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Low Cost Traditional Cassava Starch Factory Solid Waste (Thippi) Composting: A Possible Strategy for Organic Nutrient Management and Economic Security for Tribal Farmers

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Abstract

In Kerala, cassava tubers are mainly used for human consumption whereas in Tamil Nadu, it is for the production of industrial starch and sago. During the extraction of starch from tubers, both small scale and large starch and sago factories are generating on an average about 40-60 tonnes of solid waste (thippi) per annum creating serious environmental pollution. Considering the voluminous quantity of thippi discharged from these industries, we explored the possibility of making some value added organic manures from thippi. Among the various protocols tried, the cheap and traditional way of composting using earthworms gave better result in making it in to a nutrient rich organic manure. It had the highest plant nutrient content with low C:N ratio (8:1). The mean N, P, K, Ca, Mg, Fe, Mn, Cu and Zn content in thippi compost was 1.32, 3.82, 0.40, 2.18, 0.96, 1.11, 0.08%, 11.23 and 89.93 ppm respectively which is 3.5, 49,7, 32.5, 8, 185, 100, 2.5 and 12 times respective of nutrients compared to raw thippi. A study on the mineralization pattern of nutrients from thippi compost under pot incubation for a period of one year indicated the maximum release of almost all nutrients during 5-7th month. Field experiments conducted for two seasons to study the effect of thippi compost as a substitute to commonly used organic manures and fertilizers including secondary and micronutrients revealed thippi compost as an alternative to FYM, green manuring *in situ* with cowpea, crop residue incorporation, vermicompost and coir pith compost and even fertilizers up to N @ 50 kg ha^{-1}, $MgSO_4$ @ 2.5 kg ha^{-1} and $ZnSO_4$ @ 2.5 kg ha^{-1}.

Key words: solid waste, earthworm, composting, mineralization, organic manure

Introduction

In Tamil Nadu, 8-10 large scale starch factories and 150-200 small scale starch and sago production units are generating about 40-60 tonnes of solid waste per annum creating serious environmental problems, including foul smell during the rainy season (Tapasnandy et al, 1996). Thippi (solid fibrous waste) discharged after the extraction of starch from cassava tuber is poor in all plant essential nutrients and had a very high C:N ratio (82:1). In order to find a suitable alternative to reduce the environmental pollution caused by thippi, an effort was made to convert thippi to organic manure through different traditional methods of composting (Chithra et al., 2013 b). Since the nutrient release from the compost is very important, a pot incubation study for a period of one year was also conducted to evaluate the extent of nutrient mineralization from thippi compost to soil for plant uptake (Agamuthu et al., 2000). The possibility of nutrient recycling through the waste also was tested by conducting field experiments for two seasons in cassava with the objective of exploring the potential of thippi compost to substitute for other commonly used organic manures, chemical fertilizers including secondary and micronutrients. Taking into account the above factors, the major objectives of the study were to find a suitable method to manage the pollution caused by cassava starch factory solid waste (thippi) near starch factories of Salem, Tamil Nadu. The study included physico-chemical and biological characterization of the waste, composting and fortifying of the waste into a nutrient enriched organic manure, study the dynamics of nutrients release (mineralization) from thippi compost for plant uptake and explore its potential as a substitute to other commonly used organic manures and chemical fertilizers including secondary and micronutrients for cassava cultivation.

Materials and Methods

Samples of thippi collected from different starch factory premises of Salem district, Tamil Nadu, were mixed together and a representative sample was formed. These samples were analysed for their physical properties viz., colour using Munsell colour chart, water holding capacity, bulk density and porosity using Keen Rackzowski method (Iswaran,1980). The chemical properties viz., pH, organic carbon (OC), primary nutrients viz., total nitrogen (N), phosphorus (P), potassium (K), secondary nutrients viz., calcium (Ca), magnesium (Mg) and micronutrients viz., iron (Fe), copper (Cu), manganese (Mn) and zinc (Zn) were analysed following standard analytical procedures for the analysis organic manures (FAI, 2011). The biological properties especially microbial count viz., bacteria, fungi and actinomycetes colonies were taken following the procedure of Wollum (1982) using specific media for each organism. The biochemical properties viz., carbohydrate, starch, cellulose, fibre, protein and cyanide were also determined (Sadasivam and Manickam, 1991).

