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Composting – A Solution to the Industrial Solid Waste Management

C. Malarvizhi[1*], P. Doraisamy[1] and M. Maheswari[1]

[1]Department of Environmental Sciences, Tamil Nadu Agricultural University, Coimbatore, 641003, India.

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Environmental pollution is the major problems associated with rapid industrialization, urbanization and rise in living standards for people. Gelatin industry solid waste contains plant nutrients and organic matter, which could enhance the availability of nutrients, enrich the soil organic matter and ultimately increase the crop growth. Hence, the study was conducted to convert gelatin industry solid waste with nutrient-rich materials such as cow dung, poultry waste and coir pith with microbial cultures for the production of nutrient-rich value-added manure. Composting of GISW along with coir pith, cow dung and poultry waste recorded the desirable C/N ratio of 12.4:1 and highest nutrient contents (1.85, 3.85 and 1.24% of N, P and K, respectively). Also, the composted gelatin industry solid waste (CGISW) was subjected to various maturity tests and phytotoxicity assay. The indiscriminate disposal and accumulation of solid wastes generated by gelatin manufacturing industries are the cause for concern. Hence an attempt has been made to convert these gelatin industry solid wastes (GISW) into bio-manure by blending with other organic wastes such as poultry waste, coir pith and cow dung with suitable microorganisms.

**Corresponding author: E-mail: malar.238@gmail.com;*

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1. INTRODUCTION

Environmental pollution is the major problems associated with rapid industrialization, urbanization and rise in living standards for people. For developing countries, industrialization was a must and still, this activity is very much in demand to build self-reliance of the country and in uplifting nation's economy. However, industrialization, on the other hand, has also caused serious problems relating to environmental pollution. The problems relating to disposal of industrial solid waste are associated with lack of infrastructural facilities and negligence on the part of industries to take proper safeguards. Assessment of industrial solid waste management problems greatly varies depending on the nature of the industry, their location and mode of disposal of waste. Recycling and reuse of solid and liquid wastes help to reduce the problems of waste disposal. In recent years, it is very clear that the resources of the world have been indeed finite. To maintain stable economic growth and a standard of living, it has become very necessary to use resources very carefully and evolve technologies for recycling waste and residues thereby saving both resources and energy [1].

The recycling of renewable organic wastes and industrial by-products as soil amendments and nutrients for the maintenance of soil health by hygienic methods is vital for increasing crop production and welfare of mankind [2]. Reduce, recycle and reuse are the primary environmental amelioration options for solid waste management. Composting is one of the best methods to convert solid wastes to a useful and value-added product. Composting is a microbiological, non-polluting and safe method for disposal and recycling of organic waste [3] and it is a dynamic process with a succession of the mixed microbial population [4].

The use of pesticide and mineral fertilizers does not necessarily lead to better farming than the use of natural and organic methods in agriculture. There is a need to encourage more productive, environment-friendly farming practices. The uses of compost have been time-tested production inputs for improving the fertility and productivity of soil because composts are an excellent source of humus and plant nutrients [5,6]. India produces about 7.942 million tonnes of organic wastes annually which could be utilized for the recovery of fertilizer, fodder, fuel and food [7]. A future goal mooted for a sustainable society is to ensure the effective utilization of waste materials in an eco-friendly manner.

Gelatin manufacturing industries generate large quantities of solid wastes and organic effluent as a result of processing the crushed animal bone. Accumulation and indiscriminate disposal of these wastes create severe environmental pollution. The Gelatin Industry Solid Waste (GISW) contains an appreciable quantity of plant nutrients and therefore by adopting suitable processing technology, these solid wastes can be effectively utilized in crop production. Hence, the present investigation was undertaken to develop an eco-friendly technology for the bioconversion of the GISW into value-added manure besides testing its suitability for crop cultivation.

