (55.8%) and minimum in ME_{75} (26.6%). The percentage of decrease in TK was in the order of ME> ME_{25}> ME_{50}> ME_{100}> $ME_{75.}$ Slight decrease in TK was also reported in waste mixtures without earthworms. Maximum percentage decrease in TK content was in MW (28.82%) and minimum in MW_{100} (10.95%). Many researchers have also observed a decrease in TK after vermicomposting [7, 35, 36]. TK concentration in the feed mixtures of MPIS with earthworms had decreased significantly as compared to without earthworm mixtures by the end of the vermicomposting, and this decrease may be due to the use of potassium by worms during their metabolic activity.

Total Sodium (TNa) decreased significantly from initial in different waste mixtures with earthworms. Maximum decline in TNa was in ME (53.0%) and minimum in ME_{75} (31.3%) waste mixture. The percentage of decrease in TNa was in order of ME> ME_{25} > ME_{50}> ME_{75}> ME_{100}, *i.e.*, more decrease in less waste concentration. The feed mixtures without earthworms also showed some decline in TNa. The maximum declines in TNa was in MW (30.0%) waste mixture and minimum (14.5%) in MW_{100} mixture, but the decrease was comparatively less than vermicomposting. Reduction in sodium concentration helps in the reduction of SAR (Sodium Adsorption Ratio) [37], thus affecting the efficiency of compost.

3.3. Changes in Heavy Metal Content

It is important to know the concentration of metals in the end product before being applied to soil due to their high risk and toxicity [38]. The heavy metals Copper (Cu), Lead (Pb), Manganese (Mn) and Chromium (Cr) decreased significantly over initial in different waste mixtures with earthworms (Table **4**). Maximum decrease in Cu was in ME_{25} (44.6%) and minimum in ME (32.7%). The percentage of decrease in Cu was in order of ME_{25}>ME_{50}>$ME_{75}$$ME_{100}$>ME. A small fraction of decrease in Cu was also observed in feed mixtures without earthworms. Maximum decrease in Cu in feed mixture was in MW_{50} (25.5%) and minimum (12.70%) in MW_{100} feed mixture. Pb content was also decreased significantly with maximum decrease in ME_{50} (42.9%) and minimum in ME_{100} (32.6%) feed mixtures with earthworms. The percentage of decrease in Pb was in order of $ME_{50}>ME_{25}>ME>E_{75}>ME_{100}$. Feed mixtures without earthworms also showed some decrease in Pb content. The maximum decrease in Pb was observed in ME_{50} (25.3%) and minimum (12.8%) in ME_{100}. Mn decreased significantly from initial in different feed mixtures with earthworms ($p<0.05$). Maximum and minimum decrease in Mn was observed in ME and ME_{100}, (36.3%) and (25.6%), respectively. The percentage of decrease in the Mn was in the order of $ME>ME_{25}>ME_{50}>ME_{75}>ME_{100}$. A slight decrease in Mn content was also observed in waste mixtures without earthworms. The maximum decrease in the Mn was observed in waste mixture MW_{75} (14.17%) and minimum in feed mixture MW_{100} (12.49%). Cr decreased significantly from initial in different feed mixtures with earthworms ($p<0.05$). Maximum decrease in Cr was in ME_{25} (40.6%) and minimum in ME_{50} (30.9%) waste mixture. The percentage decrease in Cr was in order of $ME_{25}>ME>ME_{75}>ME_{75}>ME_{50}$. A slight fraction of decrease in Cr was also observed in feed mixtures without earthworms. Maximum decrease in Cr was in MW_{25} (25.3%) and minimum (17.64%) in MW_{100} waste mixture. Ghyasvand *et al.* [39] also confirmed that the availability of heavy metals like Pb and Cd decreases due to bioaccumulation of metals by earthworms and formation of organocomplex during vermicomposting. Singh and Kalmdhad [40] observed reduction in water soluable heavy metals (Zn, Mn, Cu, Fe and Cr) during vermicomosting of wastes and suggested that the formation of organometallic complex compounds and bioaccumulation in earthworms reduced the final content of metals in vermicompost. Singh *et al.* [41] also observed a significant reduction in heavy metals (Cu, Pb, Mn and Cr) during the vermicomposting of thermal power plant fly ash. The present study observed that earthworms significantly reduced the bioavailability of heavy metals in the feed mixtures of MPIS as compared to feed mixtures without earthworms.

Table 3. Initial and final nutrient content (mean ± S.E.) and percent change over initial nutrient content of different proportions of milk processing industry sludge and cattle dung with and without earthworms.