Composting procedure

As thippi was found very poor in all essential nutrients, it was enriched with N, P and K rich raw materials viz., cow dung, cassava leaves, *Glyricidia* leaves and *Azolla* as N source, Mussooriphos as P source and rock powder as K source. Enrichment of thippi was carried out for proper decomposition, since the C: N ratio of the mixture has to be reduced by adding protein (N) rich materials (Jimenez and Garcia, 1989). Different composting agents like microbial cultures viz., microbial consortium containing *Trichoderma*, P and K solubilisers and waste management culture and addition of earthworms (*Eudrilus euginea)* were also tried (Chefetz et al., 1998). There were 9 treatment combinations which included three combinations of raw materials and three composting agents (Table 1) with 2 replications.

Composting was done for a period of 2 months, material dried, sieved and the mature compost obtained was analysed for its nutritional and anti nutritional factors.

Incubation study for evaluation of the structural degradation and mineralization pattern

Thippi composts prepared with different treatment (9 nos.) combinations were incubated in pots of (25×30×30

Table 1. Treatment for thippi composting along with the microbial cultures / organisms used

Treatments	Components	Cultures /organisms used
T1	Thippi, cowdung, Mussooriphos, rock powder (5:1:0.1:0.1)	Microbial consortium(0.1%)
T2	Thippi, cowdung, Mussooriphos, rock powder(5:1:0.1:0.1)	Earthworm(200 numbers/ lot)
T3	Thippi, cowdung, Mussooriphos, rock powder(5:1:0.1:0.1)	Waste management culture (0.1%)
T4	Thippi, cowdung, *Glyricidia* leaves, cassava leaves Mussooriphos, rock powder (5:1:0.5:0.5:0.1:0.1)	Microbial consortium (0.1%)
T5	Thippi, cowdung, *Glyricidia* leaves, cassava leaves Mussooriphos, rock powder (5:1:0.5:0.5:0.1:0.1)	Earthworm (200 numbers/lot)
T6	Thippi, cowdung, *Glyricidia* leaves, cassava leaves Mussooriphos, rock powder (5:1:0.5:0.5:0.1:0.1)	Waste management culture (0.1%)
T7	Thippi, cowdung, *Azolla*, Mussooriphos, rock powder (5:1:1:0.1:0.1)	Microbial consortium (0.1%)
T8	Thippi, cowdung, *Azolla*, Mussooriphos, rock powder (5:1:1:0.1:0.1)	Earth worm (200 numbers/lot)
T9	Thippi, cowdung, *Azolla*, Mussooriphos, rock powder (5:1:1:0.1:0.1)	Waste management culture (0.1%)

cm) dimension by mixing with soil (6 kg). The experiment was replicated twice. Samples were drawn from the pots at one month interval and analysed for all chemical parameters viz., pH, EC, OC, N, P, K, Ca, Mg, S, Cu, Fe, Mn and B. The nutrient availability pattern over a period of 12 months under incubation were statistically analysed through Duncan's Multiple Range (DMR) test.

Bulk level preparation of thippi compost and its chemical and biological evaluation

The compost was prepared in bulk resorting to the method as described under T5. This included the use of raw material as thippi (200 kg), *Glyricida* leaves (20 kg), cassava leaves (20 kg), cowdung (50 kg), Mussooriphos (10 kg) followed by the addition of earthworm for composting. After 60 days of composting, a mature compost of 190 kg was obtained after processing and sieving. This was intended for field application in cassava.

Response of cassava to thippi compost

The main objective of the field experiment was to find out the possibility of thippi compost as a substitute to other commonly used organic manures (FYM, green manuring *in situ* with cowpea, vermicompost, coir pith compost, crop residue), NPK fertilizers, secondary nutrient (Mg) and micronutrient (Zn).The experiment was conducted in randomized block design (RBD) with 16 treatments replicated thrice for two seasons using the cassava variety 'Sree Jaya'. The treatments for the field experiment is depicted in Table 2. The quantity of thippi compost for field application was fixed based on the N equivalent in different organic manures and chemical fertilizers.

Apart from tuber yield, tuber quality parameters viz., cyanogenic glucosides and starch were analysed and soil nutrient status and plant uptake of nutrients were also computed.