2. MATERIALS AND METHODS

2.1 Field-Scale Composting of GISW

Field-scale composting was conducted at the factory premises of M/S Pioneer Jellice India Private Limited, Cuddalore district to test the efficiency of different microbial inoculum converting GISW into value-added manure with three organic additives such as cow dung, coir waste and poultry manure. Windrow method of composting was followed to compost the gelatin industry solid waste. The heap was formed with alternate layers of compost additives and gelatin industry solid waste to a height of one meter and 2.5 meters long. The sides of the compost heaps were taped so that the top is about 0.5 m narrower than the base. This is covered with 20 cm of gelatin solid waste and repeated until the pile is 1.0m height according to various treatments. The combined solid wastes of the gelatin industry were mixed with other organic amendments such as cow dung, coir pith and poultry waste at a ratio of 1:0.25. In all the treatments, fly ash was added @ 10%. The microbial inoculum was added @ 2% during heap preparation. Water was sprinkled to maintain the moisture content of 55-60%.

2.2 Treatment Details

Design: RBD
Number of treatments: 5
Number of replications: 4

T_1: Gelatin industry solid waste alone
T_2: Gelatin industry solid waste +Microbial consortia
T_3: Gelatin industry solid waste + Cow dung + Microbial consortia
T_4: Gelatin industry solid waste + Coir waste + Microbial consortia
T_5: Gelatin industry solid waste + Poultry waste + Microbial consortia
T_6: Gelatin industry solid waste + Cow dung + Coir waste + Poultry waste + Microbial consortia

2.3 Assessment of Compost Maturity

2.3.1 Organic carbon

The total organic carbon content of the samples was determined by the wet digestion method [8]. A 0.5 g of sample was taken in a 500 ml conical flask and added 10 ml of 1 N $K_2Cr_2O_7$ and 20 ml of concentrated H_2SO_4. The contents were allowed to stand for 20-30 min. and 200 ml of distilled water, 10 ml of orthophosphoric acid and 1 ml of diphenylamine indicator were added. This was titrated against the 0.5 N ferrous ammonium sulphate towards the endpoint of bright green colour.

2.3.2 Nitrogen

Total nitrogen content of the samples was determined by following the Bremner method [9]. A 5 g of sample was added with 50 ml of diacid mixture (sulfuric acid and perchloric acid at 5:2) in a flask and kept for digestion until a clear solution was obtained. The digested content was transferred to a 250 ml volumetric flask and the volume made up to 250 ml. To a 5 ml of diacid extract taken 25 ml of 40 % NaOH was added. Twenty-five ml of 2 % boric acid with the double indicator (Bromocresol Green and methyl red) was kept at the distillation end. The distillate collected was titrated against 0.1 N H_2SO_4 and the N content was calculated.

2.4 Qualitative Tests

2.4.1 Starch iodine test

About one gram of finely powdered compost sample was placed in a 100 ml beaker and a few drops of ethanol were added to wet the samples. About 20 ml of perchloric acid was added to the samples, stirred and filtered through a filter paper. A few drops of the filtrate were placed on a white tile and 2 drops of iodine reagent were added to it. Matured compost gives a yellowish colour and very little precipitate; poor or immature compost give dark colour and heavy precipitation [10,11].

2.4.2 Sulphide test

One gram of finely powdered compost sample was taken in a test tube and inserted with a lead acetate strip into a sample. To this 18 per cent hydrochloric acid was added to the compost through the wall of the test tube without touching the lead acetate strip. The test tube was covered with a rubber cork and the colour change in the strip was observed.

2.4.3 Humification parameters

The quantitative test for compost maturity involves the determination of humification parameters. One hundred ml of 0.5 N NaOH was added to 10 g of compost in the beaker and incubated overnight. The extract was centrifuged at 8000 rpm for 10 min. 10 ml of the supernatant was used for the estimation of organic carbon (C_{ex}) as per the procedure given in Table 1. The remaining supernatant was acidified with 2 N hydrochloric acids and centrifuged at 8000 rpm for 10 min. Again 10 ml of the supernatant from the acidified extract was used for the estimation of organic carbon (C_{fa}) as per the procedure given in Table 1. The organic carbon content of the residue (C_{ha}) was also analysed as per the procedure given in Table 1. Using these values, the total organic carbon content [12], humification parameters like humic acid per cent, fulvic acid per cent [13] polymerization ratio, degree of humification and humification rate [14] were determined.