Nutrients		ME	MW	ME_{25}	MW_{25}	ME_{50}	MW_{50}	ME_{75}	MW_{75}	ME_{100}	MW_{100}
pH	Initial	7.86 ±0.26	7.79 ±0.02	7.73 ±0.12	7.66 ±0.04	7.67 ±0.08	7.67 ±0.03	7.91 ±0.06	7.99± 0.04	8.34 ±0.03	8.34 ±0.05
	Final	7.32 ±0.08*	7.61 ±0.02*	7.14 ±0.24**	7.48 ±0.02	7.19 ±0.10	7.43 ±0.03	7.40 ±0.08**	7.68 ±0.03	7.78 ±0.01	7.91 ±0.07
	% Change	**-6.87**	-2.31	-7.63	-2.34	*-6.25*	-3.12	-6.44	-3.87	-6.71	-5.15
EC (mS/cm)	Initial	3.68 ±0.04	3.67 ±0.02	3.54 ±0.12	3.56 ±0.02	3.35 ±0.03	3.32 ±0.03	3.16 ±0.01	3.22 ±0.10	3.33 ±0.03	3.14 ±0.03
	Final	2.41 ±0.04**	3.45 ±0.03	2.22 ±0.02**	3.27 ±0.07**	2.27 ±0.03**	3.14 ±0.03	2.38 ±0.01**	3.08 ±0.03	2.25 ±0.05*	3.55 ±0.04
	% Change	-34.51	-5.99	**-37.28**	-8.14	-32.23	-5.42	*-24.68*	-5.43	-32.43	-1.91
TKN%	Initial	3.13 ±0.03	3.21 ±0.05	3.29 ±0.02	3.29 ±0.02	3.44 ±0.03	3.43 ±0.03	3.66 ±0.01	3.68 ±0.01	3.79 ±0.03	3.84 ±0.02
	Final	4.57 ±0.03*	3.55 ±0.04	4.69 ±0.05**	3.61 ±0.01*	4.59 ±0.00*	3.76 ±0.02*	4.72 ±0.02**	3.96 ±0.01	4.67 ±0.02**	4.25 ±0.04
	% Change	**46.00**	10.42	42.52	9.72	33.43	10.49	28.96	7.60	*23.21*	10.80
TOC%	Initial	41.92 ±1.54	42.64 ±1.16	44.89 ±0.39	45.69 ±0.41	46.92 ±0.22	46.6 ±0.65	48.86 ±0.26	48.06 ±0.54	49.21 ±0.10	50.45 ±0.65
	Final	2.97 ±0.87*	35.84 ±0.64**	27.86 ±0.89**	39.82 ±1.18**	34.17 ±0.88**	38.79 ±0.54	39.03 ±0.17**	43.39 ±0.41	39.31 ±0.41	45.54 ±0.83*
	% Change	-33.27	-15.95	**-37.93**	-12.84	-27.17	-16.86	*-16.86*	-9.72	-20.11	-8.94
C/N ratio	Initial	13.27 ±0.59	13.27 ±0.59	16.98 ±0.55	13.89 ±0.08	28.01 ±0.06	13.58 ±0.11	36.79 ±1.84	13.04 ±0.2	42.79 ±1.10	13.14 ±0.23
	Final	10.10 ±0.29*	11.29 ±0.29*	7.23 ±0.07**	11.03 ±0.29*	11.78 ±0.18*	10.29 ±0.21	17.28 ±0.80**	10.94 ±0.06**	24.27 ±0.45*	10.79 ±0.08
	% Change	*-23.88*	-23.88	-57.42	-20.59	**-97.94**	-24.23	-53.03	-16.10	-43.28	-17.88
TAP%	Initial	2.81 ±0.07	2.74 ±0.01	2.61 ±0.05	2.66 ±0.01	2.46 ±0.05	2.46 ±0.02	2.01 ±0.04	2.09 ±0.01	1.88 ±0.05	1.89 ±0.01
	Final	3.93 ±0.02*	3.07 ±0.03*	3.91 ±0.02*	3.13 ±0.01*	3.42 ±0.03*	2.77 ±0.03**	2.85 ±0.04*	2.41 ±0.04	2.69 ±0.01**	2.22 ±0.02*
	% Change	39.85	11.84	**47.12**	17.64	*39.02*	12.37	41.79	15.31	43.08	17.46

(Table 3) contd.....

Nutrients		ME	MW	ME_{25}	MW_{25}	ME_{50}	MW_{50}	ME_{75}	MW_{75}	ME_{100}	MW_{100}
TK%	Initial	0.51 ±0.02	0.55 ±0.01	0.61 ±0.01	0.61 ±0.01	1.68 ±0.02	1.56 ±0.04	1.80 ±0.01	1.69 ±0.03	1.96 ±0.01	1.81 ±0.01
	Final	0.22 ±0.01**	0.39 ±0.00**	0.36 ±0.01**	0.45 ±0.01**	1.12 ±0.02**	1.32 ±0.01	1.32 ±0.02**	1.50 ±0.01**	1.40 ±0.00**	1.61 ±0.01
	% Change	**55.88**	-28.82	-40.65	-25.41	-33.33	-15.06	*-26.66*	-10.95	-28.57	-10.77
TNa%	Initial	0.90 ±0.02	0.95 ±0.01	0.94 ±0.00	0.95 ±0.01	1.27 ±0.03	1.20 ±0.01	1.53 ±0.02	1.51 ±0.01	1.91 ±0.01	1.86 ±0.05
	Final	0.42 ±0.02*	0.66 ±0.01**	0.48 ±0.02**	0.74 ±0.01*	0.81 ±0.03**	0.97 ±0.02	1.05 ±0.07**	1.24 ±0.01**	1.30 ±0.03*	1.59 ±0.01
	% Change	**-53.03**	-30.00	-48.93	-21.99	-35.82	-19.50	*-31.31*	-18.62	-31.85	-14.52

Significance level by student's paired t-test.*p≤ 0.05, **p≤ 0.01. Maximum %change is shown in bold letters and minimum in italics, with earthworm waste proportions.