Results and Discussion

Rapid appraisal of the environmental pollution due to thippi

Cassava processing industry was found to have adverse site specific effects on the environment by producing unpleasant odours and unsightly display of waste. However, the long term and broad based impact on the environment is generally minimal and can be corrected by proper waste treatment with technologies which are either presently available or under development. It is understood that, as thippi waste are presently having good demand for processing as poultry feed, rarely it will pile up and in such situations during rainy season, the leachates will pollute the ground water supply (FAO, 2004). No

Table 2. Treatment details of the field experiment

Treat-ment	Treatment composition	Treatment details
T1	POP+ FYM	NPK @100:50:100 kg ha^{-1}+ FYM @12.5 t ha^{-1}
T2	STBF + FYM	NPK @78:0:48 kg ha^{-1} +FYM@5 t ha^{-1}
T3	STBF + FYM + Mg	NPK@78:0:48 kg ha^{-1} +FYM@5 t ha^{-1}+MgSO4@2.5 kgha^{-1}
T4	STBF + FYM + Zn	NPK@78:0:48 kg ha^{-1}+FYM@5 t ha^{-1}+ZnSO4 @2.5 kg ha^{-1}
T5	POP + Thippi compost	NPK @100:50:100 kg ha^{-1}+Thippi @ 3.1 t ha^{-1}
T6	STBF + Thippi compost	NPK @78:0:48 kg ha^{-1}+Thippi compost @1.25t ha^{-1}
T7	STBF + Green manuring *in situ* with cowpea	NPK@78:0:48 kg ha^{-1}+green manuring
T8	STBF + Crop residue	NPK@78:0:48 kg ha^{-1}+CR @ 2.22 t ha^{-1}
T9	STBF + Vermicompost	NPK@78:0:48 kg ha^{-1}+VC@ 4 t ha^{-1}
T10	STBF + Coirpith compost	NPK@78:0:48 kg ha^{-1}+CPC@ 5 t ha^{-1}
T11	One fourth of STBF + Thippi compost	NP K@20:0:12 kg ha^{-1}+Thippi compost @1.25 t ha^{-1}
T12	Half of STBF + Thippi compost	NPK@40:0:24 kg ha^{-1}+Thippi compost @1.25 t ha^{-1}
T13	Three fourth of STBF + Thippi compost	NPK@59:0:36 kg ha^{-1}+ Thippi compost@1.25 t ha^{-1}
T14	Absolute control	Fertilizers and manures not added
T15	FYM alone	FYM @ 32.6 t ha^{-1}
T16	Thippi compost alone	Thippi compost @7.41 t ha^{-1}

(POP: Package of Practices, FYM: Farmyard manure, STBF: Soil test based fertilizer recommendation) systematic studies were so far undertaken to quantify the extent of solid waste discharge per annum from these factories including its hazardous effect on soil environment.

Physico-chemical, biochemical and biological properties of thippi

Physico-chemical, biological and biochemical analysis of thippi indicated that it had high water holding capacity (89%) and porosity (95%) and low bulk density (0.58g cm^{-3}). It was acidic in nature (pH: 3.6) with very poor plant nutrient contents viz., N, P, K, Ca, Mg, Fe, Cu, Mn and Zn to the tune of 0.38%, 0.07%, 0.05%, 0.06%, 60, 4.3 and 7.8 ppm respectively and had very high C:N ratio indicating that it is not all suitable for soil application as a manure as it can immobilize the soil available nutrients during decomposition (82.1) (Allison, 1973) and high percentage of starch (60%) (Chithra et al., 2013a). Microbiological characterization revealed very few bacterial colonies ($3x10^6$ CFU/ml) and there was no evidence of actinomycetes and fungi.

Nutritional evaluation of thippi compost

Among the nine different treatment combinations tried for making thippi compost, treatment, T5 showed high nutrient content with respect to primary, secondary and micronutrients which in turn was thippi combined with organic materials viz., FYM, *Glyricidia*/cassava leaves, Mussoriphos and rock powder composted with earth worm (Table 3). The mean N, P, K, Ca, Mg, Fe, Mn, Cu and Zn content in thippi compost was 1.32, 3.82, 0.40, 2.18, 0.96, 1.11, 0.08 %, 11.23 and 89.93 ppm respectively which was 3.5, 49,7, 32.5, 8, 185, 100, 2.5 and 12 times than thippi (Chithra et al., 2013c, 2013 d).