Humic acid (per cent) = $(C_{ha}/C_{ex}) \times 100$
Fulvic acid (per cent) = $(C_{fa}/C_{ex}) \times 100$
Degree of humification=$[(C_{ha}+ C_{fa})/C_{ex})] \times 100$
Humification rate = $[(C_{ha}+C_{fa})/TOC) \times 100$
Polymerization ratio = C_{fa}/C_{ha}

2.4.4 Germination test

Water extract of the composts was taken under suction and tomato, cowpea, black gram and maize seeds were used for the germination test. The seeds were positioned at equal spacing in Petri dishes lined with filter paper containing one ml of water extract of the compost and were incubated at 27°C under dark condition. The germination percentage was calculated after 24 h of incubation.

3. RESULTS AND DISCUSSION

3.1 Changes in the C/N Ratio During Composting of Gelatin Industry Solid Waste

The progressive decrease in total organic carbon and an increase in total nitrogen content consequently resulted in a significant decrease in C/N ratio of GISW during composting. The C/N ratio was wider in the beginning and narrowed down at the end of the composting period. At the end of the composting, the treatment (T_5) GISW in the combination of organic amendments along with microbial consortia registered minimum C/N ratio of 12.46 in field-scale composting (Fig.1). Reduction in C/N ratio during composting is due to the conversion of carbonaceous materials into cell biomass, carbon dioxide, water and humus [15]. Bernel et al. [16] reported that the C/N ratio is considered to be one of the simplest indices to evaluate any organic compost for its fitness for application.

3.2 Changes in Microbial Load During Composting

3.2.1 Bacteria

The population of bacteria increased from the beginning of the composting till thermophilic phase and decreased at the later stages. In Field-scale composting, the bacterial population was considerably higher 73.2 $\times 10^6$ CFU g^{-1} in the treatment (T_5) GISW in the combination of organic amendments along with microbial consortia on 30th day (Fig 2). These results are concomitant with findings of Davis et al. [17] who suggested that the bacterial population was higher than the fungal population under mesophilic and thermophilic stages. Finstein and Morris [18] showed the importance of bacteria in the composting process, particularly in the initial stages. They have concluded that bacterial metabolism is responsible for the dramatic temperature increase during composting.

3.2.2 Fungi

The fungi were responsible for the composting of many complex polymers and enabling bacteria to continue the decomposition process. The fungal populations were recorded maximum during 30th day of composting and the lowest population was recorded at the end of composting (Fig 3). The treatment (T_5) GISW in the combination of organic amendments along with microbial consortia was recorded with a maximum fungal population of 33.8 x 10^3 $CFUg^{-1}$ in field-scale composting. Gray et al. [19] and Poincelot [20] concluded that the number of mesophilic fungi underwent a marked decrease during the early thermophilic period and no recolonization of fungi took place during the subsequent low-temperature period of the composting process.

3.3 Qualitative Tests for Assessing Compost Maturity

3.3.1 Starch iodine and sulphide test

The compost sample collected at the end of the composting gave good results for the qualitative test for compost maturity *viz.*, starch iodine test and sulphide test. The starch iodine test showed complete decomposition of the polymers. Absence of black colour was noticed in all the treatments, indicated the absence of sulphide in CGISW (Table 1). This is in agreement with Kavitha and Subramanian [21] and Jayapandiyan [22] who found that phytotoxic substance if any present in wastes or produced during the initial period of composting as intermediate products of metabolism may get degraded and producing mature composts.

3.3.2 Humifiscation parameters of CGISW

Humic substances present in compost are good indicators of compost maturity. The humic acid content at the end of the composting ranged from 10.02 to 15.98 per cent, which indicated high humification and maturity of the compost (Table 1). This conforms with the observations made by Bernal et al. [16]. Higher values of humic acid, degree of humification and polymerization ratio are good indices of compost maturity [15].