Table 4. Initial and final heavy metal content (mean ± S.E.) and percent change over initial heavy metal content of different proportions of milk processing industry sludge and cattle dung with and without earthworms.

Heavy metals		ME	MW	ME_{25}	MW_{25}	ME_{50}	MW_{50}	ME_{75}	MW_{75}	ME_{100}	MW_{100}
Cu mg/kg	Initial	5.55 ±0.17	5.71 ± 0.11	9.75 ±0.11	9.36 ±0.26	12.62 ±0.14	12.88 ±0.22	17.80 ±0.24	17.71 ±0.29	22.42 ±0.22	21.99 ±0.09
	Final	3.73 ±0.09**	4.49 ± 0.11*	5.40 ±0.2**	7.42 ±0.32	7.89 ±0.09**	10.11 ±0.04	11.39 ±0.25**	14.56 ±0.18	14.97 ±0.22*	19.18 ±0.18
	% Change	*-32.79*	-21.36	**-44.61**	-20.72	-37.48	-21.50	-36.01	-17.78	-33.22	-12.77
Pb mg/kg	Initial	8.09 ±0.11	6.46 ±0.06	8.79 ±0.09	8.28 ±0.08	12.89 ±0.21	11.99 ±0.01	15.78 ±0.03	15.80 ±0.3	18.02 ±0.07	17.65 ±0.15
	Final	5.02 ±0.07**	5.63 ±0.18	5.27 ±0.10**	6.63 ±0.08*	7.35 ±025*	9.47 ±0.33	9.54 ±0.07*	11.79 ±0.11*	12.14 ±0.36*	14.16 ±0.14
	% Change	-37.95	-19.93	-40.04	-21.02	**-42.97**	-25.37	-39.54	-19.77	*-32.63*	-13.90
Mn mg/kg	Initial	40.61 ±0.44	38.61 ±0.11	48.24 ±0.68	47.07 ±0.57	55.17 ±0.42	55.37 ±0.47	68.26 ±0.26	68.34 ±0.33	85.11 ±0.87	84.33 ±0.58
	Final	25.85 ±0.17**	33.24 ±0.26*	33.90 ±0.8**	40.45 ±0.23	41.95 ±0.07*	48.23 ±0.43**	49.23 ±1.09*	58.65 ±0.48	63.32 ±0.87*	73.79 ±0.29
	% Change	**-36.34**	-13.90	-29.72	-14.00	*-23.96*	-12.89	-27.88	-14.17	-25.60	-12.49
Cr mg/kg	Initial	12.07 ±0.37	12.97 ±0.12	15.34 ±0.15	15.24 ±0.13	17.75 ±0.65	18.77 ±0.17	24.25 ±0.57	22.96 ±0.26	30.87 ±0.12	31.56 ±0.11
	Final	7.52 ±0.47**	9.80 ±0.06*	9.10 ±0.1**	12.16 ±0.12	12.25 ±0.25*	15.23 ±0.23*	16.54 ±0.16*	18.79 ±0.14**	21.06 ±0.59*	25.99 ±0.09
	% Change	-37.69	-23.97	**-40.67**	-25.32	*-30.98*	-18.85	-33.36	-18.16	-33.91	-17.64

Significance level by student's paired t-test.*p≤ 0.05, **p≤ 0.01. Maximum %change is shown in bold letters and minimum in italics, with earthworm waste proportions.

CONCLUSION

Vermicomposting with *E. fetida* was well utilized for composting to change this solid sludge into a nutrient-rich and less toxic product that can be used as an organic resource. Minimum mortality and maximum population build-up of earthworm were observed in a 25:75(ME_{25}) mixture. Range of increase in nitrogen and phosphorus was by 23.2-46.0% and 39.8-47.1% respectively from the initial to the final products with earthworms, while decline was observed in pH (6.2-7.6%), electrical conductivity (24.6-37.2%), C/N ratio (35.2-56.4%), organic carbon (20.1-37.9%), total potassium (26.6-55.8%) and total sodium (31.3-53.0%) in all the feed mixtures. Reduction of heavy metals Cu (32.7-44.6%), Pb (32.6-42.9%), Mn (23.9-36.3%) and Cr (30.98-40.67%) in the end product also favors its utilization as an organic amendment in the agricultural fields. The study indicated that the vermicomposting of MPIS might be helpful if mixed maximum at 25-50% with CD.

CONSENT FOR PUBLICATION

Not applicable.

CONFLICT OF INTEREST

The authors declare no conflict of interest, financial or otherwise.

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