The pattern of mineralization of the nine different treatment combinations of thippi compost during a period of 12 month pot incubation, showed a significant increase in pH during 8^{th} month and the maximum availability of nutrients were noticed during 5 to 8^{th} month of incubation as compared to initial soil nutrient status (Table 4) (Chithra et al., 2016a). Nutrient status was found maximum for T5 (vermicomposted) during the 6^{th} month of incubation Chithra et al., 2013b; Chithra et al., 2016b). The nutrient content of vermicomposted waste was higher when compared to traditional compost because the waste when passes through the earthworm gut it get digested by certain secretions of earthworm gut and will easily changed to degradable matter more faster than other microorganisms can do (Butt, 1993).

Nutrient evaluation of bulk level prepared thippi compost

Thippi compost prepared under treatment T5 was found the best on basis of the nutrient content and extent of nutrient release. Hence, the bulk level compost was prepared with that treatment combination. The nutrient status of mature compost revealed that, it was high in all plant essential nutrients to the tune of N:2.09%, P:1.63%, K:0.49%, Ca:2.67%, Mg:1.4%, Cu : 49.6 ppm, Zn:121.3 ppm, Fe:344 ppm and Mn:76.3 ppm. According to Jeyabal and Kuppuswamy (2001), vermicomposting using earth worms can accelerate the mineralization rate and can convert the raw materials into casts with higher nutritional value than traditional composting methods which can sustain soil quality and better productivity.

Table 3. Nutrient content of thippi compost (%) prepared using different treatments

Treat No.	N	P	K	Ca	Mg	Fe	Mn	Cu	Zn
T1	0.85d	3.025c	0.32ef	2.655	1.07b	1.013ab	0.0754bc	0.00124ab	0.0081b
T2	1.075cd	3.775a	0.35def	1.995d	0.98d	1.329a	0.0872a	0.00153a	0.0106a
T3	0.89d	3.68ab	0.305	2.415ab	1.05c	1.103ab	0.0804ab	0.00082ab	0.0086ab
T4	1.425b	2.685d	0.4bcd	2.52ab	0.83g	0.803b	0.0638d	0.00076b	0.0083b
T5	2.38a	2.975c	0.47ab	1.42e	0.77h	0.93b	0.066cd	0.00095ab	0.0092ab
T6	1.545b	3.18c	0.51g	2.29bc	0.98d	1.111ab	0.078ab	0.00105ab	0.0087ab
T7	1.175bc	3.475	0.41bcd	2.63a	1.16a	1.071ab	0.0845ab	0.00128ab	0.0089ab
T8	1.495b	3.86a	0.43bc	1.64e	0.92e	1.33a	0.0885a	0.00134ab	0.0095ab
T9	1.065cd	3.94a	0.38cde	2.055cd	0.91f	1.294	0.0798ab	0.00114a	0.0092ab
Mean	1.32	3.40	0.40	2.18	0.97	1.11	0.08	0.001	0.009
P (0.05)	<0.0001	<0.0001	0.0011	<0.0001	0.0173	0.0015	0.0014	0.2609	0.3684
CV(%)	7.29	3.36	7.03	5.07	6.87	7.09	4.71	25.14	10.58

The mean values with superscript containing the same alphabet are not significantly different at P(0.05)

Table 4. Soil nutrient availability through mineralization of the compost under different treatments over a period of one year

Parameters	Initial soil nutrient status	Content in thippi compost	Nutrient availability in pot incubated soil			
			Treatment showing higher nutrient availability	Month of maximum nutrient availability	Nutrient contents/ values	Difference over initial
pH	4.62	7.82	T7, T3	8th	5.71	1.09
EC	0.153 dS m^{-1}	4.1dSm^{-1}	T9	5th	0.25 dS $^{-1}$	0.10 dS m^{-1}
OC	1.77%	10.3%	T5	5th	2.05%	0.28%
N	216.87 kg ha^{-1}	2.09%	T5	9th	561.26 kg ha^{-1}	344.40 kg ha^{-1}
P	52.18 kg ha^{-1}	1.63%	T5	8th	126.40 kg ha^{-1}	74.22 kg ha^{-1}
K	81.14 kg ha^{-1}	0.49%	T5	9th	267.06 kg ha^{-1}	185.92 kg ha^{-1}
Ca	1.07 meq100g^{-1}	2.67%	T5	8th & 9th	2.90 meq100g^{-1}	1.83 meq100g^{-1}
Mg	0.56 meq100g^{-1}	1.4%	T5	9th	2.47 meq100g^{-1}	1.91 meq 100g^{-1}
S	10.03 ppm	-	T5	8th & 9th	42.95 ppm	32.92 ppm
Fe	40 ppm	1.23%	T5	7,8 & 9th	64.16 ppm	24.16 ppm
Cu	1.1 ppm	49.6 ppm	T4, T5	7,8 & 9th	1.44 ppm	0.34 ppm
Zn	1.47 ppm	121.3 ppm	T5	7,8 & 9th	4.58 ppm	3.11 ppm
Mn	5.41 ppm	850.8 ppm	T5	9th	12.19 ppm	6.78 ppm
B	1.06 ppm	-	T5	6,7,8 & 9th	1.63 ppm	0.57 ppm