In the present study, the CGISW registered high degree of humification ranging from 19.03 to 26.98, humification ratio from 13.41 to 22.57 and polymerization ratio from 0.65 to 0.94 which can be considered mature according to Jimenez and Garcia [23].

3.3.3 Phytotoxicity and seedling growth response

As a measure of compost maturity, phytotoxicity test for the CGISW was carried out with different crops and the results are given in Table 2. In general, germination per cent varied from 88 to 98 per cent for cowpea, 86 to 100 per cent for the black gram and 83 to 97 per cent for maize which is following Zucconi et al. [24] indicated that compost showing more than 80 per cent germination is free of phytotoxic compounds.

Table 1. Qualitative test and humification parameters of the CGISW

Treatments	**Qualitative test**		**Humification parameters**				
	Starch iodine test	**Sulphide test**	**Humic acid (%)**	**Fulvic Acid (%)**	**Degree of humification (%)**	**Humification ratio**	**Polymerization ratio**
T_1	+	-	10.02	7.16	19.03	13.41	0.65
T_2	+	-	13.98	10.36	24.62	19.21	0.86
T_3	+	-	14.63	11.12	25.16	20.84	0.89
T_4	+	-	12.88	9.28	23.30	18.11	0.84
T_5	+	-	15.98	12.50	26.98	22.57	0.94
Mean			**12.83**	**9.67**	**22.92**	**17.24**	**0.79**
SEd			**1.11**	**0.83**	**1.97**	**1.49**	**0.06**
CD (0.05)			**2.33**	**1.76**	**4.15**	**3.14**	**0.14**

T_1 – GISW(control); T_2 - GISW+ Cow dung (1:0.25)+ Microbial consortia; T_3 - GISW+ Coir pith (1:0.25)+ Microbial consortia; T_4 - GISW+ Poultry waste (1:0.25)+ Microbial consortia; T_5 - GISW+ coir pith + cow dung+ poultry waste (1:0.08:0.08:0.08)+ Microbial consortia

Table 2. Maturity test for compost from GISW

Treatments	**Germination percentage**		
	Cowpea	**Black gram**	**Maize**
T_1	88	86	83
T_2	96	98	95
T_3	97	99	96
T_4	95	97	94
T_5	98	100	97
Mean	**93.30**	**95.00**	**92.60**
SEd	**1.51**	**1.52**	**1.55**
CD (0.05)	**3.20**	**3.22**	**3.28**

T_1 – GISW(control); T_2 - GISW+ Cow dung (1:0.25)+ Microbial consortia; T_3 - GISW+ Coir pith (1:0.25)+ Microbial consortia; T_4 - GISW+ Poultry waste (1:0.25)+ Microbial consortia; T_5 - GISW+ coir pith + cow dung+ poultry waste (1:0.08:0.08:0.08)+ Microbial consortia