Effect of thippi compost on tuber yield and tuber quality parameters of cassava

The mean of the harvest data of the two years on tuber yield indicated thippi compost can be very well substituted with organic manures like FYM, green manuring *in situ* with cowpea, vermicompost, coirpith compost and crop residue. It was also seen that, up to 50% of the recommended dose of NPK, secondary nutrient, Mg and

Table 5. Effect of thippi compost on tuber yield and tuber quality parameters of cassava (Mean of 2 years)

Treat No	Treatment description	Yield (t ha^{-1})	HCN (ppm)	Starch (%)
T1	POP+ FYM	28.938	22.502	27.668
T2	STBF+FYM	27.102	17.307	26.095
T3	STBF+FYM+Mg	28.669	13.179	26.948
T4	STBF+FYM+Zn	26.534	12.054	26.009
T5	POP+Thippi Compost	29.333	8.841	26.103
T6	STBF+Thippi compost	21.830	27.967	27.422
T7	STBF+Green manure	28.579	18.017	26.532
T8	STBF+Crop residue	27.251	15.431	26.772
T9	STBF+Vermicompost	20.747	19.126	28.455
T10	STBF+Coirpith compost	19.134	17.198	28.057
T11	¼ NPK+Thippi compost	25.138	8.357	26.709
T12	½ NPK+Thippi compost	27.151	12.501	27.083
T13	¾ NPK+Thippi compost	25.757	13.983	26.736
T14	Absolute control	16.367	17.037	27.307
T15	FYM alone	27.408	12.215	26.056
T16	Thippi compost alone	27.561	10.447	28.969
CD (0.05)		3.278	8.331	NS

micronutrient, Zn also could be substituted with thippi compost. The tuber yield was found highest for POP along with thippi compost (29.333 t ha^{-1}) which was on par with green manuring *in situ* with cowpea (28.571 t ha^{-1}) and crop residue incorporation (27.251 t ha^{-1}) along with POP. In all thippi compost applied treatments, the tuber yield was higher than vermicompost (20.747 tha^{-1}) and coir pith compost (19.134 tha^{-1}). Thippi compost alone applied treatment (27.561 tha^{-1}) gave yield on par with FYM alone applied (27.408 tha^{-1}) treatment. As regards to NPK replacement with thippi compost, NPK fertilizers up to 50% (27.151tha^{-1}), $MgSO_4$ @ 2.5 $kgha^{-1}$ (28.669 tha^{-1}) and $ZnSO_4$ @ 2.5 $kgha^{-1}$ (26.534 tha^{-1}) could be replaced through thippi compost. Improvements in the properties of cultivated soil and increased crop production from additions of compost to soil have been reported (Vitayakorn et al., 1988).

Tuber quality paramaters viz., cyanogenic glucoside (HCN) was found the highest under STBF along with thippi compost (27.967 ppm) and this was on par with POP along with FYM (22.502 ppm). Reduction in HCN content was found in all thippi compost applied treatments to the range of 8-12 ppm with a mean value of 11.332 ppm and this was found lesser compared to coirpith compost (17.198 ppm), vermicompost (19.126 ppm), green manuring *in situ* with cowpea (18.070 ppm) and crop residue (15.431 ppm) applied treatments. Application of thippi compost improved tuber starch percentage and was found higher in thippi compost alone applied treatment (28.969%). However, no significant difference in starch content was found among the different treatment combinations (Table 5) (Chithra et al., 2016b)

Effect of thippi compost on soil nutrient status

Chemical analysis of soil samples from the experimental site revealed that compared to the initial soil fertility status, after two years of continuous application of thippi compost, there was considerable increase in soil pH, soil organic carbon, primary, secondary and micronutrients to a level of medium to high (Figure 1a, 1b). According to Van-Camp et al. (2004) organic amendments in the form of manures and compost influence soil characteristics by the interdependent modification of biological, chemical and physical properties.

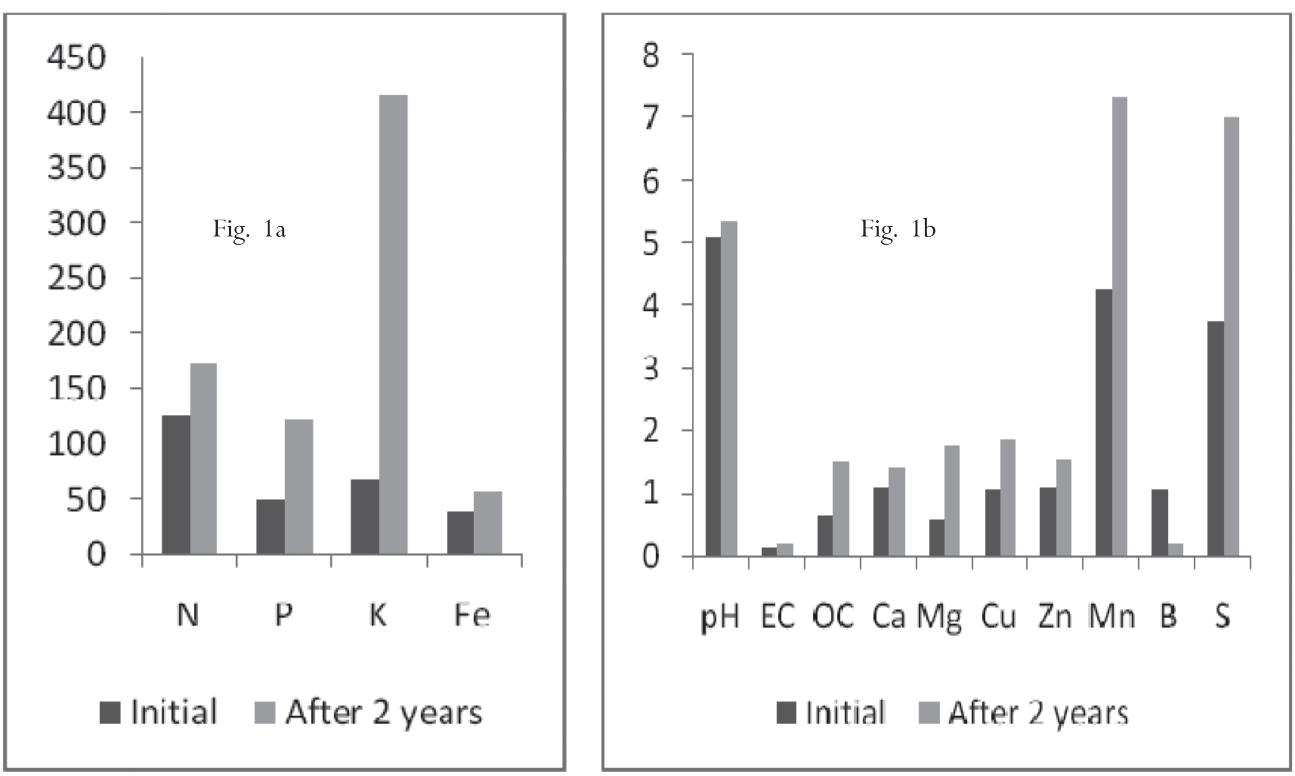

Fig. 1. Effect of thippi compost on soil nutrient status after two years
(a) N, P, K (kg ha^{-1}), Fe (ppm) (b) EC (dS m^{-1}), OC (%), Ca, Mg (meq100g^{-1}), Cu, Zn, Mn, B, S (ppm)

Conclusion

This novel and maiden attempt carried out could find out a viable solution to the environmental pollution caused by starch factory solid waste (thippi) near starch factory premises of Salem, Tamil Nadu. A good quality nutrient rich organic manure (thippi compost) was developed through the study which in turn had favourable effect on soil health in addition as a substitute to organic manures and fertilizers. This green technology can effectively mitigate the environmental hazards posed by the starch factory waste. If properly undertaken, it can increase the income and employment opportunities of the rural folk comprising tribal farmers too thus ensuring economic security to them.

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