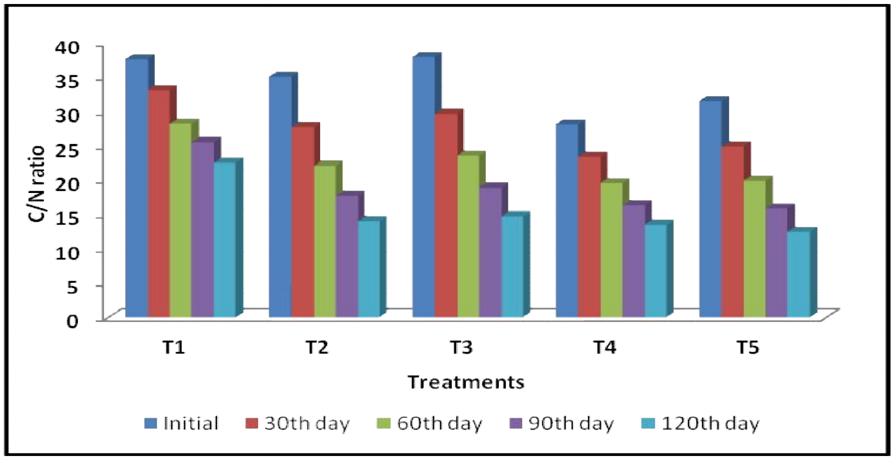

Fig.1. Changes in C/N ratio during composting of gelatin industry solid waste

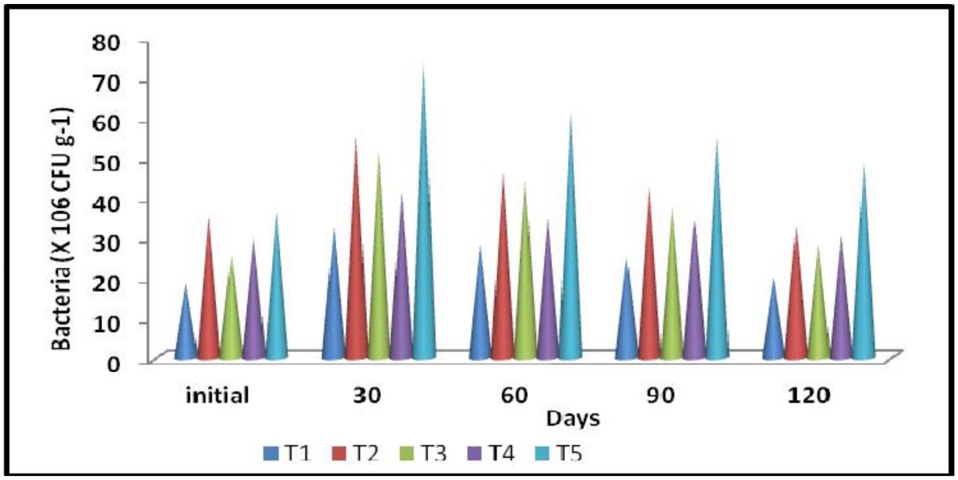

Fig. 2. Changes in bacteria population during composting of gelatin industry solid waste

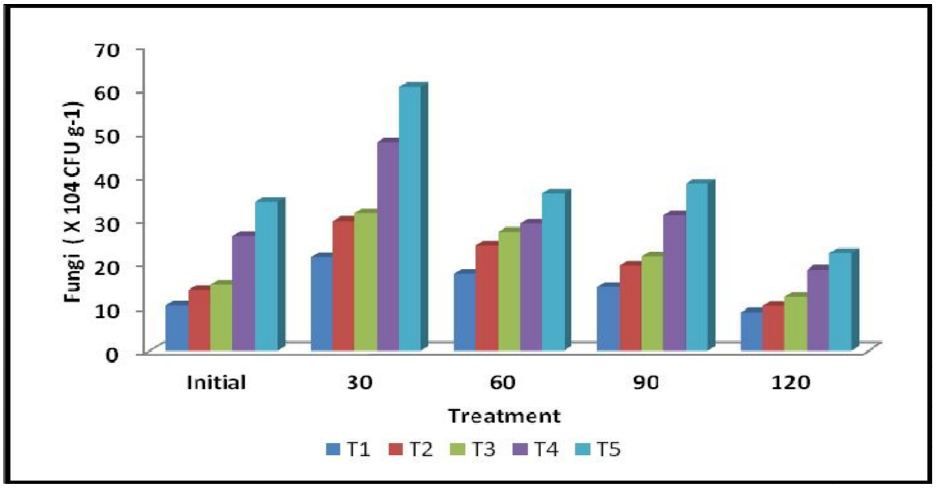

Fig.3. Changes in Fungi population during composting of gelatin industry solid waste

4. CONCLUSION

The present study concluded that the solid wastes of gelatin industries can be suitably processed along with other organic wastes to produce value-added manure which can be effectively recycled in agriculture. The high value of humification parameters in CGISW from gelatin industry solid waste inoculated with microbial consortium ensures efficient conversion of low molecular components into heavy molecular weight humus.

DISCLAIMER

The products used for this research are commonly and predominantly use products in our area of research and country. There is absolutely no conflict of interest between the authors and producers of the products because we do not intend to use these products as an avenue for any litigation but for the advancement of knowledge. Also, the research was not funded by the producing company rather it was funded by personal efforts of the authors.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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